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EdTech Society

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EdTech Society

INSTITUTE OF EMINENCE
IIT Bombay

About EdTech Society, India

EdTech Society is a professional association started in India by individuals who are committed to improving instruction and learning through the use of educational technologies. EdTech Society members are researchers, developers and practitioners in the field of educational technology. Which includes: Higher education faculty, graduate students, instructional designers, educational technology tools developers, school teachers, government, corporate and military trainers.

The vision of the EdTech Society is to be the premier organization within India in the field of educational technology best practices. The mission of the EdTech Society is to provide leadership within India and internationally by promoting research, best practices and employing the use of educational technologies principles for effective instruction and learning. Drawing from its core values of leadership, collaboration, openness and sustainability, the EdTech Society has the following goals.

GOAL 1: Create a public forum for professionals within India in the field of Educational Technology to improve teaching and learning.
GOAL 2: Actively engage professionals within India in the field of Educational Technology.
GOAL 3: Promote research and best practices by professionals in India in the field of educational technology.
GOAL 4: Enhance international awareness of research conducted by researchers in India.

The International Conference on Technology 4 Education is the flagship event of the EdTech Society. EdTech Society is excited to welcome all participants to join us at the T4E 2023 conference at IIT Bombay, Mumbai.

Edtech Society
India
https://etsociety.org/

Message from General Chairs

It is my pleasure to invite you to the latest edition of T4E 2023: the international conference on Technology 4 Education. T4E 2023 is organized by the EdTech Society, India, and hosted by IIT Bombay. T4E 2023 is being held in Mumbai, India, from November 24-26, 2023. The previous T4E conferences were held in Bengaluru, Mumbai, Chennai, Hyderabad, Kharagpur, Kollam, Warangal, Mumbai, Chennai, and Goa in 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2018, and 2019 respectively.

Starting this year, the T4E conference has expanded its scope as well as its full form, reflecting four perspectives to view the connections between technology and education:

Technology *for, of, in, across* education.

In this spirit, T4E 2023 provides a forum to bring together researchers, teachers, students, developers and practitioners widely interested in understanding ways in which learning and teaching can be enhanced with technology, new roles for technology in educational processes, and issues related to access, sustainability, policy and practice in the T4E areas. The conference considers the needs and interests of participants from universities, colleges, schools, industry, government organizations and NGOs via various session formats, including paper sessions, poster sessions, interactive workshops, best practices sessions, teaching demos and tool/product showcases.

We thank the Program Chairs, Ramkumar Rajendran, Shitanshu Mishra and Andreas Lingnau, for their enormous contribution and hard work. We take this opportunity to thank the Local Organizing Committee Chair, Syaamantak Das and Finance Chair, Sridhar Iyer for their efforts in running this conference. Special thanks to Keynote Speakers Paulo Blikstein, Amina Charania and Wenli Chen for their generous participation. This conference would not have been possible without the untiring work of several organizing committee members: Workshop Chairs - Ritayan Mitra and Prajish Prasad, Best Practices & Teaching Demo Chairs - Yogendra Pal and Briju Thankachan, Academic Outreach Chairs - Sameer Sahastrabuddhe and Jayakrishnan Warriem, Industry Liaison Chairs - T. G. Lakshmi and Kapil Kadam, and Foundation & Non-profits Liaison Aditi Kothiyal and Viraj Kumar. We thank members of the International Advisory Board for their guidance. We also sincerely thank all those who have contributed meaningfully to this conference but have remained invisible to many of us.

We welcome all participants to the T4E 2023 conference at IIT Bombay, Mumbai!

Sahana Murthy
Indian Institute of Technology Bombay, India
Maiga Chang
Athabasca University, Canada

Message from Program Chairs

The International Conference on Technology 4 Education provides a forum for researchers from academia and industry to discuss their work on the development of new technologies for education and pedagogical issues arising from the use of such technologies. The conference has four major themes: i) the Development of technologies to support education, ii) Understanding how people learn, iii) Pedagogical strategies and interventions, and iv) Access, Scale and Sustainability.

T4E 2023 received a total of 247 abstract submissions. Out of which we received 204 final submissions. At least two reviewers reviewed each paper in a double-blind review process. After the review process, 20 papers were selected as full papers, 63 as short papers and 15 papers were accepted as poster presentations. In these proceedings, with the authors' consent, we have included 17 full papers, 36 short papers, and 15 posters. Additionally, we have incorporated details of 7 workshops, 5 discussions on best teaching practices, and 10 industry demonstration submissions from the conference. Papers presented at the conference but not included in the main proceedings are listed at the end of this volume. The accepted papers are published under the EdTech Society Proceedings. We thank the technical program committee members and reviewers for reviewing and selecting papers. We thank the workshop chair and Best Practices and Teaching Demos chairs for coordinating and organizing the respective events in the program. We thank the keynote speakers for accepting our invitation and for delivering the keynote speech. We thank all authors and presenters of talks, posters, workshops and panels.

Many thanks to IIT Bombay for hosting the conference and to the entire organizing committee members and volunteers for their support and tireless effort. We hope to interact with you all again at the next T4E conference.

Ramkumar Rajendran
Indian Institute of Technology Bombay, India

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Full Papers

Touchy Pinchy Integers: Exploring how students' embodied interactions with a manipulative interface enhances conceptual understanding of integer operations

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***Abstract*—Classroom teaching experiences and existing literature suggest that early middle-school students have difficulties with operations on integers, and these lead to misconceptions. We present a touch-based system – Touchy Pinchy Integers (TPI) – designed to assist early middle-school students gain a conceptual understanding of addition and subtraction of integers, through embodied interaction. This application builds on the neutralization model of integers (canceling integers of equal and opposite signs), and existing gestures used in touch devices. By embedding touch gestures with mathematical meanings, the design allows the student to develop an alternative – and mathematically accurate – mental model of integers, based on embodied interactions. This mental model reduces their dependence on the purely rule-based system to learn integer operations, which is promoted by current static media.**

***Keywords*—Embodied Learning, Integers, Multi-touch Interfaces, Mathematics Education, Conceptual Change**

I. Introduction

Most learners find middle school mathematics challenging, as a range of new and complex topics – such as integer, decimal, ratio, proportion and algebra – are introduced one after the other, in grade 6. Children find this parade of new concepts overwhelming, and they are not able to engage with these topics enough, partly due to the lack of time. Integers are particularly surprising, and children are often unable to comprehend integer concepts and operations, as these are very different from the whole number system students are familiar with [1]. Some of the main problems students encounter are outlined below:

1) Children are first introduced to numbers as an expression of magnitude. Zero is taught as the lowest magnitude. This structure makes it difficult to interpret the new negative magnitude. In the words of one learner, "When I first encountered integers I was surprised, because I always thought the largest number is infinity and the smallest number is zero. But it broke my ideas that the numbers could go below zero also".
2) Arithmetic operations are introduced alongside whole numbers. For instance, students have only seen addition as an increase in magnitude by a given amount, and subtraction as a decrease of magnitude by a given amount. Negative numbers require re-conceptualising these operations. Studies show that half the students of age 12 -13 have difficulty in addition and subtraction operations using integers [2].
3) Students have difficulty interpreting a negative number. Given this, they are unable to grasp addition and subtraction on integers. To get around this conceptual understanding problem, they memorize rules – such as "minus minus equals plus" – to solve problems. But with many rules and little understanding of what they mean, confuse students all the more [1]. Further, as integers are a prerequisite for learning and understanding algebra [3], students' difficulty in working with negative numbers leads to algebraic mistakes, such as forgetting minus sign during operation on integers [4], trouble with negativity [5], making sense of changing role of minus sign, and getting confused with formal rules used for operations of integers [6].

To address these issues, we developed a touch-based interactive learning system, which allowed students to learn integer concepts using physical manipulation. This design sought to help children extend their existing conceptual structure, as they learn whole numbers and operations on whole numbers through the use of physical manipulatives [3]. One way to extend the use of physical manipulative to integers is to use the neutralization model, where the integers of equal value and opposite sign cancel out [4]. This model is introduced in class 6 NCERT textbook, using buttons of two different colours, one positive and another negative. A pair of opposite coloured buttons cancel out, giving a net value of zero. Studies show that students using neutralization models perform better in addition of integers. But students seem to have difficulty in subtraction problems [4].

Current multi-touch technologies provide a novel way to address this problem, as they have the potential to provide students with dynamic and interactive learning experiences for higher order concepts, similar to manipulative-based learning. Static text-based material do not have this affordance. An increasing number of students now have easy access to a smart device, through their family or community. Furthermore, the students of the present generations operate the smart devices at ease and are comfortable using various apps. As students can now interact with new interactive media on a regular basis, educators can tap the interaction affordances of such media, to design new embodied learning experiences that allow students to develop a deeper conceptual understanding of difficult mathematical concepts.

Based on this reasoning, and extending the findings from research studies in mathematics education, we developed a multi-touch application – Touchy Pinchy Integers (TPI). The design of this system is based on the neutralization model of integers. TPI provides students interactive virtual manipulatives, coupled to dynamic animations. These together provides learners with a new way to interact with integers, based on actions and visual feedback. This new interaction structure allows students to imagine integer addition and subtraction operations, instead of just memorizing meaningless rules. Interestingly, TPI also allows visualizing the change in position when an integer is multiplied with (-1). The interactive learning environment provides students immediate perceptual feedback on mathematical operations, particularly on whether their intended operation matches the outcome, and the way it is related to the outcome. If the expectations they have of the operation does not match the on screen results, they immediately get feedback suggesting an error in their model, which they can try to rectify, by trying new operations.

Importantly, TPI is designed as an *additional* support for students to understand and solve integer problems, particularly addition and subtraction, by giving them an embodied learning experience. It is not intended to replace existing methods of teaching integers. Our design is based on existing gestures used in smart design. The interactions we have designed helps 'load' mathematical meaning into these gestures.

After developing the interactive system, we designed a pilot study to test the first prototype of TPI. In this paper, we report initial observations from a pilot study, conducted with 5 grade 7 students. The students were familiar with integer operations. The article is structured as follows: Section II covers a brief overview of theoretically or pedagogically related designs of learning systems that exist in the literature. Section III covers a detailed description of our design, along with some relevant terminology. Sections IV outlines our methodology for a pilot study with middle-school students. We detail our observations in Section V and interpret them in Section VI.

II. Existing Designs

A number of interactive simulations and games have been developed to support the learning of numerical and mathematical concepts. Some of these were developed for academic research, while others are commercially released products [7]. Interactive games have been developed and studied by researchers in a variety of mathematical domains, including arithmetic [8], algebra [9], and geometry [10]. Gamification of instruction is known to improve affective outcomes and attitudes towards the learnt subjects, even in cases where there is limited evidence for students' learning gains [9].

Some mathematics learning interactives take advantage of the unique affordances of touch-based multimedia devices such as tablets and smartphones, by mapping actions to touch gestures like tapping, swiping, and pinching. Theoretically, such designs can be thought of as applying an embodied learning approach, which assumes that the mental processing of concepts can be supported by an equivalent set of appropriate physical actions [11]. This assumption is justified by recent cognitive neuroscience studies, such as the finding that learners using an abacus to do arithmetic operations, when asked to mentally do arithmetic operations, imagine abacus-based actions (activating their visual and motor areas) [12]. In contrast, learners using paper-pencil media to learn arithmetic 'write' the operations (activating frontal areas more).

An example of a system based on embodied learning is *TouchCounts* [13], a touchscreen-based interactive system to support basic numeracy among early school students. This system works by supporting the embodied representation of numbers on fingers, and mapping basic arithmetic operations to touch-based gestures. Another design that uses touchscreen gestures is *Touchy Feely Vectors* [14], which is a touch-based learning aid for vectors. It encodes actions that can be performed on vectors as embodied interactions. A system with similar theoretical underpinnings is the Mathematics Imagery Trainer for Proportion [15]. This learning aid supports understanding of proportionality without any explicit instruction, via a sensorimotor bimanual task, where the color of a screen is mapped to the proportion of distances of the user's two hands from one edge of the screen. Users embody proportion by changing the space between their hands, while keeping the proportion constant, and thus gain mathematical insight into how proportion must be maintained (speed of movement of higher hand should be doubled to maintain a 1:2 proportion) without realizing they are in the middle of a math lesson.

While *TouchCounts* aims to support learning of simple counting and basic arithmetic operations, it does not extend to the concept of negative numbers, which is the problem we seek to address. A closely related design to ours is *AlgeOps* [16], which is not based on embodied interactions. This system presents a neutralization model of integer addition in conjunction with an equivalent number line representation of the solution. In *AlgeOps* the user can build a simple integer expression such as 3 + (- 4) by incrementing or decrementing the number of balloons in two sets, where each set of balloons represents a term in the integer expression. Each balloon can be either green or red, where green represents positive, while red represents negative. Thus, when there are no balloons in a set, decrementing that set adds a red balloon to it. When the user represents the integer expression given in the prompt correctly, pairs of green and red balloons are automatically neutralized.

Our design differs from *AlgeOps* in three important ways: firstly, while *AlgeOps* uses buttons for interaction, our operations are embodied in gestures, which are known to be intuitive for touchscreen interaction. Secondly, while neutralization in *AlgeOps* is performed automatically by the system when certain conditions are met, in our system neutralization and reverse neutralization (getting a +1 and a -1 from a 0) are actions left to the user, done via pinching gestures. Thirdly, we allow the user to perform operations that go beyond addition and subtraction of one unit at a time. TPI also allows users to increment multiple values at once, as well as neutralization and reverse neutralization actions. Our system also supports a 'flipping' action, which is equivalent to multiplying the whole expression by -1.

III. Touchy Pinchy Integers

A. Design

The current prototype of the application consists of a single screen split horizontally into a top half and a bottom half. The splitting line serves as the common base of two differently colored Towers on either side of the line - one each for the positive and negative term of the integer expression generalizable as $m+(-n)$. Each of the Towers consists of vertically stacked blocks whose number represents the magnitude of the term. Thus an expression of $5+(-2)$ can be represented on screen as given in Fig. 1, with the Positive (red) Tower consisting of 5 vertically stacked blocks, and the inverted Negative (blue) Tower consists of 2 vertically stacked blocks. The red and blue Towers are termed as the Tower Pair.

The total number of positive and negative blocks in the Tower Pair give us the overall state of the integer expression. We represent this state of the system as $\{m, n\}$, where m is the number of positive blocks and n is the number of negative blocks. Thus the value of the integer expression at state $\{m, n\}$ is $m+(-n)$

The user can manipulate the number of blocks on each tower through touching gestures, which are mapped to operations on the entire integer expression. The expression $m+(-n)$ is displayed on screen at all times where m is replaced by the number of positive blocks and n is replaced by the number of negative blocks. As the user makes changes to the system via operations, the expression is dynamically updated to represent the current state.

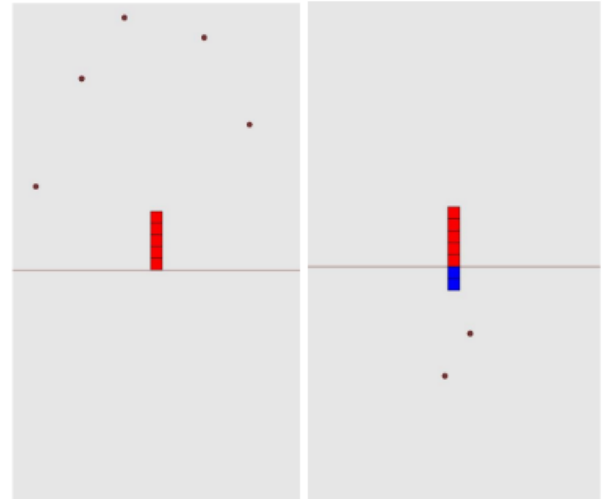

Fig. 1. Incrementing by Tapping. Brown dots indicate finger tap locations on the screen. The system can be accessed at the following link: *https://ashwinramaswamy92.github.io/TouchyPinchyIntegers/*

B. Operations on the Integer Expression via Touch Gestures

Let $m+(-n)$ represent the state of the expression prior to performing any of the following operations, meaning that there are m positive blocks and n negative blocks. The different operations, along with their effect on the expression, are given below:

Addition (Incrementation): Tapping with k fingers on either side of the screen adds k blocks to the tower on the same side (Fig. 1). Thus, tapping the top half of the screen with k fingers changes the expression to $(m+k)+(-n)$, while tapping the bottom half with k fingers changes it to $m+(-n-k)$. The added blocks visually appear on free (opposite to dividing line) side of the Tower.

Addition (Neutralization): Pinching in with two fingers triggers the disappearance of one block on each Tower (Fig. 2). This operation changes the expression to $(m-1)+(-k+1)$. The overall value of the expression thus remains unchanged. Visually, it is the two blocks closest to the dividing line that disappear. This gesture does nothing if there isn't at least one block on each Tower.

Reverse Neutralization: Pinching out with two fingers triggers the appearance of one new block on each Tower (Fig. 3). This operation changes the expression to $(m+1)+(-k-1)$. The overall value of the expression thus remains unchanged. Visually, the new blocks are added to the free side of each Tower.

Subtraction: Swiping horizontally across the distal edge of the kth (from the dividing line) block of either Tower removes k blocks from that Tower (Fig. 4). Swiping across the kth block of the Positive Tower changes the expression to $(m-$

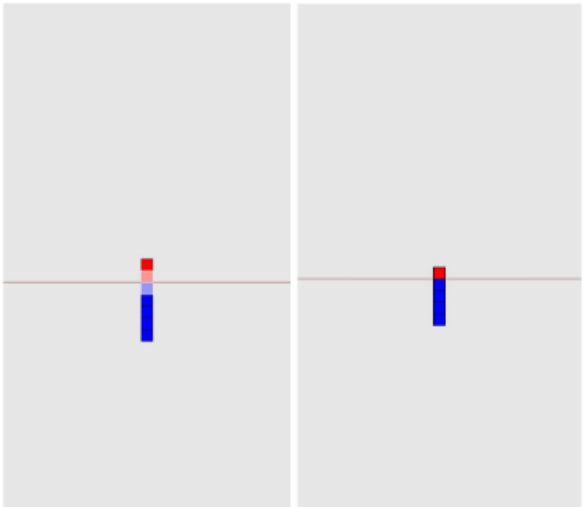

Fig. 2. Neutralization by Pinching In

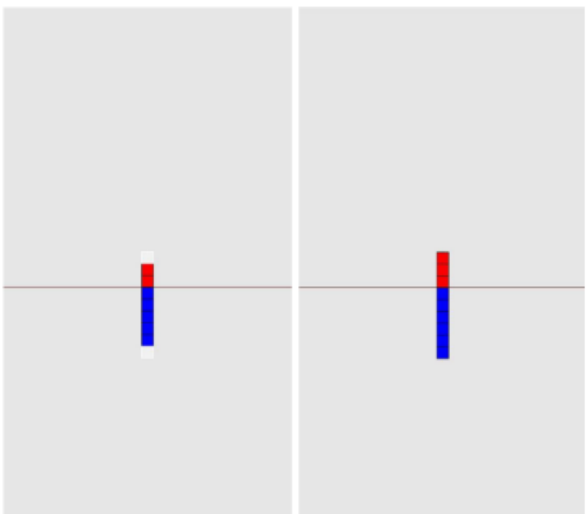

Fig. 3. Reverse Neutralization by Pinching Out

$k)+(-n)$, while swiping across the kth block of the Negative Tower changes it to $m+(-n+k)$. Visually, the k blocks closest to the dividing line are removed.

Multiplication by -1: Swiping vertically causes the two Towers to swap sides (and color) via an animation that emulates a 180^0 rotation of the Tower Pair about the z-axis (Fig. 5). This operation changes the expression to $n+(-m)$.

C. Additional Concepts

While performing the pilot study, we realized that the following two concepts have utility in both the instruction given to the students, and in our analysis:

Screen Value: This is the signed difference between the number of positive blocks and the number of negative blocks, i.e. the solution of the displayed integer expression $m+(-n)$.

Multiple Representations: Any integer can be represented by an infinite combination of states, which supports an understanding based on multiple representations. We found that it is useful to draw the students' attention to this aspect of the system.

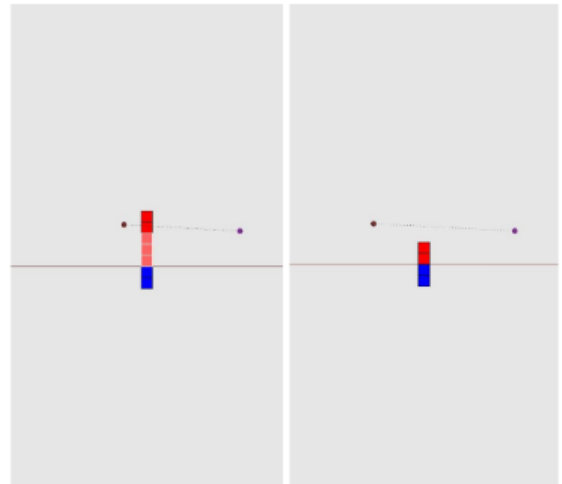

Fig. 4. Subtracting by Swiping. Brown dot indicates starting point of swipe, and purple dot indicates the end point. Dotted line represents the idealized swipe trajectory used for computation.

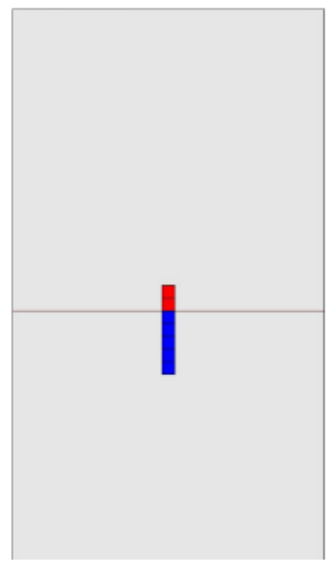

Fig. 5. Multiplying by -1 by Rotating fig 1

IV. Pilot Study

A pilot study was conducted to get feedback from children on their comfort level and interactions while using the application. The findings from this study will be used to design the upcoming iterations of the application. We also focused on developing the kind of task that needs to be given to students so that they explore the software and understand the integer concepts. The inputs from students on this aspect will help us during the planned wider study.

In the study, 5 grade 7 students at a residential school were given the application to explore. We met the students for 15 -20 minutes on a daily basis over a period of 1 week. The students were selected by their mathematics teacher, based on varying level of performance in mathematics class. These students already had an exposure to the topic integers in their grade 6. So we began with a pre-test, where the students were given simple addition and subtraction problems, to be solved using paper and pencil. The pre-test item included problems like- Addition: positive number plus positive number, positive number plus negative number, negative number plus negative number; Subtraction: Subtraction of same sign numbers i.e, Small number from big number, big number from small number, subtraction of opposite sign numbers, subtraction of integers from zero. At the end of the pre-test the students were asked to support their answers with reasons, i.e, why or how did they arrive at that answer. Students' reasoning was given importance, and not the correctness of the answer.

After pre-test, students were introduced to the software - TPI, and were asked to practice various gestures involved in the app. Students were provided with an ipad to perform the intervention tasks during most of the sessions. They were provided with a phone during one of the sessions of the intervention task. This phase was followed by a series of graduated intervention tasks performed by the students over 5 - 6 days. As this was a pilot study, the intervention tasks evolved over the interaction with the students. The tasks and instructions were altered based on real-time feedback. For instance, the idea of screen value and multiple representation i.e, $2 = 3 + (-1) = 4 + (-2)$ came up during one of the sessions with a child.

The intervention tasks involved: addition of same sign and opposite sign, subtraction of small number from a big number, both the numbers with the same sign, on day 1; subtraction of an integer from zero, subtraction of big number from small number of same sign, subtraction of integers of opposite signs, on day 2; multiplying the given integer by (-1), multiplying the given arithmetic expression by (-1), performing the integer operation through TPI for a written expression, on day 3; exploring the triple nature of minus sign through TPI on day 4. The intervention task had a three-stage structure. First stage was performing the operations on the TPI system. Second stage was predicting, with a mental simulation of the system, and verifying the answers, by performing the operations on the system. The second stage occured for all the children during their day 3. Last stage was the post-test, where students were encouraged to perform the arithmetic operations with the imaginary simulation of TPI. At a given session, the students practised all the tasks they performed on the previous sessions. Day 5 was meant for practising all the previously learned tasks, and given written integer operations, performing the operation using the TPI system.

These sessions were followed by a post-test on the following day, to observe the impact of students' interactions with the application on their reasoning. The questions given during the post-test were similar to the one during the pre-test. The only difference was that they were asked for reasons immediately after every question. This change was made because we found students struggling to remember the reason for each question when asked at the end of the test.

V. Results

After the pre-test, the students were expected to give reasons for their answers. Some of them found the reason for sum of two positive numbers to be trivial, as only a few students were able to view them as whole numbers. Some students used the number line to give reasons for their answers. Adding to the number line visualization, they also made use of the backward counting method, using their fingers. For the question $-4 - 3$ one child started at -4, with 3 in the finger and went $-5, -6, -7$. So the answer is -7. Students found it difficult to give reasons for arithmetic expression with too many minus sign e.g, $-3-(-1)$. Children get confused if the given number is -2 or -4, when they try to solve it using number line. All students supported their answers with the rules they learnt from their previous grade. The rules were their constant reason for integer operations. With two negative signs next to each other, every child instantly use the rule 'minus into minus plus' and that remained the reason for their answer.

When we analysed the post-test, we found that students made use of the mental image of TPI, similar to abacus experts relying on the mental image of the abacus to solve problems [12]. Among the 5, three were using pinching (pinching in for addition of opposite integers). gestures, and one of the children used the tapping gesture when asked to add integers of same sign. Two other students, who were comfortable with the rules and got all the answers right during the pre-test, used the rules again during the post-test. When asked why they chose to work and reason in terms of rules even though they worked with TPI, they said they are used to it and have been practising a long time with rules.

The other three children, who got confused during their pre-test, seemed more open about using the system during the post-test, and also reasoning using the system. One child was able to use all three methods - number line, rules and TPI – to work with the given operation of integers, and was able to comfortably switch between the methods. Few children misused the rules, and used them in wrong places while supporting their answers with reasons. But during the post-test, these children had an extra tool. One child stated: "I had put the software in my head". If they used rules to solve a problem, they were able to verify their answers with the idea of TPI. They were able to think clearly, and was able to reason their answer with clarity and confidence. They could manipulate the numbers by neutralizing and reverse neutralizing, which reduces error. They could also avoid manipulating the rules and using them in wrong places.

VI. Discussion: some observations for extending the design

Since the study was based on the first prototype of our system, we plan to use the results and the data to redesign the

system. The following sections outline some of the possible directions for redesign.

A. Distinction between positive and negative integers

At the beginning of the intervention tasks, all students were asked which colour block they consider positive and negative integers. All of them identified red as positive integers and blue as negative integers. When asked why, the students reasoned that red boxes are above and blue boxes are below. They had learnt from their teacher that positive integers go above and negative integers lie below. The idea of positive and negative integers in the system is thus experienced in 2 ways: colour and direction. This dual structure helps students visualize while encountering an integer operation, and thus avoid getting confused with different combination of signs. We plan to build on this feature.

While discussing about the addition of integers of opposite signs, students were surprised to see the illustration of the neutralization process (of positive and negative integers) and they exclaimed looking at the final answer. One of the students noted that during this kind of addition one box runs out in the process of pinching in, and the resultant sign is same as the type of integers remaining on the screen. This insight is a useful one, and we are examining ways to emphasize this.

While tapping the positive or negative numbers greater than 5, one child split the even number equally across both the hands i.e, represented 6 as $3+3$, represented 8 as $4+4$, while also representing it as $5+1$ and $5+3$ respectively. Some children tapped one by one. We plan to study in detail this decomposed representation of integers using the fingers.

B. Mutating rules

The children often felt an answer is right, but according to the rule they get a different answer. One child knew $-3+15 = 12$ but according to the SADS rule the answer was -12. This issue came up a few times across different students. Often they find themselves with two answers. Some students are aware of the rules, but struggle to identify where to use it. It is currently unclear how the system could be used to support the correct application of rules. We hope to develop some features that could support this process.

Negative number multiplied into negative number results in a positive number. Over time, this rule seemed to change its form for some students, as they start using statements like 'minus into minus plus', 'minus and minus makes plus', 'minus minus plus' etc. Since the last phrase is ambiguous, one student used 'minus plus minus is plus'. The child knew $-11 + -4 = -15$, but this answer was conflicting with the rule. So he concluded $-11 + -4 = 15$. After the use of the system, the child did not make this kind of mistake during the post test. It is unclear how the system supports this transition, further data is needed to understand this, and develop ways to emphasize this aspect of the system.

C. Screen value and multiple representations

The concept of screen value was introduced on day 3. When students were given a question like $0-7$, they had the tendency to put the answer directly on the screen, instead of making use of the system. When we asked to find different combinations of positives and negatives (aka multiple representations) they were able to generate $0, 1+(-1), 2+(-2), ..., 5+(-5), ...$ etc. With $5+(-5)$ the child was able to subtract -5 from the screen value of 0, to obtain 5, giving them a visual component to understand the concept of $0-(-5)$ in a concrete manner. This could be extended for subtraction of bigger integer from smaller integer of same sign, and subtraction of integers from opposite signs.

One student connected the idea of multiple representation to the concept of equivalent fractions. Similar to $\frac{1}{2}$is equal to $\frac{2}{4}, \frac{3}{6}, \frac{4}{8}$ and so on, in TPI $3 = 4+(-1) = 5+(-2)$ and so on. Another student noted that if same number of boxes are present on both the sides, i.e, if the upper half and the lower half are 'balanced', then the screen value will be zero. After the introduction of the concept of screen value, and multiple representations of same screen value, students were comfortable with removing/ subtracting bigger number from smaller number, subtracting number of opposite signs and subtracting integers from zero. A possible way to build on this effect would be to develop systematic tasks as part of the system.

When a child was given the problem $-10+8$,the answer was given as -18, using rules. When asked about the screen value, the child was able to say it is -2, and then realize that the sum of these two integers is -2. When students are asked to predict the answer for a given operation, and if their prediction happens with rules, when asked to verify it using the system, they are able to observe what actually happens, through mentally simulated imagery. We are exploring ways to support this feature in more complex situations.

D. Subtraction

Most children faced an issue with subtraction. Initially, students try to slice off the boxes from the end of the towers, as opposed to the basement of the tower, as promoted by the design. Over time, they started slicing off from the bottom. As designers, we feel it is important that the child slices off at the bottom. Once the number line is integrated into the system, students may learn quickly to slice off at the place corresponding to the magnitude in the number line.

When students see two minus sign next to each other, they often convert the subtraction problem into an addition problem before solving, since *minus into minus is plus*. Further, when they have an arithmetic expression in addition, and if the signs of the two integers are different, students follow the rule *subtract normally and put the sign of bigger number*, where they refer to normal subtraction as subtraction of small number from a big number. Another common method is: when given $7-19$, the student explains that if it was *ulta* i.e, $19-7$ then the answer is 12, so now our answer will be -12. Students remember such shortcuts, and present these shortcuts as the rationale behind their answers. After the intervention based on the system, students were able to view subtraction from

a different perspective. How the system could be extended to support the reasoning underlying such shortcuts is currently not clear.

Students were aware that adding a negative number to a positive number is same as subtracting it. Although the two process leads to the same solution with the system, the child is able to work with $5 + (-3)$, neutralizing and subtracting 3 from 5 by slicing. This gives students the opportunity to view the two different processes through their gesture, while manipulating the integer boxes. We plan to build on this feature.

E. Potentiality of zero

One student commented that he never thought of bringing together +1 and - 1 to make it zero, and generating as many pairs of +1 and - 1 without altering the screen value really helped them with operation of integers. Another view was that usually one does not naturally add and subtract one to the given expression. If one has to remove 5 from 3, in the classroom students do not think of adding and subtracting 1 during such an arithmetic operation. But since this is a core aspect of our system, they are able to start thinking in terms of this idea. In this design, to make this abstract concept concrete and perceivable to students, we had to build upon the existing "law of conservation" i.e, to preserve the net value [17]. The two gestures based on this is pinching in and pinching out. In future designs, we hope to extend this aspect in new ways.

F. Triple nature of minus sign

The minus sign has three different denotations : unary, binary, symmetry. The unary function defines the negative integer -5, the binary function corresponds the binary operation - subtraction $7 - 5$, and the symmetric function generates the additive inverse $-(-5) = 5$. Students seem to have internalized the concepts of unary and binary. When students were encouraged to perform the operations on the system, they were able to perform the -5 and $7 - 5$ correctly, without getting confused. For the first kind, they tapped with 5 fingers on the lower bottom. For the second question they tapped 7 fingers on the upper half, and sliced off 5 boxes. When asked why, one student said there was no number before minus, and in the second case there was a number before the minus sign. That gave the child the idea that first is a number, and the second it asks us to take away the number. During the tasks, the instructor also intervened at some instances, to discuss and explain the underlying mathematical importance. One such instance was the discussion about the symmetry function – i.e, flipping gesture and making sense of its mathematical meaning. One child came up with the word 'transformation' for $-(-5)$, as she observed the integer undergoing transformation on flipping. Most students were able to represent the unary and binary through the system, the symmetry function was discussed by the instructor. At the end of this discussion, students were given a problem of the type $-(2 - (-5))$ to perform in the system. There are 3 minus symbol in this expression, and all of them have different functions. All the students were able to perform the appropriate gestures for each minus symbol. They used pinch out gesture to generate -5 without changing the screen value of 2 , followed by slicing 5 blue boxes for the second minus sign in the expression. The final answer is flipped, which corresponds to the first minus symbol in the arithmetic expression. This sequence of operations indicate that the system allows students to implicitly understand the three meanings of the minus sign. We plan to build on this aspect of the system in future designs.

G. Flippery integers

Using the flipping gesture, one could illustrate that when multiplying a number n indefinitely with (-1), the value oscillates back and forth between n and $-n$. Students write -4 the moment they see $-(4)$ but the flip gesture in TPI allows them to visualise the negative number -4 as -1 operated 4 – i.e, changing symmetry of 4.

Students were able to predict the values of the arithmetic expression on the screen like $3 + (-2)$ right after introducing the flip gesture, with a single integer. The mathematical meaning was not so apparent. So there was a discussion with students regarding the mathematical meaning of flipping. Few students also added their own observation, that on flipping we obtain additive inverse of the given integers. Students were also encouraged to see how individual numbers in the arithmetic expression changed. Students were able to observe that on flipping both the numbers were replaced by their respective additive inverse. This shows that using the flipping gesture, there is a scope to illustrate the distributive property of (-1), as flipping gesture is the mathematical equivalent of multiplying the given arithmetic expression with (-1).

H. Additional points

Given the problem of forgetting rules, or too many rules to remember, students mention that the system gave them scope to operate on integers with the integer boxes in front of them, without relying on rules. While students learnt the neutralization process using different coloured cards, and drawing different coloured boxes, some students preferred TPI. One student stated that "Generation of boxes is made easier here. We can just pinch in and pinch out instead of sit and draw or think of the sign rules".

The last intervention task was to obtain -3 from 5. Students were able to come up with many ways to transform 5 to-3: Pinch out 3 times and slice of 8, slice off 5 and add -3, slice 2 from 5 and flip it to obtain -3, flip 5 to get -5 and slice off -2. Just with this simple task, students were able to explore multiple ways to try out and visualize the transformation process, and thus discover multiple arithmetic operations which might not be apparent when solving with a paper and pencil.

VII. Limitations

This pilot study was conducted with three objectives: 1) to develop a systematic approach to introduce TPI to the learners, 2) to test the appropriateness and effectiveness of the

intervention tasks and 3) to observe the behaviour of students during the TPI interactions. While these objectives were met significantly, our study has a number of limitations. We outline some these below.

Keeping in mind time demands, we had to restrict our initial sample to 7. However, 2 students dropped out in the middle, because they were not able to come regularly. Among the remaining 5 students, 2 scored perfectly on the pre-test. We chose a convenience sample, where all the participants were from the same school. This means we are not able to track any cultural or socio-economic variation in the results. Because of these limitations, we were unable to support our descriptive findings with quantitative data. We plan to follow up these preliminary findings with quantitative studies, to better understand the efficacy of TPI as an integer learning system.

Although we aimed to conduct our observations in a naturalistic and comfortable setting for the children, for ease of video recording, they were asked to sit and use the application in a specific spot. We observed that in the absence of this restriction, they exercised their agency by occasionally changing how they held the tablet, for example by moving it from their hands to their lap. Thus, an important element of the touchscreen experience is the ability to operate it in a variety of different bodily configurations. This benefit of the medium was not explored in our study, because of data collection constraints.

All the students in our study had prior exposure to instruction on integers. It would be interesting to study the effects of TPI on students (of a similar age group) with no exposure to integers through traditional methods. It is possible that students who have received instruction find it harder or less fruitful to use TPI imagery because they are presented with two competing procedural systems. In our future studies we plan to account for prior knowledge as a sample attribute, to better understand how our intervention interacts with prior conceptual or procedural knowledge.

VIII. Conclusion

The pilot study illustrated that students found the TPI system quite useful in making sense of integers, and they gained conceptual depth in the topic through their interactions with the system. We are currently running further studies, to address the limitations of our preliminary study. We also plan to build on the above observations, particularly to develop new features and capabilities that would allow students to use the system to learn more complex integer concepts.

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Fostering Engagement in MOOCs: Leveraging a Community of Practice for Discussion Forum Moderators

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***Abstract*—Discussion Forums (DF) of MOOCs have the potential to enhance learning experiences. These online social spaces, crucial for knowledge sharing and collaborative learning, can foster active participation and meaningful engagement among learners. This can be achieved by incorporating Learner Experience Interactions and orchestration dynamics, as prescribed in the Learner-Centric MOOC (LCM) Model. Community participation is an interesting and important feature, which can enhance DF engagement; however, it is not explored adequately. This ethnographic study explores the experiences and perspectives of a virtual Community of Practice (CoP) among Discussion Forum Moderators (DFMs). We investigate the strategies and practices employed by DFMs to enhance engagement in MOOC DF using participant observation and interviews. The results suggest that involvement in such a CoP positively impacts the DFMs' sense of belonging and identity, peer recognition and validation. These findings contribute to a deeper understanding of creating a CoP of DFMs to support learner engagement in MOOC DFs and offer practical insights for MOOC instructors, and learners. By implementing the identified strategies and considering the contextual factors influencing engagement, MOOC providers can create an interactive and inclusive learning environment through orchestration dynamics that foster active participation and knowledge exchange in DFs.**

Keywords— Discussion Forum Moderators, Ethnography, Learner-centric pedagogy, MOOC design, Community of Practice, Engagement

I. INTRODUCTION

Massive Open Online Courses (MOOCs) have revolutionized the landscape of online education, providing learners with access to high-quality educational resources and the opportunity to engage with a global community of learners. Within MOOCs, Discussion Forums (DFs) play a vital role in fostering learner interaction, knowledge sharing, and collaboration. However, despite their potential, MOOC DFs often struggle to foster active participation and meaningful engagement among learners. Meaningful interaction in the DF helps improve learner engagement and performance [1] among others.

Several models have been created to address issues and promote engagement in DFs. One of the components of the Learner-Centric MOOC (LCM) Model is the creation of Learner Experience Interactions (LxI) to optimize the usage of and engagement in the Discussion Forums [2], [3]. This is a prescriptive model having constructors to assist course developers. In addition to designing Focus Questions and Reflection quizzes, DF moderation during course orchestration helps in enhancing engagement [4] and leads to sustained engagement [3]. However, there are gaps in existing research on community efforts in enhancing DF enriched with LCM elements. Thus, this paper aims to study the application of principles of the LCM Model in the DF along with the impact of the Community of Practice (CoP) of Discussion Forums Moderators (DFMs) on engagement in the DF. It explores the dynamics of the DFMs among themselves as well as strategies employed by them on the DF in order to measure their impact on interactions with the learners.

II. RELATED WORK

To contextualize the present study within the existing research this section delves into the meaning, purpose, function of DFs, the ways to increase learner engagement, and the role of CoPs.

A. Discussion Forum: Concept and its importance in MOOCs

A DF is a virtual space beyond the confines of geography and temporality that supports asynchronous interactions [5], [6]. These online forums are considered to be social learning spaces that encourage diversity, facilitate peer learning, and collaborations as well as create communities of like-minded individuals [7]. Participants can connect with one another, share experiences, and build a collective understanding of the subject matter [8]. Learner participation in the DF positively impacts performance and course completion [1], [9], [10]. Considering the immense potential that DFs have in learning, several MOOC platforms incorporate this feature and MOOC creation guidelines prescribe its utilization [2], [11]. However, it is often observed that DFs in online courses are under-utilized [12].

B. Discussion Forum Engagement: Markers and Measures

Engagement of the DF is indicated not only by the number of posts but also by markers like the nature of the posts among others [13], [14]. Four interlinked dimensions have been identified that influence engagement among learners: behavioral, cognitive, affective and social [15]. Lower cognitive engagement in the DF negatively impacts performance [16].

Learners feel more engaged in a structured DF than in an unstructured one [17]. Thus, in order to increase engagement

in DF, the LCM Model prescribes the LxI component. This includes structuring the DF around focus questions (FQs) based on the course content and incentivizing participation by introducing a reflection quiz based on interactions on the DF [2].

C. Discussion Forum Moderation: Role and Functions

The DFs of MOOCs need to be managed by competent personnel, and moderated as per the requirement [2]. However, since it is not mandatory or a full-time task, there are instances where DFs are moderated by peers, instructors, moderators, even by alumni or sometimes left unmoderated [4], [14]. Moderators require a set of technical, online communication skills as well as expertise in the subject and usage of online systems [18]. DFMs have 4 important functions or roles: organizational or (managerial), social, pedagogical, and technical [19], [20]. Most of the moderators require training to acquire these skill sets [21]. The moderators typically monitor posts, study learner activity logs, provide feedback, facilitate conversations, and create a conducive ambience within the forum [22].

Many times, moderation is a volunteer task, however, most of the moderators agree to this, based on the academic credit they receive. Additionally, reciprocity (mutual exchange), personal gain, collectivism, and altruism (selfless act of assisting others) feature among the factors that motivate people to contribute to online forums [23], [24]. There are other cases, where individuals refrain from becoming moderators due to lack of time [24]. To summarize, although DF moderation is required and is a valid structural element of a MOOC, there is limited documentation on the collaborative strategies that the course team and moderators can use to effectively orchestrate a large number of diverse participants of a course.

D. Community of Practice

CoP is essentially a group of "people who engage in a process of collective learning in a shared domain of human endeavor" [25]. CoPs enable the transition of knowledge from personal and tacit to explicit and collective and that this knowledge is also diffused through CoPs [19]. The benefits of CoP include the transfer of best practices and the development of professional skills among others [26]. A virtual forum dedicated to the use of the CoP of a MOOC created a sense of belonging [27]. The study also finds that CoPs can enable its participants to innovate by being an enabler of motivation. An analysis of a CoP among Teachers identifies that the underlying tensions between various stakeholders of the CoP positively impact it and influence community dynamics [28]. A CoP of teachers who were participants of the previous versions of the LCM MOOC course, facilitated the implementation of the LCM model in online courses as well as contributed to the evolution of the tenets [29]. They also state that implementation of the LCM model through CoPs amplifies its intended outcomes.

III. Research Study

This article contributes to the existing literature by highlighting the impact of dynamics within a CoP of DFMs on interactions with the learners in the DF. The paper is derived from a 4-month ethnographic study of an orchestration of a DF in a MOOC.

A. Problem Statement

Meaningful interactions in the DF are an integral part of LxI in any Learner-Centric MOOC. Several courses enlist the assistance of DFMs to moderate discussions and encourage engagement within DFs. However, very little is known about the rationale that influences potential candidates' decision to become DFMs, the role that the CoP has in supporting DFMs and the influence on engagement in the DF.

B. Research Questions

Broad Research Questions (RQ) is an ethnographic study of the processes and interventions followed by the moderators to enhance engagement in the DF of MOOCs. Broad RQ: How does CoP among DFMs foster engagement in a MOOC?

This is split into multiple RQs as follows:

- RQ1: What factors do DFMs consider before taking up the responsibility?
- RQ2: What is the perception of DFMs about the onboarding activity?
- RQ3: What steps are taken by the DFMs on a daily basis to engage learners in the DF?
- RQ4: To what extent does involvement in a CoP have an impact on DFMs' motivation to participate in the DF?
- RQ5: What are the markers DFMs use to measure the increase in engagement in the DF?

C. Methods

This qualitative study uses an ethnographic approach [30] where patterns of behavior within the CoP are observed. The participant-observation approach was considered to be most appropriate for this study which attempts to understand the culture of the CoP. The researchers were part of the course orchestration team and hence were immersed in the day-to-day happenings on the DF and were privy to the interactions between DFMs. In addition, cumulatively they have had several years of experience in the domain.

D. Background of the Study

In order to assist in the orchestration of the Learner-centric MOOC titled *Designing Learner-Centric MOOCs* offered on the Indian MOOC platform -SWAYAM from January to March 2023, alumni of the previous batch who were toppers of the course were invited via email to volunteer as DFMs. This call to volunteer as DFMs was sent via email a few weeks before the commencement of the course. The email included a brief overview of the responsibilities, weekly time commitment and recognition that potential candidates would gain to validate their contributions as DFMs. While 9 alumni initially expressed their interest in becoming DFMs, 7 took up the responsibility. In addition, alumni of previous batches were invited to volunteer as Direct Points of Contact (DPOCs) for the DFMs.

Training sessions as recommended for skill-building [21], [31] were conducted online for the DFMs and subsequently, they were added to a social media group for further coordination. While the examinations of the course ended in March, the orchestration team regularly attended the DF till the declaration of results in April 2023.

E. Selection of Participants for the Study

While various stakeholders involved in the orchestration of the MOOC were observed and interviewed, namely DFMs, Direct Point of Contact for DFMs, and learners of the MOOC, the study lays emphasis on the process and interventions by 7 DFMs (male=5, female=2). Using convenience sampling, an alumnus of the course who initially volunteered for the role of being DFMs but later backed out was also interviewed. In addition, 4 participants (male =2, female =2), were also interviewed.

F. Data Collection

Informed consent was sought at the beginning of the study before the collection of data [30]. A variety of data sources were collated and analyzed as mentioned in Table 1.

TABLE I. RESEARCH QUESTIONS AND DATA SOURCES

Research Questions	Corresponding Data Sources
RQ1	Interviews
RQ2	Interviews, Pre-course correspondence and resources.
RQ3	Interviews, Observation logs, Data from forums and other correspondences. Orchestration documents
RQ4	Interviews, Observation logs
RQ5	Interviews, Observation logs, Orchestration documents

- Pre-course correspondence and resources: Emails and responses sent before the commencement of the course to recruit DFMs, and resources used during the orientation session.
- Observation logs: Observations were undertaken by the participant observers, who were part of the course orchestration team from before the commencement of the course till the declaration of results. This served as a means to note various actions taken by the DPOCs who conducted the orientation session and DFMs on a regular basis to engage with participants as well as reactions by participants to the actions taken by the DFMs. Observations included the dynamics of various forums and groups.
- Data from forums and other correspondences: Social media group for DFMs, Daily Group call by DFMs, DF of the course platform, social media group created by DFMs for selected participants. This was done to study the role of CoP.
- Orchestration documents: This includes daily tracker as well as reports submitted by the DFMs in various formats.

Online interviews: All online interviews were conducted after the completion of the course. The questions for the interviews were designed and validated by a group of experts. Some questions that were part of the DFM interview protocol were as follows: What motivated you to take up the role of DFM? What are the qualities expected in a DFM? On your day as the moderator, what does your typical workflow look like? What are the indicators of an Active DF? When starting a discussion thread on the DF, what strategies did you use? Did you reach out to the DFM social media group? Why? How did the members of the COP react to your input? What effect did that reaction have on your motivation levels?

Interviews were recorded, transcribed and manually coded first individually by the researchers and then compared. After discussion, a consensus was reached. Transcripts were anonymized and coded from M1 to M7 to represent the moderators who responded.

G. Data Analysis

A thematic analysis of the transcripts of interviews and observation notes was undertaken to identify pertinent codes [32]. Codes are labels that are given to specific elements in the transcript and observation notes from which themes emerge [32].

IV. RESULTS AND ANALYSIS

We present the results associated with each of the 5 RQs in the following 5 sub-sections (A-E). Each subsection contains themes that emerge from the data.

A. RQ1

Before taking up the role of DFM, candidates considered a range of factors. Identifying and understanding these factors would provide insights into their motivations.

1) Theme 1- Knowledge and Skill Development: All DFMs (n=7) indicated that they volunteered in order to deepen their understanding of the course content, and functioning of DFs which would, in turn, help them put LCM theory in practice (M2). As the MOOC was on the creation of learner-centric online courses, some were curious to know the behind-the-scenes orchestration. Considering that all the DFMs in the course were former toppers of the course, they were confident in their ability to contribute to discussions, provide accurate information, and guide participants effectively. Most of the DFMs indicated that having good communication and interpersonal skills was an important factor in their role. These crucial skills are essential for guiding discussions and encouraging active participation. This includes the ability to answer queries in a concise manner and at the same time elicit responses from others through follow-up questions. An essential quality of a DFM is the willingness to assist and engage with others in a friendly, non-confrontational manner. On the DF, they would need to effectively engage with participants, resolve conflicts as well as foster a respectful and inclusive environment. Some DFMs indicated that they joined the team as they wanted to transpose the experience gained to their own course.

[…] wanted to develop e-content or consult in the development of e-content (M3).

[…] this experience would help me position my courses (M6).

On analyzing their answer to this question, we noted that most of their gains were focused on self-improvement. DFMs considered the potential for professional growth and development that comes with the role. They see it as an opportunity to enhance their leadership skills, gain experience in online facilitation, and interact and network with like-minded individuals.

I wanted to learn how this iteration of the course works and […] implement the strategies learnt in my teaching (M1).

[…] find out how the DF worked, considering the fact that almost 1000 learners had enrolled (M4).

[…] learn different leadership styles (M6).

2) *Theme 2- Altruism:* Most of the DFMs indicated that they volunteered as they wanted to give back to the course as Alumni.

I thought let me contribute so that the learners can get a good experience (M7).

Those who volunteer as DFMs are often passionate about the subject or topic being discussed within the DF. Personal interest motivates them to share knowledge and sustain meaningful conversations. Considering the required time commitment, and their intrinsic motivation, they displayed a willingness to dedicate sufficient time to monitor discussions, respond to participant queries, and maintain an active presence within the DF. An alumnus who was unable to join as DFM stated time constraints as a factor that impeded participation.

3) *Theme 3- Networking:* This opportunity to be a DFM would also enable them to network with the course instructors, other DFMs and participants of the course. Apart from the email initiation, they also received a personal call from the course instructor which many indicated was memorable thus indicating the (former) learner-instructor connection as a factor in their decision to join as DFMs. Thus, DFMs also considered the potential of their role to network within the educational community.

B. RQ2

All DFMs indicated that the orientation sessions conducted were very useful. The nuanced perception of DFMs about the onboarding activity can vary based on their individual experiences and the effectiveness of the onboarding process. However, the common perceptions that DFMs have are indicated in the following themes.

1) *Theme 1- Support and Communication:* DFMs appreciated the orientation session as it provided clear instructions and guidance on their role and responsibilities. In addition to this value, emphasis was laid on discussing the forum's purpose and their mission as DFMs.

It provided an overview of the process (M5).

During the onboarding process, a Day of Duty was assigned to the 7 DFMs on a rotational basis as per their stated preference. This was done to ensure quick response time. DFMs were assigned a Direct Point of Contact or mentor, who was their first touch point for any assistance. Having clear and multiple communication channels as well as a support structure helped them ease into their role. However, some indicated that the onboarding activity could include more pre-course prep sessions with the DFM team so as to build bonds and brainstorm. Frequently, on various communication channels team members reflected on and evaluated the activity on the DF and their role. These mechanisms for feedback and evaluation contribute to ongoing enhancements in the onboarding experience for future DFMs.

Have an icebreaker for DFMs before the start of the course. (M2)

Let DFMs come up with strategies for engagement well before the start of the course (M4).

[...] prep[aration] work among DFMs can be started 6 months before the beginning of the course (M2).

2) *Theme 2- Skill Development:* The onboarding session was perceived as a means to develop and hone skills for effective DF orchestration. These skills included: moderation skills, communication techniques, conflict resolution strategies, and effective DF management. With sufficient and need based training, DFMs gain confidence in their ability to perform their role.

It provided strategies and tools to start a discussion even if the forum is quiet (M2)

3) *Theme 3- Community Building:* The orientation session helped them connect with other DFMs and build a sense of community. Collaborative activities that were part of the orientation encourage networking and knowledge sharing among the team. This creates a favorable environment for community building. DFMs appreciated having a DPOC and a common social media group with the orchestration team to address their questions, provide guidance, and offer support throughout their journey.

[The DPOCs] gave us a direction on how to perform. [...] It was reassuring to have a team behind to support us (M1).

C. RQ3

DFMs take several steps on a daily basis to engage learners in the DF.

1) *Monitoring*: On their day of duty, almost all of the DFMs indicated that the first stage of their typical workflow included visiting the forum to check posts (of the earlier day/same day) in their free slots. The time of visit varied from person to person since all of them were working in different institutions. The variable time slots were mutually adjusted, and the DFM peers got accustomed to the slots and managed their responses accordingly. For example, read these comments by some of the DFMs about their time slot choices:

I was comfortable working late nights so I would receive feedback from the team the next day (M1).

I used to keep waiting till 11.30 pm if any additional posts come (M4).

2) *Consulting:* Second stage was to go through the handover message sent by the DFM of the previous day and the course content to formulate the response. Many of the DFMs also mentioned that they used to visit the internal chat group and discuss with peers.

Check the handover message from the previous day to see what needs to be done and inform the DFM group that it is my turn (M2).

When a DFM was not able to contribute on a particular day, we observed that they reached out to their fellow DFMs for assistance on the group chat

3) *Posting on the DF:* It was observed that in order to encourage learner participation, DFMs actively initiated and facilitated discussions on relevant topics. They posted thought-provoking questions, shared relevant resources, and/or introduced discussion prompts to stimulate engagement and encourage learners to share their thoughts and opinions. They also ensured timely responses to learners' queries, comments, and contributions, providing guidance, feedback, and encouragement to maintain an active and responsive learning community. While posting on the DF, they employed the following strategies:

- Creating a positive and productive learning environment: Through deliberate use of personalized posts and tonality, DFMs maintained a conducive learning environment. They also intervened when necessary to redirect discussions, encourage participation, or resolve conflicts. DFMs play a crucial role in establishing a safe and inclusive environment where learners feel comfortable expressing their opinions and sharing their thoughts. They enforce community guidelines, promote respectful and constructive dialogue, and address any instances of inappropriate behavior or conflicts that may arise.
- Using personalized prompts: To engage learners, DFMs posted follow-up questions based on their posts. These prompts were meant to seek learners' perspective, experience or further information and examples to support their comments. This guidance helped learners develop critical thinking skills and enhance their understanding of the subject matter.
- Encouraging peer interaction: DFMs facilitated peer interactions either through subtle prompts or explicitly introducing learners having common interests. Apart from providing learners with a platform to share their perspective and lived experience in a structured manner, DFMs encouraged peer review and collaborations. By engaging with peers' posts, learners displayed a sense of community.

4) Handover: This involved preparing a short handover report to the team and DFM of the next day. At the end of the day of duty, DFMs either had a short call, chat or post with details of their experience on the DF. This handover communication also included queries that they were unable to answer and any interesting posts that they read. Majority of DFMs preferred the creative aspect of their role such as working on the audio report as a group or individually. It is clear that the Moderation Procedures like the tracking sheet, the handover message and the daily report serve as ways for the DFMs to record their activities, stay organized and also be mindful of their replies. The handover component of the day also presents a space for the DFMs to regularly reflect on their own moderation practices, assess the effectiveness of their engagement strategies and sought feedback from learners and fellow moderators. They used this feedback and self-reflection to continuously improve their approach and enhance learner engagement in the DF.

I always felt fulfilled at the end of the day (M4)

I like to work in an organized manner, the tracking sheet and the reporting, I found it interesting (M1).

D. RQ4

To a large extent, DFMs indicated that involvement in a CoP had a positive impact on their participation. The CoP was described as *friendly, reassuring, healthy* (M1) with a *professional* (M3), *open and non-judgmental atmosphere* (M2, M3).

[The] group is the backbone of the DFM (M2).

My opinions were taken positively […] I received personal validation for MOOC creation experience (M6).

Here are four ways in which CoP involvement influences DFMs' motivation.

1) Theme 1- Support in Overcoming Challenges: The challenges faced by the DFMs were broadly of two types: Forum related and Personal. Forum-related challenges include lower levels of participation. Personal challenges include time management and access to internet tools. It is notable that for both these challenges, DFMs relied on the CoP for resolution in more ways than one. When participation levels were low, DFMs brainstormed post ideas or collaborated to form mini-action groups among participants that focused on practicing the LCM principles. When a unique query was asked on the forum, they brainstormed answers among themselves before answering it on the DF. As for personal problems, when DFMs were unable to assume duties for the day they reached out to their DFM peers. All DFMs indicated that they frequently got in touch with and were contacted by their DPOCs and Course Instructors. The role of the DPOCs and Course Instructor was to provide support to the DFMs. They would check-in from time to time to provide motivation, constructive feedback, guidance on posting responses and appreciate reply posts by DFMs. In addition, this CoP included feedback mechanisms from their peers. This constructive feedback has several benefits that range from improving moderation skills to understanding learners' requirements and deploying engagement strategies. The CoP provided a conducive atmosphere for DFMs to be heard, be supported and get validation, thus motivating them to participate and perform on the DF

2) Theme 2- Sense of Belonging and Identity: In order to facilitate communication and coordination for orchestration, a social media group was set up by the course team. All DFMs indicated that asynchronous discussion on social media platforms was used for group, daily update meetings along with one-on-one calls with the team.The CoP being a group of like-minded individuals with shared interests in promoting learning, a mutual sense of belonging was felt by respondents. They say that this sense of common identity within the CoP motivated them to contribute more.

[…] being asked to be DFM was a form of recognition (M4).

A sense of commitment to the purpose of the CoP and camaraderie was observed as DFMs pitched in for each other to answer queries on the forum and in the creation of creative reports of the happenings on the DF. Apart from fielding queries on the DF, DFMs volunteered to take on more responsibilities like attending and moderating chat of the live interactions and responding to queries, and collaboratively designing quizzes based on the DF. In addition, they also created a social media group for participants of the course indicating initiative and further involvement in the community.

[…] there was a need to create a poll and I went out of my way to experiment with embedding polls etc. I was creative after a long time (M1).

Respondents said that the CoP gave them the motivation to do newer. More creative tasks that they otherwise would not have the opportunity to do. This was amplified further by

the realization that their actions make a difference in the dynamics seen in the DF.

3) Theme 3- Peer Recognition and Validation: The social media group provided an avenue for the team to post updates, get clarification and suggestions on posting, and provide their opinions on aspects of orchestration.

Never thought it was needed but I did it to validate the answer. I saw other DFMs also did this. It was nice (M7).

[...] in the group there is the space to say I have made a mistake or I am learning and people will help (M2).

[…] the group is always there to brainstorm…- enable one on one connections (M4).

Within the CoP, the DFMs felt they would get valid answers while asking questions and felt safe enough to seek solutions to the issues they might be facing in the moderation process. They also are able to admit any mistakes that may have been made, with the assurance that they will not be judged but help will be given to rectify the mistake. This definitely made the CoP a space of mutual respect and open communication which are both essential factors in the process of knowledge transfer.

4) Theme 4- Learning and Professional Development Opportunities: To many DFMs, professional development through resource sharing, initiation of collaboration and knowledge enhancement were by products of belonging to this CoP. This led to renewed participation in the DF and implementation of newly learned skills and techniques to support learner engagement. The secondary benefit of this, is that it further motivated them to handhold other DFMs if and when the need arose.

[…] when I mentored some other DFMs in report creation, I was surprised to see that their work was done even though at times I could not be present for the meeting due to personal issues. (M2).

E. RQ5

DFMs identified markers and measures to identify and improve engagement.

1) Theme 1- Markers of DF Engagement: The DFMs who had the experience of being participants in a previous offering of the course mentioned 4 markers for an Active DF. They used a combination of these markers to measure the increase in engagement in the DF.

- Quantity of posts: The volume of posts on a forum on a particular day and more specifically the number of replies to a discussion prompt
- Quality of posts: The quality of posts, not merely the length but also the nature of query/comment are also essential indicators.
- Diversity of participants posting: The number of learners posting as well as having learners consistently communicating through posts either as a reply to the weekly FQs, or answering follow-up questions and queries.
- Number of Learner-to-Learner discussions in addition to Learner-DFM interactions.

2) Theme 2- Measures of DF Engagement: Various measures were put into place to ensure that the markers were met. They include the following

- Explicitly stating expectations to participants of the course so that participants are aware of the benefits of posting on the DF.
- Designing discussion points like weekly FQ and additional FQs to engage the learners. While FQs and RQs are a core component of the LCM model, some DFMs suggested the increase in the number of questions to elicit responses from the participants.
  During the initial time in the course, we should add more FQs or Polls or activities (M7).
  Include questions that cater to the imagination, personal experience and individual perspective. So learners can write based on their perspective instead of giving some generic answers (M6).
- Utilizing conversation strategies when starting a discussion thread include addressing the participants by their names and maintaining a friendly yet serious tone to the posts.
- Acknowledging good posts by participants. DFMs used different means to value the participant's experience or words such as a compliment or acknowledgement of the participants' posts. A majority stated that incentivization of participation on DF and other communication channels like DF of the Live interactions by acknowledging good posts. This was done in order to involve them further in the conversation.
  […] identify and incentivize those who are normally active on the DF (M4)
  All learners interviewed, indicated that they appreciated the personalized feedback.
- Posing conceptual and probing questions to help learners deepen their understanding or posing follow-up questions to further the conversation. *Don't give the answer directly, instead lead the learner to the answer and let them discover it. Asking a question back to the learner on how a certain element can be applied in his or her domain (R2). Frame the answer in a probing way eliciting further interaction (M3)*
- Cross-posting where participants were directed to existing posts.
- At times, consciously not responding to select posts to let the participants discuss.
  […] sometimes not interfering with peer interaction can help (M4).

In addition, after interacting with participants in various smaller groups, the insights gained point towards bridging the linguistic gap by providing learners in a multilingual context the possibility to use their language of choice, to communicate in the DF.

V. Discussion

Our study reveals that factors like knowledge and skill, networking, and altruism motivate candidates to volunteer as DFMs. By taking these factors into account, DFMs make an informed decision about their readiness to assume the responsibility of moderating the DF. Our findings are in line with prior studies which confirm that factors like knowledge

self-efficacy, personal gain, collectivism, and a variant of altruism among others are key drivers in knowledge-sharing online CoPs [23], [24].

The onboarding orientation activity conducted before the start of the course received positive reviews from DFMs who gained three kinds of benefits: Orchestration-focused gains, Skill-focused gains, and Community-focused gains.

With sufficient orientation and training, DFMs feel confident in their capacity to effectively perform their roles. This essential onboarding process helps acknowledge and address DFMs perceptions, expectations and specific requirements ensuring a positive boost to their experience. The training of e-moderators equips them with the required skill sets which in turn is reflected in DF interactions [21].

On a daily basis, DFMs undertook 4 steps: Monitoring, Consulting, Interventions on DF and Handover. While posting they employed a range of strategies. By employing these strategies, DFMs can create a dynamic and interactive learning environment within the DF, fostering active participation, knowledge sharing, and collaborative learning among learners. These strategies are similar to those used by instructors-led DFs [22].

Being an integral part of a CoP gives DFMs not only a sense of belonging and recognition, but also provides safe spaces for learning, feedback and collaboration. This in turn fuels motivation to actively engage with learners in the DF and foster engagement among the participants, creating a ripple effect conducive to community building.

According to the DFMs, the 4 markers for an Active DF are quantity of posts, quality of posts, diversity of participants posting and peer-to-peer discussions. This is in line with prior studies [13], [14] which have also identified other markers that need to be taken into account. The measures put into place to ensure that the markers were met are: explicitly stating expectations to participants of the course, designing discussion points and utilization of conversation strategies.

A. *Limitations of the study*

In addition to the qualitative observations, quantitative data from more DFMs would have strengthened our findings. However, this orchestration strategy to deploy DFMs limits the sample size. Further, it was difficult not only to find other courses deploying this strategy but to also gain permission to access them. Considering that online interviews with DFMs were conducted after the course ended, limitations of interview methods like memory reconstruction could affect the data.

VI. CONCLUSION

The findings of this ethnographic study concludes that CoP provides support, suggestions, and validation to DFMs. Thus, interaction among DFMs multiplied as evidenced by the increase in number of individual/collaborative tasks. This demonstrates that an inclusive and non-judgmental community encourages DFMs to participate more. As a result, an increase in participant engagement on the DF is observed.

The study recommends the following strategies related to DFMs and DF moderation useful for MOOC designers: (a) selection of DFMs who are alumni of the course, (b) incorporation of orientation sessions prior to the course, (c) training on moderation specific technical features of the platform, (d) operationalization of DF specific communication strategies, (e) inculcation of community building ethos. These strategies are replicable and could be implemented in other courses to ensure higher completion rates.

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What Supports do Teachers Need for Effective Learning Designs while Integrating Technology? A Mixed Methods Study

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***Abstract*— Learning designs (LDs) involve intentional and systematic planning of learning experiences and activities to achieve specific educational goals. Creating effective learning designs is a complex task for school teachers, because they encounter various challenges that impact successful integration of technology in the classroom. Previous solutions such as teachers' training programs & workshops, online portals for sharing best practices, teaching frameworks & guidelines and learning design frameworks & tools have been developed to address this issue. However, these solutions have been reported to be insufficient in improving teachers' ability to design effective LDs. Therefore, it is necessary to understand the needs and supports that teachers required for learning design. This paper explores the supports that school teachers required for designing effective LDs and also investigate how teachers' demographics and background or context affect LD support required by teachers. We adopted a mixed research with 203 teachers from different schools in Delhi, India. Our results show that teachers need learning design support for creation, contextualization and collaboration. This study also suggests significant differences in teachers' support required for learning design according to the use of technology in the classroom and availability of computer at teachers' home.**

Keywords*— *Learning Design, ICT integration, lesson planning, teacher education, learning design tool, teacher needs.

I. Introduction

The COVID-19 pandemic sparked a significant 'shift to digital' in school education due to the widespread adoption of online remote teaching [1]. This has brought online teaching and digital technologies to the forefront of educational practice and opened the door for future innovation, change, as well as concerns about how we teach and learn. This has led to a growing emphasis on the integration of technology and student-centered approaches in education. However, school teachers have reported to have difficulty in integrating information and communication technology (ICT) in the classroom [2]. This is mainly due to challenges in designing effective learning designs (LDs) with ICT integration in the classroom.

A widely cited definition of LD is provided by Conole, which states that learning design "involves designing the teaching and learning process, including the use of both pedagogical and technological approaches, to create an effective learning experience"[3]. This definition emphasizes the importance of integrating pedagogical principles with the effective use of technology to enhance the learning experience. LDs involve carefully selecting and sequencing instructional strategies, resources, assessments, and learning environments to support student engagement, understanding, and skill development. Effective LDs promote student engagement, motivation, and meaningful learning experiences. They provide a structured framework for organizing instructional materials, activities, and assessments to support student learning outcomes. By incorporating pedagogical strategies, technology integration, and diverse learning resources, effective LDs cater to the needs and interests of students, facilitating more profound understanding and knowledge retention. Research suggests that well-designed LD can significantly enhance student achievement and academic performance [4]. When teachers utilize effective LDs, students are more likely to develop critical thinking skills, problem-solving abilities, and creativity, essential for success in the 21st century.

Designing effective LDs that leverage technology and promote student engagement is a complex task that requires pedagogical expertise, technological proficiency, and a deep understanding of student needs [5]. Teachers play a pivotal role in this process, as they are responsible for designing LDs that foster meaningful interactions, cater to diverse learner needs, and facilitate the acquisition of knowledge & skills. Thus supporting teachers in designing effective LDs has become a significant area of research and development.

Various strategies and interventions have been implemented to assist teachers in representing their teaching ideas and adopting student-centered LD practices. These efforts aim to enhance the quality of education and promote more engaging and meaningful learning environments. One such approach involves the use of learning design tools that provide guidance and support throughout the design process [6]. These tools offer frameworks, templates, and resources that can assist teachers in structuring their learning activities and aligning them with intended learning outcomes. Training programs and workshops have also been employed to enhance teachers' understanding and skills in learning design [7]. These initiatives provide opportunities for teachers to learn about pedagogical theories, instructional strategies, and effective use of technology in designing student-centered learning experiences. Community-based platforms have emerged as another avenue for teachers to share knowledge, exchange ideas, and collaborate on learning design [8]. These platforms create spaces for educators to engage in discussions, access resources, and learn from each other's experiences, fostering a sense of community and professional development.

Despite these efforts, teachers' still do not adopt LD tools as expected. Existing efforts have been reported to be insufficient in improving teachers' ability to design effective LDs [9]. Teachers find it difficult to translate theory into practice [10] or customize best practices for their own context [11]. In addition, researchers have highlighted barriers such as lack of awareness or familiarity with student-centered

approaches, resistance to change, institutional constraints, and limited support or incentives for implementing innovative design practices [12] [13] [8]. Additionally, challenges related to time constraints, workload, and the complexity of integrating technology into design processes may also hinder the adoption of student-centered LD practices. Research also suggests that many teachers encounter obstacles in designing and implementing student-centered LDs [1]. These challenges often stem from a lack of adequate support that can assist teachers in navigating the complexities of integrating technology into their instructional practices. To address this gap, it becomes crucial to explore and identify the specific support requirements that Indian teachers needs to effectively design LDs.

This study aims to delve into supports required by teachers in India for creating effective LDs. It utilizes a mixed-method approach, starting with in-depth qualitative interviews (N=6), followed by a quantitative survey (N=197) to examine the types of support teachers require for designing effective LDs while integrating ICT in the classroom. Additionally, the study aims to analyze how teachers' demographics and contextual variables may impact the required LD support. By understanding these needs, we aim to provide insights that can inform the development of targeted support for teachers to create effective learning designs.

II. Literature Review

In recent years, there has been a growing emphasis on student-centered learning and the integration of technology in educational practices. This shift has presented both opportunities and challenges for teachers, who are tasked with designing effective LDs that harness the potential of technology while catering to diverse learner needs.

A. Effective Learning Design

Learning designs provide a framework for teachers to structure and organize their teaching, ensuring alignment between learning objectives, content delivery, and assessment methods[10].The concept of LDs recognizes the importance of considering various factors, such as the needs and abilities of learners, the subject matter, the learning context, the available resources, desired learning outcomes, pedagogical approaches, and available technologies, to create an engaging and meaningful learning. It encourages educators to design learning experiences that cater to diverse learning styles, promote active participation, foster critical thinking, and support acquiring knowledge and skills. Educators can create cohesive and coherent learning experiences by employing LDs beyond merely transmitting the information. They focus on engaging learners in meaningful tasks, collaborative activities, problem-solving exercises, and authentic assessments that promote deep understanding and application of knowledge [14]

Designing LDs that focus on the needs, interests, and abilities of learners is crucial for effectiveness. This includes incorporating active learning strategies, promoting student engagement, and providing opportunities for student choice and autonomy [15]. Clearly defining learning goals and objectives helps students understand what is expected of them and guides the instructional design process. Learning goals should be specific, measurable, achievable, relevant, and time-bound [16]. Connecting learning to authentic and real-world contexts enhances relevance and meaning for students. Designing learning experiences that reflect real-life scenarios and challenges helps students see the practical application of their learning [17]. Incorporating ongoing assessment and timely feedback into learning designs supports student progress and informs instructional decisions. Various assessment strategies, such as formative assessments, self-assessments, and peer assessments, contribute to the effectiveness of the learning process. Integrating appropriate technology tools and resources can enhance the effectiveness of learning designs. Technology can support collaboration, provide access to information and resources, and facilitate interactive and multimedia-rich learning experiences.

B. Existing Support for Teachers

Previous research has highlighted the importance of various forms of support, such as professional development programs, collaborative communities, mentoring, and access to resources and tools [18].

Professional development programs play a significant role in supporting teachers' LD practices. These programs can provide teachers with the necessary knowledge and skills to effectively integrate technology into their LD practices [19]. Professional development programs can provide training, workshops, and resources to support teachers in understanding and implementing effective LDs [20]. This supports included troubleshooting, training on specific technologies, and guidance on selecting appropriate digital tools for LDs.

Collaborative communities, such as professional learning networks & communities of practice, offer opportunities for teachers to share ideas, collaborate, and receive peer feedback thus enhancing their LD capabilities [8]. Collaboration & collegial support are crucial for teachers in implementing LDs. Collaborative environments provide opportunities for reflection, problem-solving, and the sharing of best practices. Mentoring has also been recognized as an effective form of support for teachers in LD. Mentors can provide guidance, feedback, and personalized support to teachers, fostering their professional growth and confidence in designing effective LD.

Furthermore, access to appropriate resources, such as learning design frameworks, technology tools, and instructional materials, is crucial in supporting teachers' design practices. Teachers require access to high-quality curriculum materials and resources that align with the learning designs they intend to implement. This support can include curriculum guidelines, instructional materials, and digital resources that support active learning, differentiation, and engagement. School administrators play a vital role in supporting teachers' implementation of learning designs. This support includes providing time for collaboration and professional development, allocating resources and funding, and creating a supportive school culture that values and encourages innovative teaching practices.

A study conducted by Bennett et.al to explore the support that assists university teachers in their design processes. They identified several crucial influences on design decisions, including teachers' perceptions of student characteristics, their own beliefs and experiences about teaching & learning, and contextual factors. Also, suggested various supports to improve design practices. These included enhancing teachers' knowledge of students, facilitating the sharing of practices, providing guidance on pedagogical theory, and enabling flexibility in design processes and within the designs themselves. The study emphasized the potential of support tools to engage with these influential factors and improve

design decisions [16]. Similarly, Arpetti et.al support for reflection, considering the educational needs of learners, ease of use, time efficiency, design reuse, and guidance in the design process were identified as crucial requirements by teachers [21]. The sharing of design practices was considered neutral, while software compatibility, graphical representation of designs, collaboration features, author identification, and aesthetics were found to be less important for teachers when it comes to learning design. Conole evaluated LD tools and identified support features such as flexibility, particularly in adapting designs to different educational contexts, was desirable and positively received by teachers. Support for the reuse and adaptation of designs was preferred over creating entirely new designs. Usability was consistently valued by teachers in various evaluation studies. The textual representation of designs was also appreciated by teachers when evaluating a tool [6]. In a systematic review conducted by Dagnino et al. identified categories of teachers' needs included flexibility for the reuse, revision, and adaptation of designs to educational needs, as well as support for the design process itself and providing guidance. The review also highlighted the importance of support for retrieving existing designs, facilitating cooperation among teachers through peer evaluation and collaborative editing, and supporting reflection through graphical or textual representation of designs. Other important factors included ease of use, textual & graphical representation, & activating design thinking processes aligned with teachers' familiarity and institutional design culture [22].

This literature review has identified various forms of support, including professional development, collaborative communities, mentoring, and access to resources. These studies collectively highlight the significance of various supports, such as knowledge enhancement, sharing practices, flexibility, ease of use, design reuse, and reflection, in assisting teachers with learning design processes and promoting effective educational practices. To understand the specific support required by Indian teachers in designing effective LDs, there is need to explore their experiences and perspectives. By addressing the support requirements of teachers, we can empower teachers to overcome barriers, leverage technology effectively, and create engaging and impactful learning designs for their students. This review of literature and analysis of LD tools helped us identify different supports. These categories of supports would be used to help our coding in the research studies within Indian contexts.

III. Background: Teacher Preparation and Training in India

In India, teacher preparation and training are managed by institutes like National Council for Teacher Education (NCTE), State Councils of Educational Research and Training (SCERTs), District Institutes of Education and Training (DIETs), and universities offering Bachelor of Education (B.Ed.) and Master of Education (M.Ed.) programs that are responsible for policies and initiatives. These institutions are responsible for designing and implementing teacher training programs to equip educators with the necessary knowledge, skills and competencies required for effective teaching. NCTE is main governing and regulating body which is responsible for setting the standards and guidelines for teacher education programs in the country. The primary focus of teacher preparation in India is on developing pedagogical knowledge, subject content expertise, classroom management skills and competencies required for effective teaching. The training programs aim to equip teachers with the necessary foundational knowledge and teaching strategies to effectively engage students in the learning process. The program covers various subjects related to education, including pedagogy, educational psychology, curriculum development, assessment and evaluation, classroom management, educational technology, and inclusive education etc. Students engage in both theoretical coursework and practical training. Theoretical coursework includes lectures, seminars, and discussions on educational theories, teaching methodologies, and relevant research. Practical training includes teaching practice in schools, where students gain hands-on experience in planning and delivering lessons, managing classrooms, and assessing student learning.

Teacher Professional Development (TPD) programs in India are managed by various organizations and entities, including government bodies, educational institutions such as SCERTs, DIETs, non-governmental organizations (NGOs), and private entities. NCTE plays a significant role in setting guidelines and standards for teacher professional development in the country. In India, TPD programs are designed to enhance the knowledge, skills, and competencies of teachers to improve their instructional practices and keep up with emerging trends and challenges in education. TPD programs aim to support teachers in their professional growth and provide them with opportunities for continuous learning and development. These programs typically focus on pedagogical advancements, subject-specific updates, classroom management techniques, educational technology or digital tools training etc. TPD programs in India may be delivered through various modes, including workshops, seminars, conferences, online courses, and mentoring programs. The duration and intensity of these programs can vary, ranging from short-term workshops to long-term professional development courses.

The focus on incorporating technology effectively into teaching practices is often limited to a single course on educational technology, which may not adequately prepare teachers to leverage technology in a meaningful way across various subjects and instructional contexts. Also, there is often limited emphasis on LDs, which involve the deliberate planning and organization of instructional activities to optimize learning outcomes. The focus is more on teaching methods rather than designing learning experiences that cater to diverse student needs and promote active and meaningful engagement. This highlights a gap in the Teacher Preparation and TPD programs in India, so there is need to support teachers in developing teachers' understanding and application of LDs and leveraging technology for enhanced teaching and learning experiences. For this, we need to understand and identify the supports needed by Indian teachers for LDs.

IV. Method

The broad research question (RQ) addressed in this study was "What *supports do teachers need for designing effective LDs while integrating ICT in the classroom?* To address this, this study employed exploratory sequential mixed method in which the initial phase typically involves collecting and analyzing qualitative data, followed by a quantitative phase. Creswell defines exploratory sequential mixed methods as a

research approach "in which the researcher begins with a qualitative exploration of a phenomenon and then uses the results to inform subsequent quantitative data collection" [23]. In our study, the qualitative phase aims to explore the support for LDs that Indian teachers require via in-depth interviews. We also conducted a quantitative phase study aimed at gathering empirical data on the kinds of support needed by teachers for LDs and identify the prominent or dominant one. Also, investigate if there are any significant differences in support needed by teachers for designing effective LDs according to their demographics & contextual variables.

V. Qualitative Study

The qualitative phase aims to explore the support required by teachers in designing effective LDs. Details of this phase have been previously published [24]. Here we provide a summary of the study design and findings.

We selected teachers from different types of schools (government, government aided-private, and unaided-private) in Delhi via interviews. We conducted interviews via online mode with a total of 6 teachers (4 males, 2 female), consisting of 3 in-service teachers and 3 pre-service teachers. Each interview took approximately 1 hour. Participants' academic backgrounds spanned various disciplines, including sciences, social science, mathematics, and languages. Prior to the study, the majority of participants (5 out of 6) had not utilized any LD tools. Using thematic analysis [25], eight themes emerged which were categorized based on their similarities. The three categories emerged as: creation, contextualization, and collaboration as shown in Table1.

TABLE I. Details of categories and themes emerged from emphirical evidences

Categories	Themes
1. Creation	**a) Templates** : LDs pprovided with prompts that can be easily filled by teachers without specific technical skills. **b) Basket of strategies:** LDs must have sets/samples of lessons on the same topic with different strategies. **c) Review/ Comparison mechanism:** Existing LDs provided that help in building new learning designs or reviewing new designs. **d) Reusability:** provided LDs were readily understood, adapted and reused by teachers in their context.
2. Contextualization	**e) Understanding students' needs:** LDs must cater to the needs of the learners. **f) Relatable examples/content in context:** LDs must provide specific examples that are related to the context of the learners.
3. Collaboration	**g) Expert/Mentor support:** LDs must provide a mechanism for expert feedback. **h) Peer-support:** LDs were created with support of peers like collaborating to create new designs or to review designs of their peers.

Through this qualitative approach, we gained valuable insights about the supports that teachers required to design student-centered LDs successfully. These findings have serve as a foundation for second phase of the study.

VI. Quantitative Study

Based on the qualitative study findings, we identified variables, developed instrument to measure the kinds of supports required by teachers for effective LDs, identify the prominent ones and generate hypothesis The RQs in the quantitative phase are:

RQ1.What kinds of supports do teachers need for designing effective LDs while integrating ICT in the classroom? Which kind is more dominant or prominent?

RQ2 What are the demographic and contextual variables that affect the LD support requirement of teachers?

A. Participants

The participants in this study were school teachers from various educational settings in Delhi, NCR, which were the schools sampled for the study. Snowball sampling techniques were used for selecting participants (school teachers). A total of 167 teachers volunteered to participate in this study.

B. Instrumentation

A Learning Design Support Questionnaire (LDSQ) was developed to collect data on support required by teachers in designing effective LDs based on the existing literature and theoretical frameworks. The questionnaire comprised 12 items to measure three kinds of support: creation, contextualization, and collaboration. Each item was rated on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). In addition to the LDSQ, a demographic and context-related information section was included in the questionnaire to gather data on teachers' age, gender, teaching experience, highest educational qualifications, grade level taught, training in information and communication technologies (ICT), availability of resources (e.g., computer laboratory, internet access, computer access in school, computer access in the home.), type of school and use of ICT by the teachers.

To establish the content validity of a questionnaire, experts in the field of education and educational technology are involved in the review process. These experts possess specialized knowledge and expertise in the specific domain of the research topic. They identified items that were redundant, unclear, or irrelevant to the construct being measured. Experts also suggested additional items that enhance the content coverage of the questionnaire or provide alternative wording or response options. Researchers carefully considered the feedback and recommendations provided by the experts and made necessary revisions to the questionnaire based on their input. This iterative process of review and revision helped establish the content validity of the questionnaire, ensuring that it measures the intended construct accurately and comprehensively.

Data was collected from 30 teachers to establish reliability. Cronbach's alpha was used to test reliability, and the results revealed that the scales and sub-scales had acceptable internal consistency reliabilities. LDSQ is a self-reporting survey that measures a continuum of three kinds of support for LDs: Creation, Contextualization and Collaboration. This survey comprises 12 statements using a 5-point Likert scale with response options ranging from

"disagree strongly" to "agree strongly." It also consists of 12 items about demographics variables and for understanding the context of the teachers. The names of variables and the number of items are as follows: Creation (5 items, i.e. Q1, Q2, Q4, Q8, Q9); Contextualization (5 items, i.e. Q3, Q5, Q10, Q11, Q12) and collaboration (2 items, i.e. Q6, Q7) reported that the Cronbach alpha internal-consistency reliabilities ranged between .75-.82. The reliability of the overall LDSQ is established with Cronbach's alpha i.e. 0.9. The reliability of variables: creation (.779), contextualization (.753) and collaboration (.825). Sample questions included:

- A repository of lesson plans in my topic will help.
- A template that I can use to generate my lesson plan will help
- Support from a mentor while I create lesson plans will help.
- Access to multiple examples of activities for a given topic will help in lesson planning.

C. Data Collection

LDSQ with items on teachers' characteristics, context and supports required for LDs was distributed among teachers through various online modes, i.e. WhatsApp, Gmail, telegram etc. and asked them to share their friends, colleagues. Data collection was conducted through an online survey i.e. Google Form administered to the participants. The survey was distributed using online platforms, and participants were given a specified time frame to complete the questionnaire. To ensure anonymity and confidentiality, participants were assured that their responses would be kept confidential and used for research purposes only. Informed consent was obtained from all participants, ensuring their voluntary participation and understanding of the study's objectives and procedures. The data collected were kept confidential and used solely for research purposes.

D. Data Analysis

Quantitative data analysis was conducted to examine the support requirements of teachers for designing effective LDs and investigate potential differences based on demographic and contextual factors. First, descriptive statistics were performed. Descriptive statistics, such as means and standard deviations, were calculated to determine the overall level of support needed for each kinds of support (creation, contextualization, collaboration) required for designing effective LDs. Then, the Shapiro-Wilk test was done to test the normality of the data for it to qualify for parametric tests. The test results for the normality of our data (p=<.001), thereby violating the normality assumption. Therefore, we used the skewness and kurtosis results between −1.0 and +1.0 and assumed the distribution to be sufficiently normal to qualify the data for a parametric test. The sample size was also significant. There, inferential statistics, such as t-tests and analysis of variance (ANOVA), were used to analyze the data and identify significant differences in LDs support requirements based on demographic and contextual variables. The quantitative study employed a well-designed questionnaire (LDSQ) to gather data on the support requirements of teachers in designing effective learning designs. The data analysis aimed to identify the kinds of support needed and explore potential differences based on teachers' demographics and contextual factors.

E. Quantitative Study Findings

Teacher demographics namely age, gender, teaching experience, highest educational qualifications, grade of teachers, subject taught, and context-related factors assessed in this study, namely, training in ICT, type of schools, availability of computer laboratory, internet access, computer access in school, computer access in the home and the use of ICT in the classroom. K–12 teachers were included in the sample, regardless of the number of years of teaching experience, subject-matter expertise, or other demographic variables (gender, age). Of the 200 teachers who received the surveys, 167 responded with usable returns.

1) Frequency distribution of demographics and context related data of participants(n=167)

TABLE II. FREQUENCY DISTRIBUTION OF DEMOGRAPHICS VARIABLES OF PARTICIPANTS

Variables	Frequency	Mean	SD
Gender			
Male	52 (31.13%)	47.7	9.37
Female	115 (68.86%)	46.8	9.33
Age Group			
21-30	17 (10.17%)	48.4	8.75
31-40	73 (43.71%)	47.6	10.13
41-50	47 (28.14%)	46.6	8.83
51 -above	30 (17.96%)	46.0	8.57
Teaching Experience (in yrs)			
1-5	43 (25.74%)	47.3	9.21
6-10	37 (22.15%)	48.4	9.68
11-15	30 (17.96%)	45.9	11.52
16-20	21 (12.57%)	48	7.63
21-25	12 (7.18%)	48.4	7.42
25-above	24 (24.37%)	44.8	11.52
Educational Qualification			
UG+B.Ed.	33 (19.76%)	47.1	8.52
UG+B.Ed.+PG	106 (63.47%)	46.6	9.69
UG+B.Ed.+PG+M.Ed.	19 (11.37%)	48.6	8.78
D El Ed	9 (5.38%)	50.2	9.27
Teaching Grade Level			
PGT	31 (18.56%)	47.7	8.88
TGT	113 (67.66%)	46.5	9.36
PRT	22 (13.17%)	49.4	9.88
Subject Taught			
Science	28 (16.76%)	47.6	9.99
Langauge	54 (32.33%)	44.7	10.17
Social Science	34 (20.35%)	47.9	7.71
Mathematics	22 (13.17%)	48.1	8.51
Computer Science	8 (4.79%)	49.1	5.49
All	21 (12.57%)	49.5	10.72

Table 2 presents the frequency distribution and descriptive statistics of the demographics variables of the participants. It shows that out of the total (167) participants, 52 individuals (31.13%) identified as male, while 115 individuals (68.86%) identified as female in which majority belongs to 31-40 age range groups. The highest percentage of participants, 43 individuals (25.74%), falls within the 1-5 years of teaching

experience category. The highest percentage of participants, 106 individuals (63.47%), hold a UG+B.Ed.+PG qualification and majority (67.66%) were trained graduate teachers (TGT).

Table 3 presents the frequency distribution and descriptive statistics of the context-related data of the participants. Majority (58.08%) of the teachers have not attended any training or workshop related to ICT. Majority (97%) of teachers belong to government school. Majority (86.82%) of school have computer laboratory but not internet access. Majority of teachers have access of computer in home not at school. Still, 65.26% of teachers uses ICT in the classroom.

TABLE III. FREQUENCY DISTRIBUTION OF CONTEXTUAL VARIABLES OF PARTICIPANTS

Variables	Frequency (%)	Mean	SD
ICT training/workshop			
No	97 (58.08%)	46.4	10.2
Yes	70 (41.92%)	48.1	7.98
School Type			
Govt. aided	3 (1.79%)	49	9.64
Govt.	162 (97.0%)	47.1	9.25
Private	2 (1.19%)	45	21.21
Computer Laboratory in School			
Yes	145 (86.82%)	47.6	9.22
No	22 (11.97%)	43.6	9.40
Internet Access			
Yes	65 (38.92%)	48.7	8.85
No	102 (61.07%)	46.1	9.52
Own Computer access in School			
Yes	42 (25.14%)	47.7	8.39
No	125 (74.85%)	46.9	9.64
Laptop/Computer access at home			
No	68 (40.71%)	45	10.5
Yes	99 (59.28%)	48.5	8.14
Use ICT in the classroom			
Yes	109 (65.26%)	48.6	8.60
No	58 (34.73%)	44.3	10

2) Frequency distribution of demographics and context related data of participants of teachers' agreement scores on each items of LDSQ (n=167)

Table 4 revealed that teachers require all three kinds of support in designing effective LDs i.e. creation, contextualization and collaboration. Teachers need creation support like Templates / Prompts that they can quickly fill without specific technical skills. A basket of strategies that consists of sets/samples of lessons on the same topic with different approaches. Comparison mechanism having sample LDs provided that help build new learning designs or review new designs reused by teachers were able to effectively adapt and reuse previously documented learning designs according to their own needs. Teachers need contextualization support, like learning designs must cater to the needs of the learners. Relatable examples/content in context: Learning designs must provide specific examples of the learners' context. Also, shows that out of three support teachers require contextualization related support more in designing effective LDs, followed by creation and collaboration.

3) The result of significant differences between Learning Design Support and demographic & context related varaibles of teacher.

To address RQ2. The following hypothesis was tested.

1. H0: There is no significant difference between support required by teachers for learning design and demographic variables namely age, gender, teaching experience, highest educational qualifications, grade of teachers, subject taught.
2. H0: There is no significant difference between support required by teachers for learning design and. Context related variables, namely, training in ICT, type of schools, availability of computer laboratory, internet access, computer access in school, computer access in the home and the use of ICT in the classroom.

Findings revealed that the demographic-related variables like gender (p=.592), age (p=.756), teaching experience (p=.634), highest educational qualifications (p=.621), grade of teachers (p=.429), and subject taught (p=.390), are not significantly different with Learning design support requirement of teachers. The following context-related factors like training in ICT (p=.252), type of schools (p=.952), availability of computer laboratory (p=.058), internet access (p=.083), computer access in school (p=.621) are not significant with Learning design support requirement of teachers. Apart from that, we found that there is a substantial difference between LDS and teachers who use ICT in the classroom(p=.004) and have computer access at home (p=.016).

TABLE IV. THE FREQUENCY DISTRIUTON OF TEACHERS' AGREEMENT SCORES ON EACH ITEMS OF LDSQ

Teachers' agreement scores on each items of LDSQ.						
S. No.	***Items***	***SD***	***D***	***N***	***A***	***SA***
1.	A repository of lesson plans in my topic will help.	3 1.8%	13 7.8%	35 21%	55 32.9%	61 36.5%
2	I intend to use the lesson plans in the repository as is.	6 3.6%	13 7.8%	53 31.7%	64 38.3%	31 18.6%
3	I intend to revise and re-prepare the lesson plans in the repository.	3 1.8%	11 6.6%	41 24.6%	65 38.9%	47 28.1%
4	A template that I can use to generate my lesson plan will help.	2 1.2%	8 4.8%	41 24.6%	64 38.3%	52 31.1%
5	Access to multiple examples of activities for a given topic will help in lesson planning.	2 1.2%	3 1.8%	36 21.6%	52 31.1%	74 44.3%
6	Support from a mentor while I create lesson plans will help.	4 2.4%	6 3.6%	46 27.5%	62 37.1%	49 29.3%
7	Support from peers while I create lesson plans will help.	3 1.8%	6 3.6%	44 26.3%	58 34.7%	56 33.5%
8	Support in framing LOs will help me in lesson planning	1 6%	9 5.4%	40 24.0%	64 38.3%	53 31.7%
9	Support in framing assessment questions alignment with LOs will help me in lesson planning.	2 1.2%	6 3.6%	45 26.9%	58 34.7%	56 33.5%
10	Support in selection of appropriate Edtech tools for defined purposes will help me in lesson planning.	3 1.8%	7 4.2%	45 26.9%	61 36.5%	51 30.5%
11	Support in selection of appropriate Edtech tools for particular topics will help me in lesson planning.	3 1.8%	4 2.4%	44 26.3%	68 40.7%	48 28.7%
12	Sample lesson plans based on different strategies for the same topic will help in comparison.	1 0.6%	5 3.0%	36 21.6%	67 40.1%	58 34.7%

VII. DISCUSSION AND CONCLUSION

The research conducted among teachers in Delhi, India revealed diverse areas of support needed by teachers to develop learner-centric LDs. Our findings indicate that teachers require substantial assistance in creating and contextualizing learning designs, as well as opportunities for effective collaboration in their development [25]. Also, shows that out of three supports, teachers require contextualization related support more in designing effective LDs, followed by creation and collaboration. These findings are consistent with prior studies examining the support teachers require when designing learning designs. For instance, Dagnino et. al. [22] research emphasizes the need for teachers to have access to pre-designed templates and flexibility in making pedagogical decisions while structuring learning designs. In our study, teachers demonstrated a willingness to receive support in conceptualizing and applying the learners' context. Similarly, the endeavor to familiarize oneself with students' backgrounds and characteristics is identified as a recurring theme in the research conducted by Bennett et al. [16].

There are several variables that can affect the learning design support requirements of teachers, including their level of experience, their subject matter expertise, their technological proficiency, their pedagogical content knowledge, and the context in which they are teaching. Research studies have explored the impact of these variables on teachers' learning design support requirements. In our study, we found that there is no significant difference between support required by teachers for LDs creation and teaching experiences. In contrast to this, a study found that teachers with more experience tended to require less support in terms of designing effective learning while teachers with less experience needed more guidance and support [26].

In present study, we found that there is a statistically significant difference between teachers used and not used ICT in the classroom with the supports teachers required for LD. Our study found that there is a substantial difference between LDs and teachers who have computer access at home. A study found that teachers in schools with limited resources required more support in designing technology-enhanced learning activities than teachers in more affluent schools. In addition, the context in which teachers are teaching can also impact their learning design support requirements. Overall, the learning design support requirements of teachers are complex and multifaceted, and are influenced by a range of factors. Understanding these factors can help educational designers and policy makers provide appropriate support and resources to teachers to enhance their teaching practices.

Understanding the support requirements of teachers in learning design has significant implications for both practitioners and researchers. Practitioners can utilize this knowledge to develop targeted support programs and resources that address the specific needs of teachers. By providing teachers with the necessary support, educational institutions can enhance teaching quality, student engagement, and learning outcomes. For researchers, this study contributes

to the existing literature on learning design supports. It provides insights into the specific support requirements of teachers and highlights areas that warrant further investigation. Future research can delve deeper into the effectiveness of different forms of support, explore the impact of contextual factors on support requirements, and identify innovative approaches to support teachers in designing effective learning experiences.

Furthermore, this study contributes to the broader conversation on educational innovation, as it explores the intersection of pedagogy, technology, and teacher support in the digital era. Moving forward, further research and the development of targeted support interventions are necessary to bridge the gap between theory and practice in learning design support. This research will contribute to the growing body of knowledge surrounding learning design practices and help bridge the gap between theory and practice in educational settings. These findings have serve as a foundation for future research and the development of practical strategies to enhance teacher support in learning design practices.

In conclusion, supporting teachers in designing effective learning designs is crucial for harnessing the potential of technology and promoting student-centered learning. Understanding and addressing the support requirements of teachers can empower teachers and lead to enhanced learning experiences for students.

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Fostering Computational Thinking skills in middle school students using CT@Home mobile application

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***Abstract*—Computational thinking skills are recognised as the necessary 21st century competency among learners of various levels. There is an increase in awareness on the potential benefits of introducing computational thinking (CT) skills in the school level curriculum. The existing solutions like block-based activities, AR-VR apps, game-based learning solutions require more relatable and authentic learning contexts. The present study conducted with 49 middle school students (7th and 8th) traces how an educational application called CT@Home can be used to foster logical thinking and CT skills by providing authentic learning experiences through a relevant context which is meaningful to the learner. We investigated the effectiveness of the application around three specific constructs: learning gain, usability, and self-perception. The results suggest that applications like CT@Home which can provide context-based learning, helps in building a positive perception towards learning CT skills among middle school students. Finally, we also discuss some of the important challenges that students faced while interacting with the CT@Home application.**

***Index Terms*—Computational Thinking, Logical thinking, Usability, Learning Gain, Context-based learning, Authentic learning**

I. Introduction and Literature Review

Computational Thinking (CT) is defined as " the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent" by Cuny–Snyder–Wing [1].

Additionally, CT is a problem- solving approach used in computer science that involves breaking down complex problems into smaller, more manageable parts or patterns and developing algorithms or step-by-step procedures to solve them. It involves a set of skills and thought processes, including abstraction, decomposition, pattern recognition, and algorithmic design, that can be applied to a wide range of problems, even beyond those typically encountered in computer science. The proponents of this theory claim that the skills are generalizable across disciplines [2] as they are not only limited to programming or coding; rather, computational thinking can be used to approach and solve problems in any field, from science and engineering to social sciences and humanities. Also, the key argument of applying CT practices is to reason at multiple levels of abstraction while solving problems [3].

As a skill, CT helps students develop problem-solving abilities, logical reasoning, and creativity. Additionally, it can also inform students about the effective use of technology. Hence, by learning it in schools, students can be prepared for the challenges in the real world [3]. In recent years, there has been a growing interest in using educational technology to teach CT concepts, as seen from the increasing number of CT papers [4].

There are multiple frameworks that are used to characterize CT. These frameworks can be broadly seen as a) core programming-related frameworks, and b) generalised frameworks that are aimed at general problem-solving skills. The former kind of framework suggested by Brennan and Resnick, categorizes CT in terms of concepts, practices, and perspectives which are related to programming. Similar categorizations are available in the works of other authors in the domain. Subsequently, the later frameworks which focus on problem-solving skills categorize it as abstractions, decomposition, logical thinking, and so on. The frameworks such as those proposed by Sellby and Woollard, and others have similar categorizations [5].

ICT applications are often used to facilitate learning, particularly for school students. One such example can be seen in the review by Fagerlund et. al.,[6] on teaching CT in programming using Scratch. This review was scoped to teaching programming concepts that foster the development of CT skills in students. Additional CT interventions have also been used for other applications (LEGO MINDSTORMS, CTSiM platform, Alice, etc.). Shute et al. provides a synthesis of the studies done with the CT interventions for different grade levels. The tools used for these interventions were exclusively digital and were facilitated through technology in classrooms [7].The advantages of using such tools are that it provides a unique way of self-expression through coding by providing a block-based programming environment in which students cannot make syntactic mistakes by the virtue of the design of the application [7]. Added to this, the impact of video games on the development of CT skills shows promising results

regarding the development of cognitive and attitudinal changes among elementary school children, such as promoting the learning of some CT components, improving attitudes towards computer science (CS) [8], and development of algorithmic solutions to a problem [9].

Computational thinking skills are being taught using a multitude of mobile applications. Papadakis et al., in their work, have presented a comparative analysis of the CT concepts supported by four widely used applications [10]. These applications provide learners with engaging activities and coding environments that facilitate the learning of CT concepts. They can be integrated in the curriculum to teach different CS concepts [11]. This has also been mentioned in a relatively recent review [12]. The integration of CT into curricula has also shown to be effective in STEM subjects in general, with game design-based instructional methods being one of the most popular ones [13]. Examples include the integration of MIT app inventor to teach mobile app development [14], and as a game-based classroom course for 3rd and 4th-grade students [15].

Connecting students' knowledge with the real world is crucial for developing logical reasoning skills and teaching the concept of looping. This integration of knowledge and the real world is known as authentic learning, which provides students with a more meaningful and relevant learning experience [16-17]. The authentic context also promotes learning among students[18-19].This approach not only fosters their understanding of the concepts but also motivates them to continue learning and apply their knowledge to solve real-world problems [20-21].

The present study focused on analyzing how a mobile-based application called CT@Home can be utilized to support teaching of the conditional and loop concepts in CT in an authentic context. The context used was Earth hour, in which based on certain conditions like date and time, students have to use block based instructions based on concepts of looping to perform actions to switch "OFF" or "ON" the lights at a home based learning environment. We expect this study will also contribute towards understanding the different elements of design that are required to develop mobile-based learning applications to foster CT skills in students and help educators to design more effective educational technology tools.

The present study focuses on how middle school students can be engaged in CT related activities using CT@Home mobile application. It looks at how students can learn computer science concepts like loops, nested loops, and conditionals through apps, in an authentic real-life context of celebrating Earth hour and saving home energy by coding the instructions for IoT (Internet of Things) based on the home appliances that were represented in the application. The present study was conducted as part of the Research Methodology in Educational Technology course.

The remaining part of this paper is organized in the following manner, first we discussed the design of CT@Home mobile application, followed by the description of its implementation in the real-life scenario. Further, we present the results in the form of learning gains of the students, their perceptions of CT and the usability of the application's interface.These results are followed by discussion and conclusion section where applicability of CT@Home in fostering the CT skills is discussed.

II. Design of CT@HOME

CT@Home is an android based application to help novice students typically in the middle school level, to develop introductory logical and computational thinking (CT) skills. The pedagogy used in CT@Home is based on learning by doing and computational tasks, which supports to improve logical thinking skills while solving CT problems. It allows learners to work at their own pace and be actively engaged in the learning process, where the learner is engaged in introductory CT activities in the context of their familiar surroundings, at home.

The CT@Home application has three levels (Fig.1). In level 1, the learners can navigate through different rooms in a house using direction buttons. Each room has different IoT devices (eg. TV) which can be manipulated using actions (move right, left, up and bottom), after checking conditions (eg. whether TV is switched ON or OFF) using different sensors. The level 2 activity is intended to develop logical and computational thinking skills in learners through the concept of Earth hour which takes place annually on the last Saturday of March. In this level, three types of sensors (Date, Time and light) are used to programme the bulbs in a room using pseudocode so that they go OFF on 26th of every month from 8:30 pm to 9:30 pm. Necessary prompts were also given for scaffolding purposes for the learners in each step. The activity involves logically coding the steps to use the correct sensors, conditions and actions to turn off the lights for one hour (Fig.2).

Using the application, learners get a deeper understanding of the different steps involved in computational thinking applied at different scenarios and observing the outcomes (Table 1).

TABLE I
Different steps involved in CT and the corresponding tasks performed in Level 2 of CT@Home

Steps involved in CT	**Corresponding tasks in Level 2 of CT@Home**
Decomposition (breaking down a complex problem into smaller, more manageable parts)	Identifying the steps involved like choosing the date, time and actions
Pattern recognition (identifying connections between different parts of each task)	Selection of proper SENSOR first, followed by CONDITION and then ACTION in each step
Abstraction (identify the important information required to solve the task)	Selection of exact date, time and actions
Algorithmic thinking (defining a step-by-step solution to the problem that can be replicated for a predictable and reliable outcome)	Steps followed in executing pseudocode to turn the bulbs ON and OFF to celebrate Earth hour

The Level 3 of the application was focused on applying the CT skills by learners to set up a security system using motion sensors and home appliances within rooms in a house.

Fig. 1. Screenshot of CT@Home

Fig. 2. Screenshot of CT@Home (Level 2)

The different IoT objects can be manipulated using actions after checking the conditions using sensors. The CT@Home application was thus designed to increase the relevance of CT among students in their everyday contexts and aims to make CT more accessible and useful to a wider range of students. While the application offers three levels of scaffolded learning experiences, this study was limited to Level 2 due to time and technical constraints. Levels 1 and 3 of the CT@Home application were excluded from the study, as they involve physical movement within an empty room. The decision to exclude these levels was made in light of the logistical challenges associated with creating a suitable environment for Level 1 and Level 3, including the need for an empty room and the additional time required for setup and study.

III. METHODS

A. Research Questions

The primary goal of CT@Home mobile application is to assist middle school students who are new to computational thinking (CT) in developing fundamental skills of logical reasoning and problem-solving. Through the present study, the authors try to find answers to the following research questions: What is the effect of CT@home on logical thinking of middle school students? What is the usability of CT@Home application in facilitating tasks related to logical thinking skills? What are the middle school students' perception about CT skills?

B. Participants

A total of 49 students (34 girls and 15 boys), studying in grades 7th and 8th in schools affiliated to Maharashtra SSC board participated in the study. Most of the students were proficient in Hindi and Marathi and could understand English as well.

C. Procedure

The entire study was conducted in two batches within a closed room. At the beginning of the study, numbers from 1- 49 were randomly assigned to each participant and they were asked to identify themselves on all documents using only this number. A random sampling technique was followed (Fig.3) to select participants in each batch. Each participant individually participated in the study, which was carried out for about 1.5 hours. At first the study on the effect of CT@Home on logical thinking was carried out followed by usability of the application and study on students' perception about CT skills. The participants and their parents had signed the necessary assent and consent forms before the study. All researchers were present throughout the study to explain the study procedure, provide necessary instructions, facilitate and address the concerns raised by the participants during the study. An introductory video on Earth hour (in English) was shown to all participants and explanation on the video was given in Marathi (mother tongue of students) before the study. The instructions were given in both English and Marathi languages.

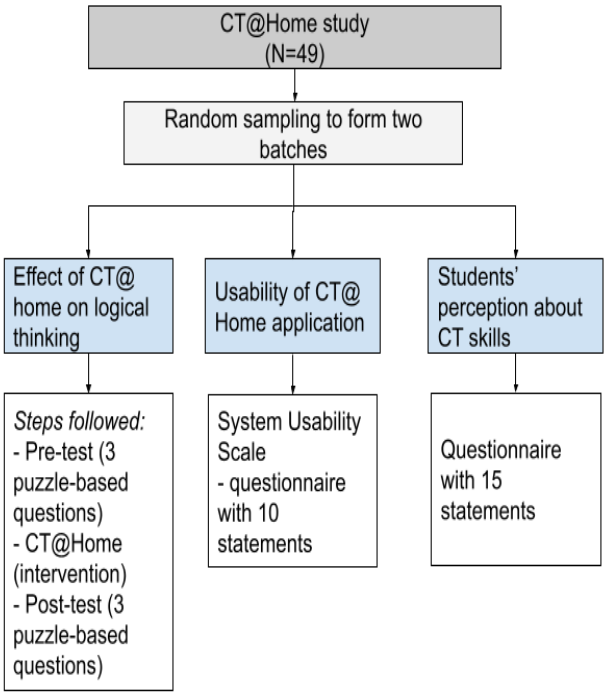

Fig. 3. Design of the conducted study

D. Data sources and instruments

(a) To assess the changes in logical and CT skills, the students responded to a pre-test and post-test (3 puzzle-based questions each) during the study. After the pre-test, the participants were allowed to explore the CT@Home app (Level 2) installed in tablet PCs. The questions for both pre-test and post-test were framed based on the Computational Thinking Test (CTt) developed by Román-González et al., 2017[22]. A primary face validity of the instrument could only be done due to limitation in time. In the study, the students were given 20 minutes to complete each test and most of the participants completed their writing prompts within 10-15 minutes.

(b) To understand the usability of CT@Home application in facilitating tasks related to logical thinking skills, a modified version of System Usability Scale developed by Putnam et al., 2020 was used[23].The questionnaire consisted of 10 different statements for which each participant has to mark his/her most appropriate response. The responses of each participant were analyzed on a 5-point Likert scale.

(c) To understand the students' perception of CT skills, a survey was conducted with 15 statements for which each participant has to mark his/her most appropriate response (Kong et al., 2018)[24]. The instrument was originally designed to study the perception of students towards programming. The responses of each participant were analyzed on a 5-point Likert scale.

IV. Results

The learning gain was computed using Hake's formula given by (Spost –Spre)/(Smax – Spre), where Spost represents the posttest score, Spre represents the pre-test score and Smax represents the total score of the test[25]. The learning gain of 27 participants could not be included for further analysis as they achieved perfect scores in both pretest and post-test[26]. The analysis was carried out for the remaining 22 participants and the normalized Hake's learning gain was computed for the participants (Mean= 0.8257, SD=0.35). The learning gain indicated that CT@Home plays a positive role in learning computational thinking skills.

The data of pre-test (Mean= 2.38, SD=0.78) and post-test (Mean= 2.89, SD=0.3) was observed to violate the normality and equal variance assumption required for t-test. Hence, a Wilcoxon signed rank test was performed between the scores of pre-test and post-test. The test revealed a significant difference between the scores of pre-test and post-test mean ($z = 3.96$, $p<.001$) with effect size ($r = 0.40$).

The reliable instrument System Usability Scale (SUS) was used for measuring the usability. The SUS contains 10 statements. Participants were supposed to score those 10 statements with one of the five responses that range from Strongly Agree to Strongly Disagree in a 5 point Likert scale. In SUS, odd number statements and even number statements are phrased positively and negatively[27].

All 10 SUS statements were modified by adapting them as per the participants' level of understanding[28]. Two examples of original and modified SUS statements are as follows:

Original Statement 1: I think that I would like to use this system frequently

Modified Statement 1: If I had this [app] on my phone, I think that I would like to play it a lot

Original Statement 2: I found the system unnecessarily complex.

Modified Statement 2: I was confused many times when I was playing [app]

The result shows that positive statements were scored between agree to strongly agree and the negative statements were scored between disagree to neither agree or disagree (Fig.4.). Participants' responses to these statements were converted to SUS score using the standard formula (((rating of odd questions)- 5)+(25- (rating of even questions))*2.5.[29] SUS score of CT@Home app (Mean= 61.37, SD= 13.891) is considered as good [30], however, no formal interview was conducted but an informal conversation with participants proved useful to validate the score as good.

The perception about CT skills was conducted via a perception survey comprising 15 statements (Fig.5.). Statements were classified into four categories: meaningfulness, impact, creative self-efficacy, programming self-efficacy and in each category 4, 3, 3, 5 statements respectively (Fig.6.). Perception survey form was based on a 5 point Likert scale. The statements ranged from Strongly Disagree to Strongly

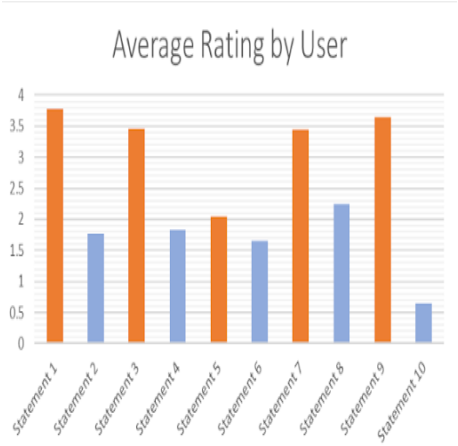

Fig. 4. SUS survey analysis of CT@Home app. Orange bars indicate positively phrased questions, such as statement "If I had this [app] on my phone, I think that I would like to play it a lot" and blue bars indicate negative phrasing of the same, such as statement "If I had this [app] on my phone, I think that I would like to play it a lot" . The longer orange bars and shorter blue bars indicate internal validity of the instrument as well the overall positive sentiment associated with the instrument.

Agree with 0 to 5 score respectively. One statement from each category are as follows: Category: Meaningfulness Statement 1. Computational Thinking (CT) is useful to me. Category: Impact Statement 5. I want to use Computational Thinking (CT) to help solve problems in the world. Category: Creative self-efficacy Statement 8. I would like to design things using Computational Thinking (CT). Category: Programming self-efficacy Statement 12. I can learn how to do Computational Thinking (CT). The participant's response was taken after the post-test. The score of perception about CT skills which is based on 5 point Likert scale (Mean=4.40, SD= 0.395)

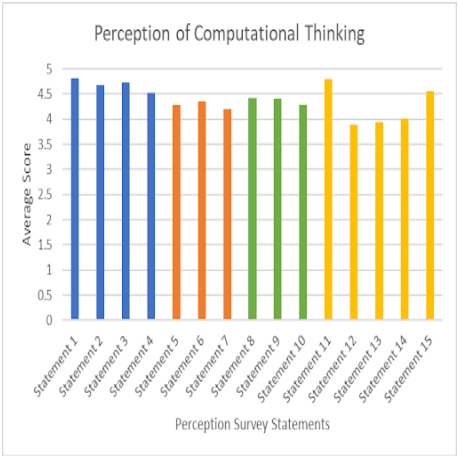

Fig. 5. Average user rating for perception of computational thinking. X-axis represents perception survey statements and y-axis represents the average perception rating received for each statement. Blue bars represent meaningfulness, orange bars represent impact, green bars represent creative self-efficacy, yellow bars represent programming self-efficacy.

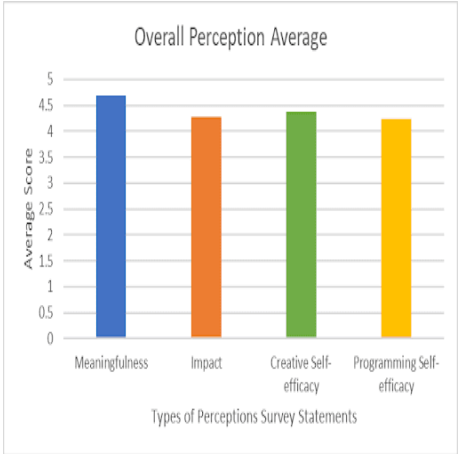

Fig. 6. Mean user rating for subsection of perception survey. X-axis represents categories of perception survey statements and y-axis represents the average rating received for each category. Blue bars represent meaningfulness, orange bars represent impact, green bars represent creative self-efficacy, yellow bars represent programming self-efficacy.

V. Discussion and Conclusion

In this study, an android application named 'CT@Home' was designed to foster middle school students' computational thinking skills using relevant real life contexts/scenarios. The application was designed such that it could be used without any support from the instructor. From the three levels as designed in the application, level-2 constituting use of IoT devices in the Earth Hour context, was tested with 49 students of grade 7 and 8, enrolled in Maharashtra SSC board, with the objective to improve students' logical thinking skills while solving CT problems and their perception towards CT.

From the findings of the study, the significant difference between pre-test and post-test scores and a high learning gain (0.82), implies improvement in the students' learning post playing with the application. However, while calculating the learning gain, the scores of a large number of participants scoring maximum marks in both pre and posttests, were excluded. Additionally, a considerable high Total Average Perception Score (4.39) along with a high learning gain, indicate the outcome of the study in a desirable direction. Despite the positive results, we remain cautious about the interpretation, as the students' perception about CT could be based upon their experience with the application (technological familiarity), rather than their perception about CT in isolation. It might be because the students were hearing the term for the first time, as CT is still not formally part of the standardized curriculum. Even though the researchers tried to introduce the concept before letting them fill the perception questionnaire, there is a reasonable chance they might have reflected on the sum total of their experience using the app instead of reflecting on their experience with CT only.

We have used System Usability Scale (SUS) and informal observations to evaluate the usability of the application for investigating the user experience in our study. Hence, we have observed participants' interaction with this application,

and we found usability issues, indicators of enjoyment, and engagement to understand the impact of various features of the application on students' user experience. All participants in the study attempted the questionnaire. Based on the SUS calculation formula, the mean value of SUS scores was 61.37, indicating a below average usability of the application's interface (SUS score 68 is considered average). This may be due to the fact that some features of the application were not intuitive, leading to difficulties in navigating and effectively utilizing the features of the application. Also, some design issues were observed by the study team.In the study, the "Sensor Button" was observed to include both Date and Time, resulting in confusion during user interactions. Additionally, when presented with three options, the interface accepted only the correct option without providing any error prompts. These issues were examined in the research paper, focusing on describing the observed phenomena and findings. Students were confident to play with the app, but they had to take guidance and support to understand the tasks, clarify the doubts and interact with the app. This could impact their engagement and perceived value of the study. Hence, there was a need for implicit scaffolding in the app interface. Despite these limitations, we found that even though the students encountered challenges due to some non-intuitive features in the application and many failed attempts to complete the level, they were actively engaged throughout the process and made several attempts, again indicating a positive perception of the students towards the learning process. If the content taught through the application is perceived as relevant to their studies, or problem-solving abilities, students are more likely to view computational thinking positively. Hence, it can be concluded that the use of mobile applications like CT@Home integrating relevant, everyday authentic contexts, could be used for improving students' performance and perception about computational thinking skills, as indicated by this study. Moreover, it also encourages teachers to introduce as well as use applications like CT@Home to enhance computational thinking skills among students at middle school level.

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A Systematic Review of Theoretical Perspectives and Technology-Based Strategies for Fostering Critical Thinking Skills in the Age of Misinformation

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***Abstract*— This paper is a systematic review of the literature on critical thinking (CT) and misinformation, with the purpose of exploring how they are conceptualized, theorized, and addressed by various theoretical perspectives and technology-based strategies. This topic is important as misinformation poses serious threats to individuals and society, and critical thinking is vital for discerning and evaluating information sources. The review methodology involved using the PRISMA framework to search 10 databases and finalized 49 papers for this systematic review. The review brings together knowledge from multiple domains such as philosophy, psychology, digital literacy and technology to identify best practices for designing a technology-enhanced learning (TEL) environment that fosters critical thinking skills in students. The findings show that critical thinking is a dynamic and evolving skill that requires constant practice, updating, and media literacy skills. The review also suggests several technology-based strategies for dealing with misinformation and promoting critical thinking, such as cognitive tools, digital fact-checking tools and platforms, gamification, and interactive learning tools. Furthermore, it recommends that technology-enhanced learning environments for critical thinking should consider the cognitive, affective, and behavioral aspects of this skill, and provide learners with authentic and meaningful tasks that require them to apply their critical thinking skills in real-world situations.**

Keywords—Technology-enhanced learning (TEL) environment, Critical thinking skills, Misinformation, Media literacy

I. Introduction

A. Prevalence of misinformation in the digital age

Online misinformation, including fake news and viral deception, undermines democracy, shared truth, and public trust [6] [33] [34] [44]. Misinformation refers to unintentionally misleading information, while fake news deceitfully mimics real news articles without journalistic standards [6] [13] [26] [31]. Large volumes of fake news spread easily on social media and may influence events [15] [34] [43].

Recent systematic reviews concerning misinformation have highlighted that scholarly investigations have centred around defining misinformation, probing its causes and effects, and assessing potential solutions [34] [43] [44]. This includes analysing false content, writing style, distribution patterns, and source credibility [44]. Though a small number of people directly encounter misinformation, effects can be significant for some prone to biases, selective exposure, lack of critical thinking, and repeated exposures [29] [34]. Technical challenges also exist due to online content volume and diversity, where intent and facts cannot always be computationally determined [43].

Social media prioritizes engagement over accuracy through personalized, selective content reinforcing views [7] [18] [19]. This can lead to echo chambers and incomplete judgments relying on heuristics rather than logical evaluation [19]. Detection and downranking efforts have limitations and do not fully address cognitive susceptibility [6] [13] [18].

Developing critical thinking skills to independently evaluate information rationally shows promise [6]. Critical thinking includes analysing arguments and evidence to form reasoned opinions [19]. Cultivating these skills can help resist misinformation while contributing accurate information [6] [19] [29]. Interdisciplinary collaborations remain important for explainable, efficient detection methods [43] [44].

B. Importance of critical thinking in combating misinformation

Recent systematic reviews emphasize that critical thinking is a crucial skill for judging the quality of online information and spotting fake news [1] [21]. Critical thinking involves abilities like analysing arguments, making inferences through inductive and deductive reasoning, judging claims, and solving complex problems [20]. It also involves being open-minded, inquisitive, flexible, seeking reasons, and considering diverse perspectives [20]. However, background knowledge alone is insufficient for critical thought; these skills develop from an early age but deficiencies still exist in adults [20].

There are a few potential solutions to discern accurate from inaccurate online information. One approach is educating end-users on critical evaluation [11] [18]. People are more susceptible to believing false claims if they rely more on intuition than critical thinking [18]. Personal deliberation and focusing on accuracy can help people distinguish facts from falsehoods, especially when providing reasoning [18]. Additionally, in the digital environment, there is the capability for microtargeting individual beliefs through recommendation feedback loops [11]. This phenomenon underscores the importance of equipping users with the skills to critically assess the information they encounter online.

Another strategy is reason-checking news content through assessing argument quality [26]. The online sphere fuels both misinformation, which is misleading without intent, and disinformation, which is intentionally deceptive [26]. While fact-checking combats falsity, prebunking targets distortions more effectively [26]. As advocated, critical thinking allows

identifying misleading claims by evaluating argument flaws, as news acts as a form of argumentation to convince audiences [26]. The presence of fallacious reasoning therefore signals questionable information [26]. Educating critical evaluation and reason-checking news are approaches to discern accuracy online [18] [26].

II. Objectives and Method

A. Purpose and objectives of the paper

The present research offers a fresh perspective on the intertwined subjects of critical thinking and misinformation, distinguishing it from prior research conducted by other authors. This study blends the concepts of critical thinking and misinformation, recognizing their interconnectedness in the digital age. This fusion provides a more comprehensive understanding of how critical thinking can effectively counter misinformation.

Furthermore, the current study introduces an innovative solution in the form of a technology-enhanced learning (TEL) environment. This approach acknowledges the role of technology in contemporary education and employs it to cultivate critical thinking skills tailored to address the challenges posed by misinformation in the digital era. This practical dimension differentiates the current research by not only pinpointing issues but also providing a potential solution.

Additionally, this study formulates specific guiding questions for its investigation:

- How is critical thinking defined and conceptualized in the context of misinformation?
- What are the main theoretical frameworks for understanding and addressing critical thinking and misinformation?
- How can technology be used to support critical thinking and counter misinformation?

These guiding questions structure the study's systematic approach, facilitating deeper insights and offering a more comprehensive perspective compared to the broader reviews conducted by earlier researchers.

Moreover, this research places significant emphasis on practicality by illustrating how critical thinking skills can be applied in everyday life. By bridging the gap between theory and real-world application, this practical orientation renders the research accessible and relevant to a wider audience.

Another notable aspect of this study is its interdisciplinary approach. By integrating elements from the fields of education, technology, and media literacy, this research provides a fresh and comprehensive outlook on addressing the intricate challenges of misinformation while fostering critical thinking skills.

This paper explores how critical thinking can effectively combat misinformation in the digital age and puts forth a design for a learning environment that imparts critical thinking skills. The paper comprises six sections: Section II outlines the research objectives and methodology, Section III presents the research findings on critical thinking and misinformation, Section IV discusses the research's contributions and limitations, and proposes a design for a critical thinking learning environment. Finally, Section V concludes the paper with a summary, reflection, and future directions.

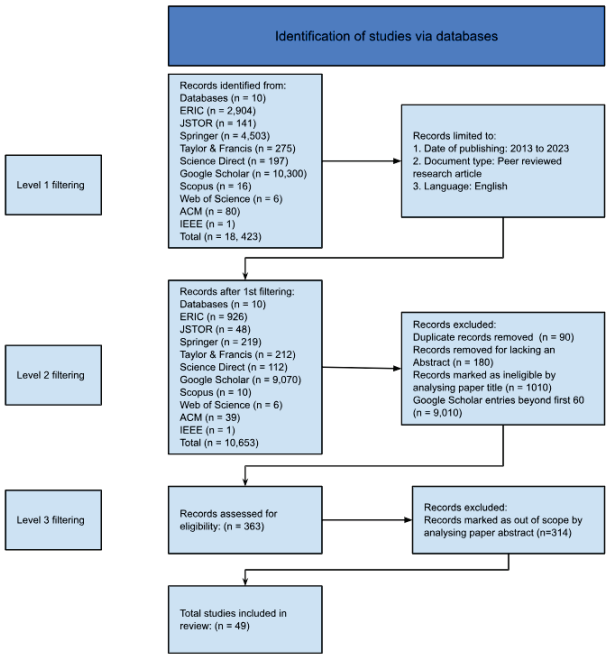

Fig. 1. PRISMA analysis details

B. Method

The authors adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to conduct this study and select the relevant papers [23]. Their research topic was 'review and design of a technology-enhanced learning environment for critical thinking and misinformation'. They searched 10 journal databases using the following keyword string: ("information literacy" OR "media literacy" OR "digital literacy") AND ("critical thinking" OR "critical evaluation") AND ("misinformation" OR "fake news") AND ("technology" OR "e-learning"). They applied three levels of filtering to the search results, as shown in Figure 1. First, they limited the results to peer-reviewed research articles published in English between 2013 and 2023. Second, they excluded duplicate records (n = 90), records without an abstract (n = 180), records with irrelevant titles (n = 1010), and Google Scholar entries beyond the first 60 (n = 9,010). For example, a paper titled New Dialogues in Spanish and Portuguese Studies: Pedagogical and Theoretical Perspectives from the Digital Humanities was removed because it was not related to their research topic. Third, they analyzed the abstracts of the remaining 363 records and checked if they addressed either or both of the following criteria: (a) the problem of misinformation, and (b) the ways to teach critical thinking skills using technology. Only the papers that met at least one of these criteria were included in the final list which was a total of 49 papers (access the full list here: https://shorturl.at/dszE8). To ensure reliability of the study results, the abstracts of a sample of 10 finalized records were independently reviewed and coded according to the selection criteria. Inter-rater agreement was calculated using percentage agreement where there was an agreement on 9 out of 10 abstracts, resulting in an inter-rater agreement percentage of 90% [3]. Any disagreements were discussed and the issue was resolved by consensus. Finally, the authors also manually calculated the frequency of major themes in all papers.

III. Findings

The findings of this study reveal how critical thinking is defined, conceptualized, and applied in the context of misinformation. The study also identifies the key components and skills associated with critical thinking, as well as the role of critical thinking in discerning and evaluating information sources. Furthermore, the study explores the theoretical lenses that can be used to examine critical thinking and misinformation, such as cognitive approaches and literacy perspectives. Finally, the study presents some technology-based strategies that can help deal with misinformation and develop critical thinking, such as cognitive tools, digital fact-checking tools and platforms, and gamification and interactive learning tools.

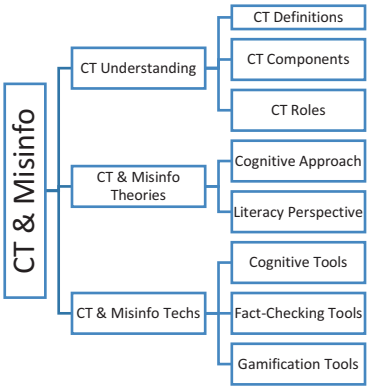

Fig. 2. A block diagram of the findings on critical thinking and misinformation

A. *Understanding Critical Thinking*

1) Definitions and conceptualization of critical thinking in the context of misinformation

Critical thinking (n=64) was one of the most observed themes in literature. Critical thinking is a key pillar of media literacy, as it enables individuals to make true and reasonable decisions about their actions or the accuracy of information [26]. Critical thinking is a purposeful, self-regulatory judgment that involves interpretation, analysis, evaluation, inference, and explanation based on various considerations [26]. Similarly, scholars suggest that effective critical thinking involves a logical approach, inquisitiveness, objectivity, and reliance on evidence [40]. Critical thinking requires the examination and evaluation of ideas, arguments, and information to ensure their quality and accuracy [28]. An adequate critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, fair-minded in evaluation, prudent in making judgments, willing to reconsider, diligent in seeking relevant information, reasonable in selecting criteria, and focused in inquiry [28].

2) Key components and skills associated with critical thinking

Critical thinking is a complex and multifaceted ability that involves various cognitive skills and attitudes, as well as methods and technologies to evaluate and process information. According to a group of experts, some of the cognitive skills that enable critical thinking are logical thinking, inference skills, and the ability to identify and avoid logical fallacies and cognitive biases [40]. Both, logical fallacies (n=23) and cognitive biases (n=66) were highly observed themes in the literature. Apart from abilities, critical thinkers should have attitudes such as inquisitiveness, objectivity, and reliance on evidence, which motivate them to seek out relevant and reliable information, to question their own assumptions and perspectives, and to base their judgments on facts rather than opinions or emotions. Additionally, critical thinkers should be able to evaluate the credibility of web information by checking author information, publication date, and comparing sources, as well as to detect and avoid misinformation, disinformation, and propaganda [40]. Furthermore, some experts suggest that critical thinking also requires the ability to design and implement activities to improve student's critical and analytical thinking skills, especially for teachers who want to foster critical thinking in their students [4] [32]. They also emphasize the importance of reading and writing skills, as well as skills for comprehending, interpreting, analysing, and criticizing texts, for effective communication and understanding of different types of texts. Finally, another expert propose that technologies can also support critical thinking by providing tools and platforms that facilitate information access, analysis, synthesis, and presentation, as well as enhancing user engagement and motivation [8]. However, they also argue that these technologies should prioritize information gain over attention capture and that they should be ethical, fair, and unbiased systems that respect users' rights and values.

3) The role of critical thinking in discerning and evaluating information sources

One of the main strategies to mitigate the effects of fake news and viral deception is to promote media literacy and critical thinking skills, which can help people differentiate between what is real and what is fake, and identify sources of information that are credible and reliable [30] [38]. Critical thinking has been an object of discussion across disciplines ranging from Philosophy to Psychology to Informal Logic, and it has become a key pillar for media literacy [26]. Critical thinking involves the assessment of the quality of arguments that constitute a news claim, and the recognition of arguments that are fallacious or misleading, such as cherry-picking, false analogies, and hasty generalizations [26]. To exercise critical thinking skills, people can use various methods of prebunking, which are ways to inoculate people against fake news before they encounter it. Prebunking methods can be fact-based, logic-based, or source-based, and they can instruct people against misleading rhetorical strategies and content features that make fake news spread fast [26]. In addition to education and awareness campaigns that teach people how to prebunk fake news and viral deception, social media platforms can also play a crucial role in combating them. They can invest in algorithms and tools that can detect and flag fake news and viral deception, and they can also promote credible sources of information and provide users with the tools to verify information [38].

B. *Theoretical Lenses for Examining Critical Thinking and Misinformation*

1) Cognitive approaches

The cognitive approach is a theoretical lens that examines how individuals process and evaluate new information in relation to their existing knowledge and beliefs [8]. According to cognitive dissonance theory, people tend to assess new information based on its compatibility with their prior beliefs, which requires cognitive effort. Cognitive dissonance (n=2)

was observed as theme in at least two papers in the literature. Confirming preexisting beliefs generates positive affect, while encountering opposing information triggers negative affect [8]. However, this approach also reveals the challenges and limitations of critical thinking and misinformation in the digital age.

One of the challenges is the backfire effect, which occurs when directly confronting misinformation to debunk it leads to further reinforcement of confirmed beliefs due to the increased availability of evidence [8]. Backfire effect (n=5) was observed as theme in multiple papers in the literature. Another challenge is the illusory truth effect, which occurs when people perceive repeated statements as more credible, creating a false sense of familiarity and validity [33]. Maya Shankar, a behavioural scientist, suggests that when people hear something repeatedly, they may not remember its truthfulness but find it recognizable [11].

The cognitive process approach identifies four components through which people interact with fake news: reception, information acceptance, cognitive integration, and sharing [33]. Reception refers to how misinformation captures the attention of internet users. Negativity bias and the illusory truth effect are two factors that influence reception. Negativity bias makes individuals more focused on negative information, which is prevalent in fake news. The illusory truth effect leads individuals to perceive repeated statements as more credible, creating a false sense of familiarity and validity [33].

Information acceptance, the second component, involves evaluating the truth value of information to decide whether to integrate it into one's knowledge network. This evaluation can be analytical, intuitive, or lacking in evaluation, depending on cognitive effort and motivation. However, truth evaluation can be biased by various factors, such as cultural identity, personality traits, and pre-existing knowledge and attitudes. These factors make certain concepts appear more fluent and truthlike than others [28]. Additionally, confirmation bias plays a role, as individuals actively seek and accept information that aligns with their worldview while dismissing contradictory information [33]. Humans also struggle to identify deception, often perceiving information as reliable [33]. These biases make people more susceptible to fake news during the information acceptance process.

Cognitive integration, the third component, involves assimilating accepted information into existing knowledge networks. Misconceptions can arise if integrated information or its semantic relationships are missing or false, resulting in fragmented and inaccurate conceptions of the world [33]. Confirmation bias reinforces these misconceptions through selective exposure to information that aligns with existing misconceptions, leading to larger flawed knowledge structures. This can foster a cognitive state known as naïve realism, wherein individuals perceive their perspective as the only valid one and dismiss alternative information as irrational or biased [33]. Filter bubbles created by algorithms that recommend customized content based on users' previous history can further limit exposure to diverse perspectives, exacerbating vulnerability to fake news [36]. Sharing, the fourth and final component of the cognitive process approach, refers to how the integrated information is disseminated among internet users, especially on social media platforms [33].

2) Literacy perspectives

Fake news and misinformation are pervasive problems in the digital age, and they require effective strategies to counteract them. Literacy can be an effective educational strategy in this regard. Not surprisingly, literacy (n=700+) was the most observed theme in the literature, it consisted of multiple sub-themes like information literacy (n=88), media literacy (n=592), digital literacy (n=24), critical literacy (35), data literacy (n=30) etc. Information literacy is the ability to find, evaluate, and use information effectively and ethically [33]. Information literacy interventions aim at enhancing the cognitive processing of online news by fostering self-evaluation of knowledge and skills, knowledge construction and reorganization, and knowledge and skills transfer [12] [25] [33]. However, the positive effects of information literacy on debunking fake news are rather limited, and more research is needed to explore the effectiveness and applicability of information literacy interventions in different settings and populations [33].

Another strategy to counteract fake news is media literacy and critical literacy, which are skills of critical "reading" and evaluation of information in the digital age [9] [11] [14] [35]. Media literacy and critical literacy can provide a pre-emptive safeguard against misinformation by increasing the awareness of the four processes of interacting with fake news: reception, information acceptance, cognitive integration, and sharing [33]. For example, at the reception level, news recipients need to be warded against emotional framing and the impacts of negativity bias, which are powerful mass communication methods that can influence their attention and beliefs [33]. Approaches based on inoculation theory provide one way of fostering such healthy scepticism towards emotional content [33]. Therefore, media literacy and critical literacy are crucial skills to resist fake news illiteracy, which can fuel flawed evaluation of news and misinformation processing, and result in change resistant misconceptions [15] [24] [33] [39].

C. Technology-Based Strategies to Deal with Misinformation and Develop Critical Thinking

1) Cognitive tools

One of the technology-based strategies to deal with misinformation and develop critical thinking is to use cognitive tools, which are digital tools that enhance cognitive processes such as reasoning, problem-solving, and decision-making [2]. Cognitive tools can help people to evaluate and construct arguments, which are essential skills for critical thinking and media literacy. For example, various computer software packages have been created to support argument mapping, which is a technique for visualizing the structure and quality of arguments [26]. Some of these software packages are Araucaria, iLogos, Rationale, and LiteMap [26]. The educational efficacy of these tools has been tested across different domains and contexts, and they have been shown to improve critical thinking skills and outcomes [26]. Another example of a cognitive tool is a chatbot that provides participants with good arguments rebutting the most common counter arguments against genetically modified organisms, with the aim of preventing the formation of misconceptions [26]. Chatbot (n=5) was observed as theme in at least two papers in the literature. The ArgTech research centre has also showcased how argument technology can be applied to the media sphere, teaching how to improve debate skills and appraise argumentative structures in news reports, with the goal of instilling those critical literacy skills needed to reduce polarization and strengthen communication persuasive skills

[26]. Therefore, cognitive tools can be useful and effective strategies to counteract misinformation and foster critical thinking in the digital age.

2) Digital fact-checking tools and platforms

Another technology-based strategy to deal with misinformation and develop critical thinking is to use digital fact-checking tools and platforms, which are digital tools that verify the veracity and reliability of information and sources. Digital fact-checking tools and platforms can help people to evaluate the credibility of news claims, which can be influenced by various characteristics of posts or of people's interaction with them, such as number of quoted sources, prior exposure to a claim, official-looking logos and domain names, post topic and author username, etc. [18]. However, digital fact-checking tools and platforms also face some challenges and limitations, such as the nuance, subtlety, and open-texture of statements that make the veracity of statements much fuzzier than a simple true–false distinction. Therefore, many fact-checking organizations do not check facts as much as provide interpretation, contextualization, and exegesis [26]. Moreover, some digital fact-checking tools and platforms also incorporate other features and functions, such as recommendation systems that nudge people to make better news consumption choices or recommender systems that explain interface where users' emotional profiles are factored in the interaction with pedagogical agents who compare and contrast various stances of an issue [5] [26] [42]. Therefore, digital fact-checking tools and platforms are diverse and complex strategies to counteract misinformation and foster critical thinking in the digital age.

Some other examples of technological tools and platforms to counter misinformation are social media monitoring tools, image verification tools, natural language processing (NLP) tools, and deep learning algorithms. Social media monitoring tools help to monitor social media platforms for fake news and malicious viral content, and to identify suspicious content, bots, and fake accounts [10] [38]. Image verification tools help to detect fake news and malicious viral content by verifying the source and authenticity of images used in news articles and social media posts, using techniques such as reverse image search and metadata analysis [38]. NLP tools help to analyse the language used in news articles and social media posts to detect fake news and malicious viral content, using machine learning algorithms to identify suspicious language patterns, such as the use of emotive language, hyperbole, and exaggeration [31] [38]. Deep learning algorithms help to analyse large amounts of data to identify patterns and trends that indicate fake news and malicious viral content, using machine learning techniques to analyse social media activity, including likes, shares, and comments [16] [27] [31] [38]. Therefore, these digital fact-checking tools and platforms use various techniques and algorithms to verify the veracity and reliability of information and sources in the digital age.

3) Gamification and interactive learning tools for critical thinking development

Digital games are digital tools that engage and educate users through interactive and immersive scenarios. Game (n=299) based learning was one of the most frequent technology-based strategy to teach critical thinking and fight misinformation. They can help users to learn and practice the skills of identifying and resisting misinformation and disinformation, by exposing them to the methods of persuasion and manipulation used by fake news producers and spreaders. For example, some digital games teach users how to recognize misleading sources, headlines, or images, through trial and error, e.g., Fakey, NewsWise, and Real or Photoshop [22] [26]. Some other digital games simulate the decision-making processes of communication gatekeepers' e.g., BBCireporter and NewsFeed Defenders [26]. A more sophisticated generation of digital games cast the player as the "fake news spreader" who learns by doing successful misleading strategies used by disinformators, e.g., Bad News, Go Viral!, and The Harmony Square [26]. Impact evaluations have shown that these tools are highly advantageous and effective in inoculating users against misinformation and disinformation [11] [26]. Therefore, digital games are useful and engaging strategies to counteract misinformation and foster critical thinking in the digital age.

One example of a digital game that aims to counteract misinformation and foster critical thinking is Chamber Breaker (CB), which is a game-based system designed to help increase one's awareness of and respond to the echo chamber effect. The echo chamber effect is a phenomenon where people are exposed to only like-minded information and peers, and ignore or reject alternative information that contradicts their views [33]. CB has been designed based on psychological concepts, such as inoculation, heuristics for judging, and gamification. Inoculation is a strategy that exposes people to weakened versions of fake news arguments and refutes them, in order to increase their resistance to misinformation and disinformation [26]. Heuristics for judging are mental shortcuts that people use to evaluate the credibility and reliability of information and sources, such as the number of quoted sources, the official-looking logos and domain names, etc. [18]. Gamification is a strategy that enhances intrinsic motivation by employing game-like elements, such as problem-solving, engaging storylines, and game mechanics (e.g., scores, tokens, achievement badges) [19]. Gamification can effectively promote self-awareness, user engagement, and feelings of excitement, fun, and desire, while inducing improvements in targeted behaviours [19]. CB incorporates these psychological concepts in its design and features. For example, the story of CB reflects the process of creating the echo chamber phenomenon, where people in the game scenarios support the polarized opinions posted by the player [19]. CB also provides score-winning, score-balancing, and badge-winning functions to reward the player for completing the tasks [19]. Therefore, CB is a digital game that can help people become more aware and critical of the echo chamber effect and its consequences.

IV. Discussion

This paper aims to enhance critical thinking in the context of misinformation, which is a dynamic and evolving ability that requires constant practice and updating. To address the first research question, the paper synthesizes the main concepts, definitions, and frameworks of critical thinking from various disciplines and perspectives. Critical thinking can be defined as a purposeful, self-regulatory, and logical judgment that involves interpretation, analysis, evaluation, inference, and explanation of ideas, arguments, and information based on various considerations, such as evidence, criteria, context, and perspectives. To address the second research question, the paper reviews the main theoretical frameworks for understanding and addressing misinformation, such as information literacy, media literacy, and critical literacy. These frameworks can help understand

and address the cognitive processes and challenges involved in interacting with misinformation. It also highlights their interrelationships and complementarities.

The paper argues that critical thinking and misinformation are not only individual phenomena, but also social and cultural ones, as they are influenced by the information sources, platforms, and networks that people use. Moreover, it suggests that critical thinking is a complex and multifaceted ability that involves cognitive, affective, and behavioral aspects, as well as the use of appropriate methods and technologies to access, evaluate, and process information. Therefore, the paper proposes that technology-enhanced learning environments for critical thinking should consider these factors and provide learners with opportunities to develop their cognitive skills and attitudes, as well as to engage in authentic and meaningful tasks that require them to apply their critical thinking skills in real-world situations.

To address the third research question, the paper discusses some of the technology-based strategies that can support critical thinking and counter misinformation, such as cognitive tools, digital fact-checking tools and platforms, gamification, and interactive learning tools. It also explores how digital games can be effective and engaging tools that can help users to learn and practice the skills of identifying and resisting misinformation and disinformation. Digital games can expose users to the methods of persuasion and manipulation used by fake news producers and spreaders, as well as make them more aware and critical of the cognitive and social phenomena that influence their information behavior.

As discussed before, critical thinking is not only an individual skill, but also a social and collaborative practice that involves communication, interaction, and feedback from others. Therefore, technology-enhanced learning environments for critical thinking should provide learners with opportunities to participate in social and collaborative activities that require these skills. Moreover, the paper suggests that learners should develop their digital literacy skills, such as evaluating information credibility, detecting and avoiding misinformation, disinformation, and propaganda, and using technology ethically and responsibly [7] [41]. These skills are essential to cope with misinformation in their daily lives and to foster a culture of critical thinking and information literacy among learners, educators, and citizens. The paper also implies that policymakers should promote ethical standards and regulations for the production and dissemination of information in the digital media, and support the development of digital citizenship and civic engagement among the public. Additionally, the paper suggests that technology-enhanced learning environments for critical thinking should foster learners' awareness and responsibility for their information behavior and its consequences for themselves and others.

The findings of the analysis on the frequency of major themes in literature shed light on the prevalent strategies employed by researchers to combat misinformation. Among these strategies, critical thinking (n=64) emerges as a popular approach in tackling the challenges posed by misinformation. It is evident that researchers recognize the significance of developing the ability to identify logical fallacies (n=23) and cognitive biases (n=66) as essential components of critical thinking. Moreover, the emphasis on media literacy (n=592) in the realm of research stands out, signifying its prominence as a domain to address misinformation effectively, surpassing other literacies such as information literacy (n=88), digital literacy (n=24), critical literacy (n=35), and data literacy (n=30). Remarkably, the utilization of a game-based approach (n=299) in interventions aimed at combating misinformation and promoting critical thinking is noteworthy, suggesting the effectiveness and attractiveness of gamification in educational initiatives.

Based on the findings of this paper, it can be claimed that to effectively foster critical thinking skills to deal with misinformation, a TEL environment requires various resources that support different aspects of learning. One of these resources is a collaborative platform that enables students to collaborate and engage in peer discussions through features such as discussion forums, chat functionalities, and shared document editing capabilities. This platform facilitates social interaction and knowledge construction among students. Another resource is authentic problem scenarios that are based on real-world issues or current events and involve misinformation. These scenarios allow students to explore and analyze the challenges associated with misinformation and apply their critical thinking skills in realistic contexts. A third resource is tools for information evaluation that help students evaluate the credibility and reliability of information sources, such as fact-checking websites, guidelines for source evaluation, and critical thinking frameworks (like the Paul-Elder Critical Thinking Framework). These resources provide students with criteria and strategies to assess the quality and accuracy of information. A fourth resource is collaborative argument mapping tools (like Rationale) that support collaborative sense-making and critical analysis of information. These tools allow students to visually map out arguments, identify logical fallacies, and assess the strength of evidence. They also enable students to compare and contrast different perspectives and viewpoints on a given issue. A fifth resource is peer feedback and reflection opportunities that foster critical thinking and collaborative learning. These opportunities allow students to provide constructive feedback on each other's arguments and evidence, as well as reflect on their own learning process and outcomes. These resources are based on the findings of a research study which designed and evaluated a TEL environment for misinformation literacy [18].

Apart from the above resources, the TEL environment also needs to implement two instructional strategies that are based on the findings of two research studies [18] [33]. These strategies are: problem-based learning and action-based sharing. Problem-based learning is a pedagogical approach that engages students in collaborative problem-solving of real-life scenarios that require them to construct and apply conceptual knowledge of fake news characteristics and mechanisms [37]. These scenarios are presented in a detailed and realistic way, using interactive media elements to contextualize the problem, and divided into manageable parts that can guide students' work process. Problem-based learning also provides instructional guidance that can scaffold the problem-solving process, especially for students who are not familiar with the learning domain, such as worked out examples, instructional videos, or question prompts. Moreover, problem-based learning stimulates interactive activities that foster social knowledge construction and student engagement, such as group discussions or peer review, and provides guidance and structure for group work and discussions, such as instructor questions or question prompts.

Furthermore, problem-based learning involves using digital tools that facilitate collaborative learning, such as discussion boards, etherpads, or wikis, which allow synchronous collaboration. Problem-based learning can also motivate students to self-evaluate their existing knowledge and skills, and to initiate conceptual change when they encounter information that contradicts their prior beliefs or expectations. Action-based sharing is a design feature that requires students to perform some actions before sharing any content, such as clicking a button, choosing a tag, or writing a comment, to indicate whether they think a story is accurate or not and why. These actions are intended to be simple and quick, similar to current sharing behavior, but also to encourage students to reflect on the information they share and to become aware of the value framing techniques and the illusory truth effects that can influence their judgments. These actions can also prompt students to rely less on their intuition and more on their analytical information processing, which is a more deliberate and effortful way of evaluating information. By integrating these two instructional strategies, researchers can create effective TEL environments to combat misinformation and develop critical thinking in students.

This paper has some limitations that need to be acknowledged. Firstly, the systematic review process employed in this study involved multiple filtering levels based on specific criteria. Unfortunately, this rigorous filtering process may have resulted in the exclusion of potentially interesting and relevant papers due to its strict and narrow criteria. Secondly, although the paper effectively explores cognitive and literacy theories as theoretical frameworks to understand and address cognitive processes and challenges associated with misinformation, it overlooks other significant theoretical frameworks, such as social psychology theories. This omission of social psychology theories was a direct result of that fact that none of the 49 shortlisted papers used such a theory. Lastly, the paper adequately investigates technology-based strategies that support critical thinking and combat misinformation, including cognitive tools, digital fact-checking tools and platforms, gamification, and interactive learning tools. However, it fails to delve into the integration of Computer Supported Collaborative Learning (CSCL) principles, which could facilitate collaboration within technology-enhanced learning environments. This gap in the research also connects with the limitation of not exploring theoretical frameworks like social psychology theories.

V. Conclusion

Misinformation is a serious problem in the digital age that requires critical thinking skills. Critical thinking is the ability to use logic, reasoning, and evidence to process information and arguments. This paper reviews the literature on critical thinking and misinformation, and proposes a design of a technology-enhanced learning (TEL) environment that can support these skills. This paper contributes to the knowledge and practice in the field of TEL, and provides practical guidance for policy makers, educators, researchers, and individuals who want to promote critical thinking and combat misinformation.

This paper has some suggestions for individuals, educators, and researchers. Individuals should critically examine digital information, diversify and balance their information intake, use critical thinking and digital tools for media literacy, and seek feedback and dialogue with others. Educators should include critical thinking and misinformation topics in the curriculum and learning objectives, use various pedagogical approaches and methods, model critical thinking and information behavior in their teaching practice, and encourage learners to reflect on their learning. Researchers should collaborate with other researchers from different disciplines and perspectives, conduct more empirical or experimental studies with diverse populations and contexts, and test the proposed design of TEL environment for critical thinking from this paper.

Based on the previously discussed limitations, the paper suggests some future research directions. Firstly, future studies should conduct a more comprehensive and inclusive systematic review of the literature on critical thinking and misinformation. Secondly, future studies should explore other theoretical frameworks that can help understand and address the social and emotional aspects of critical thinking and misinformation, such as social psychology theories. Thirdly, future studies should investigate how computer-supported collaborative learning (CSCL) principles can be integrated into the proposed design of a TEL environment for critical thinking.

This paper hopes to inspire more research and practice on this topic, as well as more awareness and responsibility among information consumers and producers. This paper believes that critical thinking is a vital skill for individuals to navigate the complex and dynamic information landscape in the digital age. This paper also believes that technology can play a significant role in supporting critical thinking and counteracting misinformation.

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Detecting Affective States in Engineering Design Problem using Interaction data from TELE

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***Abstract*—The use of interaction data to detect emotions in learning environments is a growing research field. However, most of the existing machine learning models that make use of interaction data have been developed for systems that teach or train students in conventional subjects like mathematics or science. This paper presents an investigation of affect detection in a learning environment that focuses on engineering design thinking. Machine learning models were developed to detect boredom and frustration in "Call the Plumber," a learning environment designed to teach students engineering design. The results indicate that these models can effectively detect boredom and frustration, with F1-Scores of 0.817 and 0.765, respectively. This research contributes to the field b y d emonstrating the potential for machine learning techniques to improve affect detection in engineering design-thinking learning environments.**

***Keywords*—Engineering Design, Affect Detection, Boredom, Frustration.**

I. Introduction

Researchers in the field o f e ngineering e ducation a re now focused on ways of engaging K–12 students in engineering design [10] . These engineering design problems promote scientific practices s uch a s q uestioning, c arrying o ut investigations, collecting data and its analysis, constructing explanations, and using evidence to justify those explanations. All these practices will enhance their understanding of scientific k nowledge and help them establish the link between science and engineering [19]. Also, engaging students in plausible design problems will be helpful in improving their understanding of STEM subjects. Indeed, numerous studies have found that using engineering design as a context for science instruction results in promising learning gains [1], [15], [18].

The process of actively involving students in such complex design problems is in itself a challenging task. Despite the fact that researchers and educators are aiming to engage students in a systematic exploration [24] . Students often seem to opt for trial-and-error methods rather than making well-informed decisions. This approach to learning or problem-solving defeats the purpose of introducing engineering design practices in education [4], [8]. Also, it may either increase the probability of failure in achieving the goal or delay its success by a significant amount of time. as students can avoid difficult-to-complete or achieve tasks [7].

So in order to make their learning meaningful and improve their performance in the engineering design task, considering their affective states while learning becomes crucial. The reason for such consideration is the presence of a sound body of literature that highlights the role of emotions in learning. In fact, Azevedo et al. (2017) identified emotions as one of the fundamental components of learning, the others being cognition, meta-cognition, and motivation [2]. This attracted the attention of many researchers who wanted to build systems to identify or detect students' emotions during learning.

Affect detection models were developed for learning environments dealing with biology, medicine, physics, etc. However, affect detection in complex design tasks has yet to be investigated. In this paper, we have focused on detecting middle school students' affective states while they are working on a complex design task in a learning environment called "Call the Plumber". The focus has been on detecting the affective states of boredom and frustration. because boredom sends students into a vicious cycle [3] and frustration acts as a goal blocker [23].

For the study, a total of 17 participants in the age group of 12–14 years participated. Participants' video recordings, screen recordings, and interaction log data were collected. Affective state tagging was created by two trained observers with an inter-rater agreement of 0.90. Multiple machine learning models were developed for detecting boredom; Random Forest yielded the best F1 score of 0.817, while Naive Bayes for detecting frustration yielded a F1 score of 0.765.

In the following sections, Section 2 examines the existing literature on affect detection. Section 3 describes the learning environment. Section 4 describes the research methodology

in detail; subsequently, we discuss the results in Section 5. Finally, in Section 6, we present the conclusion and limitations of the study.

II. Literature Review

The inextricable and indispensable link between emotion and learning has fuelled the growth of affective computing, which aspires to build computer systems for learning that are emotionally sensitive [12]. The aspiration behind building such systems is the ubiquity of emotions in the teaching-learning process. For instance, emotions help grab the attention of the learner and, to a great extent, determine what is learned and what will be retained (Emotions in Education: Asian Insights on the Role of Emotions in Learning and Teaching). All this has led to an increase in the focus on exploiting the role of emotion in educational research in the past two decades [9], [11], [12].

Although Darwin in the nineteenth century first scientifically explored emotions [25]. The research in the educational domain started with exploring Paul Ekman's six basic emotions, namely anger, sadness, fear, disgust, happiness, and surprise [14]. However, it was soon realised that these are rarely experienced during learning and are not much relevant to academic performance [12]. 2 This led to the development of "learner-centric emotions" or "academic emotions". Academic emotions are defined as emotions that are experienced by students when they are involved in the learning process and are linked to the learning outcome.

A. Affect Detection in TELE

Researchers have developed various affect detection models to detect an affective state in a technology-enhanced learning environment [6]. Affect detection in TELE guides students in learning and provides help to identify and correct their errors, and such a system can also track students' motivational and emotional states during the learning session [5]. The affect detector model is used to provide personalised feedback in mathematics tutor Mindspark, which can respond to frustration using motivational prompts [23]. For Mindspark, a number of features are created to detect frustration by considering the number of goals, goal blocking factor, and time spent on each question from the log data. Some of the TELE environments where the researcher has worked on detecting emotions are shown in Table 1.1.

Autotutor is a fully automated computer tutor that simulates human tutoring and is used for detecting six cognitive-affective states in undergraduate students. Self-report measures for every 20-second interval were synchronised with interaction data. Results show the occurrence of surprise and delight is lower compared to other states like boredom, frustration, engaged concentration, and confusion. Confusion and engaged concentration were found to be persistent [16]

Aplusix II is an algebra-intelligent tutoring system (ITS) that was used to detect six cognitive-affective states in middle school students. The human observation was carried out by one pair of observers at an interval of 20 seconds. Boredom results in a higher chance of gaming the system, and delight was found to be a persistent emotion [20]

Cognitive Tutor Algebra I is a mathematics ITS used to detect six cognitive-affective states in middle-school students. The human observation was carried out by two expert field observers, each observation noted at an interval of 20 seconds. The emotional judgement during the observation was based on context, actions, utterances, facial expressions, body language, and interactions with teachers or fellow students. In this paper, ML models are used to detect the affective states of engaged concentration, confusion, frustration, and boredom. A total of 58 features are developed, such as correct or incorrect responses, number of previous actions, and students' past performance. The ML algorithms used are K*, Jrip, REPtree, and Naive Bayes. The best performers for frustration and boredom are REPTree and Naive Bayes [13].

Betty's brain, an online learning environment, was used to detect the relationship between achievement emotions (confusion, frustration, engaged concentration, boredom, delight) and basic emotions. For tagging achievement, human coding was used, while for basic emotions, Imotion software was used. The ML algorithms used are Random Forest, Decision Tree, Neural Network, Naive Bayes, and logistic regression. The Random Forest performs superiorly to all other algorithms. This paper also analyzes the link between basic emotions and complex achievement emotions in a computer-based learning environment. And conclude that confusion maps to the basic emotions of high anger and high disgust, frustration maps to the basic emotions of high disgust and low fear, and engaged concentration maps closely to low or moderate levels of joy and sadness [21].

The Physics Playground is a science learning platform that was used for affect detection. A human observer was present to record student affective states during their interaction, in addition to the computer expression recognition toolbox (CERT) to estimate the likelihood of 19 action units. separate detectors built for each affective and cross-validated at the student's level. Delight was detected by the classifier due to noticeable facial features. Also, the ML algorithms used are K-means clustering, Bayes Net, Naive Bayes, and logistic regression. For detecting boredom and frustration, k-means clustering and Bayes Net performance were the highest. citekai2015comparison.

Tutoring Video CORPUS is a computer-mediated tutorial dialogue for introductory computer science that was used for affect detection in teenagers. The post-session survey was conducted after every tutoring session. During tutoring, participants' database logs, webcam video, skin conductance, and Kinect depth video were recorded. A subset of 20AU was selected using CERT. The model has predicted frustration by the intensity of brow lowering [17].

TC3 is a simulated medical training scenario that was used for affective state detection in undergraduate students. Posture data were captured using Kinect motion-tracking sensors, and from the interaction log, 39 different features were extracted based on their actions. Machine learning classifiers were used

TABLE I
AFFECT DETECTION IN TELE

Learning Environment	Domain	Affect Detected
AutoTutor [13]	Computer literacy	6 cognitive-affective states and Neutral
Aplusix II	Algebra	6 cognitive-affective states and Neutral
Cognitive Tutor Algebra I	Mathematics	Engaged, boredom, frustration, and confusion
Betty's Brain	Climate change	confusion, frustration, engaged concentration boredom, delight
Physics Playground	Physics	6 cognitive-affective states
Inq-ITS	Physics	boredom, confusion, frustration, and engaged concentration
Tutoring Video CORPUS	Computer Science	Frustration, performance, Temporal Endurability
TC3Sim	Medicine	6 cognitive-affective states
Mindspark	Mathematics	Frustration and Boredom

for prediction results that show that confusion is modelled more effectively with posture data [22].

Most of the research in the field of affect detection in education has explored TELE in conventional domains like math, physics, chemistry, etc. However, there is a paucity of literature on detecting emotions in engineering design problems and how student interaction with the system affects their performance. Our research promised to fill this gap by examining the interaction behaviour of achievers and under-achievers in design problems. Moreover, we have developed models that detect frustration and boredom while students interact with the system with decent accuracy.

III. LEARNING ENVIRONMENT: CALL THE PLUMBER

The learning environment is developed based on the engineering design activity PlumbingSim, developed by [10]. The module of PlumbingSim is developed in such a way that it provides students with scaffolding and encourages them to solve the design challenge. These challenges require an understanding of many interconnected concepts, such as system thinking, a suboptimal model, and an optimal model. 'Call the Plumber' is a web-based learning environment that is an online version of the PlumbingSim (shown in Figs. 2 and 3). For now, this learning environment is only developed for individual students who engage in complex design tasks. One such problem is "Build a water connection with a pressure of 17, 21, and 25 PSI at sinks 1, 2, and 3, respectively, with a budget of not more than 3000. Also, constraints were added to the learning environment, like a restricted time limit and a fixed budget. To accomplish this task, students are required to use pipes and bends of different sizes (say, 0.5 inches or 1 inch) to get the desired water pressure at different sinks. Furthermore, the price of the pipes varies according to their dimensions.

IV. METHODS

A. Participants

The participants (students) chosen for the study were 8th grade students due to the research curriculum's alignment with their grade curriculum. A total of 20 students participated, of which 11 were male and 9 were female, with their ages ranging between 13 and 15. The data on 17 students (9 males and 8 females) from a total of 20 participants were used for the final analysis, and the data on 3 students (2 males and 1 female) were used for the pilot study. Also, to get consent from participants, a Google form was circulated through schools for voluntary participation in the study.

B. Data

Data from the following three channels were collected-

1) Log Data: The learner's every interaction with the learning environment is being recorded. We also recorded a timestamp and user ID along with the action.
2) Screen recording: Participants' screens were recorded using the OBS studio. It helped in understanding and tagging the affective state, as it set the context for interaction.
3) Facial recording: The study was conducted online. The facial expressions of the participants were recorded using a webcam, and this data was used for tagging emotions using a human coding mechanism.

C. Phases and Task

The study was divided into the following three different phases:

1) Demonstration Phase: In this phase, the researcher demonstrated, by lecturing and showing videos, the concept of water pressure, i.e., how water pressure varies with changing diameter or size. Also, the participants were told about the cost of the pipes according to their size. This is followed by training the participants about optimal and suboptimal design. After that, participants are introduced to the different features of the learning environment.
2) Training Phase: This phase was aimed at making students familiar with the learning environment. In this phase, students had to work on the design problem to build an optimal solution within 15 minutes. The problem given at this level is almost identical to the actual problem, with a lesser complexity level. The

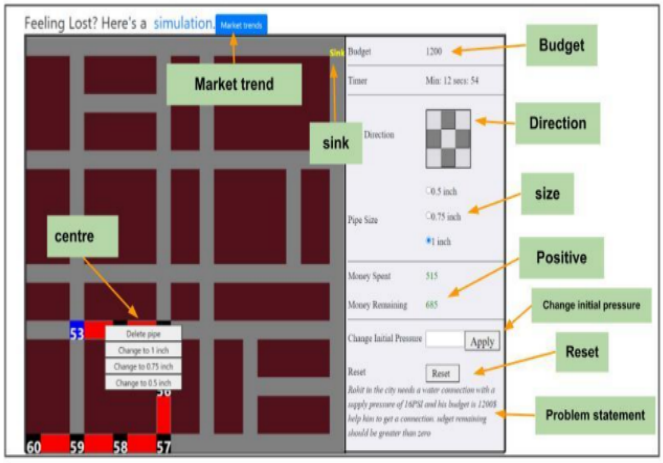

Fig. 1. The figure shows the Learning Environment in the training phase. As shown in the figure, there is only one sink situated at the top right

Fig. 2. The figure shows the application phase. In this phase, there are three sinks and at each of these sinks, a different pressure is required.

design challenge was to "build a water connection with a supply pressure of 16 PSI and a budget of 900."

3) Application Phase- In this phase, students have to work on a more complex design problem that has to be completed within 30 minutes. In this phase, the design challenge is to **"Build a water connection with pressures of 17, 21, and 25 PSI at sinks 1 and 2 with a budget of no more than 3000."**

D. Tagging Affective States

The affective-state tagging was done by two trained observers who were master's students in the Educational Technology department. For tagging students' affective states, we have used both facial recording and screen recording. The screen recording data is used for understanding context while tagging the emotion. The affective-state tagging was done by considering the context as well as their facial expression, body language, gestures, etc. The affective states were classified as boredom, frustration, engagement, and neutral (all other emotions except the three mentioned). Also, if student faces or screens were unable to be captured at any particular instance of 20 seconds, then it will be marked as "NAN," which we are not considering in our analysis.

As explained above, when tagging the affective state, we took the students' behaviour aspect, duration of emotion, and context into consideration during tagging. During our emotion tagging, we marked students as bored when the following characteristics were observed:

1) Student stops working on the challenge for the duration of more than 40secs
2) Student resting on their hand
3) Student reaches an impasse or gives up
4) Statements like "Sir, times up can we finish?" or repeatedly said, "Sir, it's not possible."
5) Student speaking in a lazy tone and looks exhausted

A student with the following characteristics was marked as frustrated:

1) Student repeatedly following the same path for solving the incorrect challenge
2) Student facial expression shows lips tightening, inner-outer eyebrow raise
3) Student scratching head or banging on the table
4) Statements like "shhh", or "ohh" or "shit", or "Cheech."
5) During solution, the condition doesn't match or repeated alert message

E. Inter-rater training

Before the actual study, all the observers had gone through training in facial expression coding (Kanade et al., 2000). At first, the observer was trained in coding affective states for collaborative learning tasks where participants were solving a complex problem. A timestamp of 20 seconds for each observation was taken for coding the affective state, and after that, all three observers independently coded the emotions and for any disagreement about the coded affective state, all observers used eight indicators of emotions (Pekrun, 1992; Hascher, 2005) to discuss, explain, and reason for tagging the particular emotions. After that, an inter-rater agreement was calculated, which was around 0.37, which was very low. The main reasons for getting less agreement were:

- The length of stimulus that we have taken is only 1 minute, which is very little.
- The observers had coded both basic emotion as well as cognitive-affective state

The two observers coded videos for a longer duration of about 20 minutes in the second phase of training in coding affective states. It had 60 relevant instances of the affective state. The procedure for coding the affective state was the same as mentioned above. The inter-rater reliability of the coded affective state was found to be 0.90 for two observers.

F. Data cleaning

In the analysis, only the data that had been collected in the application phase was considered. To refine our feature

TABLE II
LIST OF FEATURES EXTRACTED FROM INTERACTION DATA AND THEIR DESCRIPTION

SNo.	Feature	Description
1.	Actions per 20-secs	Total number of actions performed per 20-sec interval
2.	Actions prior 20-secs	Total number of actions performed prior 20-sec interval
3.	Pipes added per 20-secs	Total number of Pipes added per 20-sec interval
4.	Pipes added prior 20-secs	Total number of Pipes added prior 20-sec interval
5.	Pipes deleted per 20-secs	Total number of Pipes deleted per 20-sec interval
6.	Pipes delete prior 20-secs	Total number of Pipes deleted prior 20-sec interval
7.	Change dia per 20-secs	Diameter changed per 20-sec interval
8.	Change dia prior 20-secs	Diameter changed prior 20-sec interval
9.	Add 1-inch	Number of 1-inch pipes added per 20-secs
10.	Delete 1-inch	Number of 1-inch pipes deleted per 20-secs
11.	Change dia 1-inch	Number of pipes diameter change to 1-inch per 20-secs
12.	Add 0.75-inch	Number of 0.75-inch pipes added per 20-secs
13.	Delete 0.75-inch	Number of 0.75-inch pipes deleted per 20-secs
14.	Change dia 0.75-inch	Number of pipes diameter change to 0.75-inch per 20-secs
15.	Add 0.5-inch	Number of 0.5-inch pipes added per 20-secs
16.	Delete 0.5-Inch	Number of 0.5-inch pipes deleted per 20-secs
17.	Change dia 0.5-Inch	Number of pipes diameter change to 0.5-inch per 20-secs
18.	Market trend per 20-secs	Market trend checked per 20-sec interval
19.	Market trend prior 20-secs	Market trend checked prior 20-sec interval
20.	Reset per 20-secs	Reset the board per 20-sec interval
21.	Reset prior 20-secs	Reset the board prior 20-sec interval
22.	Alert per 20-secs	Alert observed per 20-sec interval
23.	Alert prior 20-secs	Alert observed prior 20-sec interval
24.	Active 20-secs	Student active or inactive per 20-sec interval
25.	Active 40-secs	Student active from last 40-sec interval
26.	Sink1	Students reached sink1
27.	Sink2	Students reached sink2
28.	Sink3	Students reached sink3
29.	Money Spent	Total money spent by the students at that instant

TABLE III
PERFROMNCE OF MODELS DEVELOPED BY DETECTING BOREDOM

Model	AUC	CA	F1	Precision	Recall
Random Forest	0.660	0.844	0.817	0.813	0.844
AdaBoost	0.637	0.821	0.805	0.795	0.821
Decision Tree	0.609	0.807	0.791	0.779	0.807
Neural Network	0.610	0.830	0.787	0.775	0.830
Logistic Regression	0.611	0.832	0.765	0.707	0.832

TABLE IV
PERFROMNCE OF MODELS DEVELOPED BY DETECTING FRUSTRATION

Model	AUC	CA	F1	Precision	Recall
Random Forest	0.552	0.808	0.754	0.729	0.808
Naive Bayes	0.591	0.795	0.765	0.748	0.795
Decision Tree	0.544	0.775	0.754	0.738	0.775
Neural Network	0.568	0.809	0.755	0.731	0.809
Logistic Regression	0.584	0.824	0.748	0.685	0.824

set for our affect detector, coded labels were synchronised with student action within the ”Call the Plumber” activity. As emotion tagging was done based on 20-second intervals, for synchronising, a time of 20 seconds was taken as a reference.

V. Results

This section presents the results of the study by 1) describing the features extracted from the interaction data followed by feature reduction and normalisation 2) reporting the performance of various ML models for boredom and frustration.

A. Feature Extraction, Reduction and Normalization

A total of 30 features were created from student interaction with the system, as shown in Table 2. The entire duration of the interaction was divided into windows of 20 seconds. For each of these windows, the observers had tagged whether a particular affective state was present or absent. Since the affective state in the current window was also influenced by the affective state in the previous window, we also considered the actions performed in the previous window. The application phase task is connecting a number of pipes from the source to the sink, with different diameters, to get the desired pressure at the sink end. This required the following set of actions:

1) adding of pipes
2) deleting the existing pipes
3) changing the diameters of the existing pipes

As in Table 2, features 3 through 17 are extracted using the previously mentioned information. Feature 3 (”Pipes added per 20 seconds”) and Feature 4 (”Pipes added prior to 20 seconds”) represent the total number of pipes added during and prior to the current window, respectively. Similarly, features 5 and 6 represent the number of pipes deleted in these windows. The third action in the list, namely changing the diameter, was captured by features 7 and 8. In the learning environment, the students had to choose pipes with diameters of 0.5 inch, 0.75 inch, and 1 inch, respectively. Adding, deleting, or changing the pipes for one of these is captured through features 9–17. The environment also provided a button to ”reset everything,” i.e., to remove all the connections that have been made. ”Reset every 20 seconds” captured whether the student had opted for this reset mode in the current window. Similarly, the action ”Reset prior 20 seconds” reflects whether this action was taken in the previous window or not. The ”Market Trend” button present on the top of the maze allows the user to check the cost of each pipe and the pressure offered by the pipe; in order to check this information, the learners were supposed to hit this button. Feature 18 and 19 capture whether the learner has performed this action in the current and previous windows or not. In case students were not able to get the desired pressure at the sink or overshot the budget, the system generated an alert; the features ”Alert per 20 seconds” and ”Alert prior to 20 seconds” indicated the presence and absence of this. The feature ”Active 20-secs” provided information about whether activity (i.e., movement of the cursor or clicks) was observed in the time period of 20 or 40 seconds. The feature money spent represents the amount spent in that window. In order to eliminate the highly correlated features, we calculated the Pearson correlation coefficients between the features. Some of the features were highly correlated, as represented in Table 5. Therefore, we have not considered these features in our final analysis.

TABLE V
Correlation between features

Feature 1	Feature 2	Correlation value
Active 40 secs	Active 60 secs	+0.976
Actions per 20 secs	Actions prior 20 secs	+0.949
Alert per 20 secs	Alert prior 20 secs	+0.803

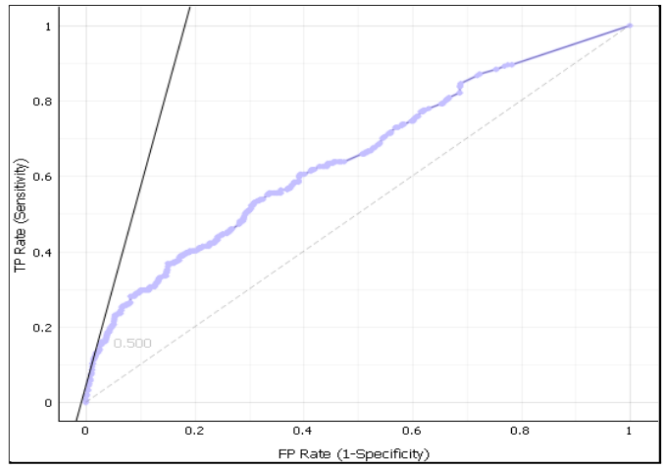

Fig. 3. The figure shows the Receiver Operating Characteristic (ROC) curve which shows the performance of a Random Forest model for boredom detection at all classification thresholds

After this, we normalised all the features since each one had a different range. For the predictive analysis of the affective states, each affective state was predicted separately, e.g., BORED was distinguished from NOT BORED (other affective states), FRUSTRATED was distinguished from NOT FRUSTRATED (other affective states). Both the detectors were evaluated using ten-fold cross-validation. Classification algorithms used for prediction are Random Forest, Adabost, Decision Tree, Naive Bayes, Neural Network, and Logistic Regression. Detector performance was assessed using an F1-score which is a harmonic mean of precision and recall. The range of F-1 score varies from 0 to 1.

B. Boredom Detector

There were a total of 853 instances, of which 241 were coded as BORED. Out of all the classification algorithms used, the performance of the best five models for frustration detection is presented in Table 4. The results indicate that Random Forest outperformed all other algorithms in terms of F-1 score, with an F-1 value of 0.817. Also, the ROC curve for the Random Forest is shown in Figure 3.

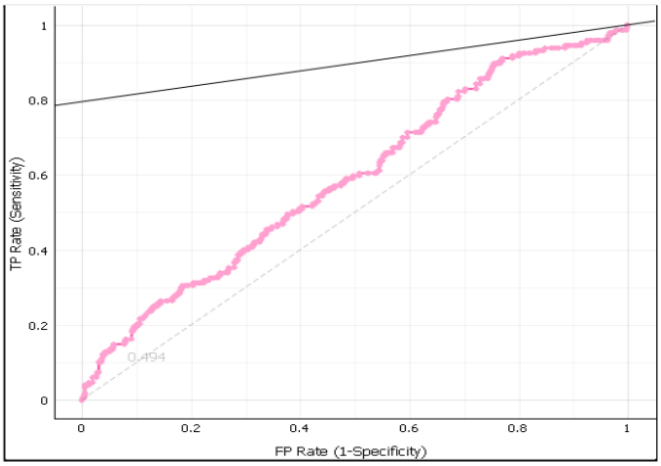

Fig. 4. The figure shows Receiver Operating Characteristic (ROC) curve which shows the performance of a Naive Bayes model for frustration detection at all classification thresholds.

C. Frustration Detector

There were a total of 853 instances, out of which 283 were coded as FRUSTRATED. Out of all the classification algorithms used, the performance of the best five models for frustration detection is presented in Table 5. The best algorithm for prediction was Naive Bayes with an F-1 score of 0.765. Also, the ROC curve for the naive Bayes is shown in Figure 4.

VI. Conclusions and Discussion

This article makes an attempt to use students' interaction data for the prediction of two affective states, namely, boredom and frustration. The significance of our work lies in the fact that the detection of affective states in a learning environment focusing on engineering design problems is not present in the literature (to the best of our knowledge). Conducting affect detection in such a complex learning environment is a different challenge than in other learning environments. The lack of on-demand aid [11] and the lack of action-by-action assessment of correctness, as seen in problem-based tutors, make it difficult to develop features similar to those found in problem-solving and dialogue tutors.

This study has some potential limitations, which we will discuss in the next paragraph. As the students in the study share some common demographics, the results are not generalizable. Another major limitation of the study is the small sample size. Also, since feature extraction depends on the task and the design of the learning environment, many of the features are specific to this and hence not directly implementable for developing models for another learning environment.

VII. Future Work

The future work will be along the following directions-

1) The results show that the models predict the two affective states decently. However, the detection of the states is the first stage, and it is crucial to understand how this affects students' performance in complex tasks like engineering design tasks. Prior studies have shown that boredom is associated with poorer learning gains while frustration is less associated with poorer learning gains in dialogue tutors, problem-solving games, and problem-solving-based intelligent tutoring systems. It is not clear how these affective states affect students' learning or task completion. It is crucial to understand the persistence of these affective states as well as to what extent these affective states affect task completion and the process of solving tasks.
2) Once the relationship between these affective states and task completion is established, responding to boredom and frustration will be our next goal. The response to them should be in a manner that promotes problem-solving with proper reasoning as opposed to trial-and-error methods, along with enhancing engagement in the task.

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Revealing students' intuitive ideas through Drawings: Insights for Technology-Driven Instructional Designs

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***Abstract*—Drawings have been a valuable pedagogical tool for science educators. While drawings have been used for analyzing students' conceptual understanding and evaluating their level of expertise, they have not been fully explored to understand students' implicit ways of thinking(knowledge that students' use but are not aware of) when they create scientific explanations. Previous studies have suggested how drawings can act as a window into students' ideas that are not captured in their verbal explanations, however this has been given limited attention. This research aims to bridge this gap by investigating students' drawings to uncover implicit elements in their understanding of scientific c oncepts. T he s tudy a nalyzed d rawings b y thirty-five g rade e leven s tudents, d epicting t heir u nderstanding o f the heat transfer phenomenon. The diverse range of elements in students' drawings reflected t he a ctivation o f v arious implicit ideas like perceived notions of matter interactions, agentic views of vapors, changing ideas about transfer processes, and how they influenced t heir c onceptual u nderstanding o f h eat transfer concepts. The findings p rovide i nsights o n t he t ype o f scaffolds that students need such as prompts and tools enabling students to consider various elements or modify the structure of important elements to enhance their scientific u nderstanding. T his study has implications for technology-based instructional design.**

***Index Terms*—Scientific e xplanations, d rawings, i mplicit thinking, intuitive thinking, technology-driven instructional design, heat transfer**

I. Introduction

The acquisition of scientific c oncepts b y s tudents begins long before their formal education in classrooms. Students' understanding is shaped by various experiences with the world [1] [2]). Although such experiences collectively contribute to students' understanding of scientific p henomena, n ot a ll ideas are consciously or formally gathered [3]. Students' implicit ways of thinking, rooted in tacit knowledge and intuitive thinking, exert a considerable influence o n t heir learning process [4] [5] [2] [6], encompassing concealed ideas that utilize knowledge elements they are unaware of during their application [7] Students employ diverse intuitive reasoning and approaches when explaining scientific p henomena [8]. Intuitive nature is evident in a significant p ortion o f undergraduates' reasoning, often relying on formula-driven or intuitive approaches, which differ from established science's causal, law-like, and statistical-based explanations [9]. Not just students but teachers' explanations too encompass various intuitive approaches, including analogies, metaphors, and other intuitive reasoning strategies [10]. Hence, recognizing how students employ intuitive approaches in their scientific explanations is crucial for understanding their impact on formal acquisition of scientific concepts.

While previous studies in the field of science education have focused on uncovering students' intuitive thinking through verbal explanations [11] [6], the examination of students' drawings depicting scientific phenomena have not received adequate attention. Visual representations play a vital role in scientific learning, with scientific diagrams and the ability to interpret, draw, and explain them being integral components of science curricula [12]. Students frequently use drawings to communicate their ideas, making their mental representations visible and facilitating a deeper comprehension of scientific phenomena [13].Existing technologies have helped support students' visualization skills and conceptual understanding of scientific topics [14]. Analyzing students' drawings can help provide further insights into their intuitive thinking and reveal additional layers of understanding that may not be evident in verbal explanations alone [15]. Recognizing the diverse levels of conceptual understanding conveyed through students' drawings underscores the significance of leveraging this visual medium to support their scientific learning experiences. Integrating the analysis of students' drawings with the exploration of intuitive thinking allows for a more comprehensive understanding of how students engage with scientific concepts and phenomena, paving the way for improved instructional designs. While drawings have been used for understanding conceptual understanding and evaluating student's level of expertise, they have not been fully explored to understand the influence of students' implicit ways of thinking on their creation of scientific explanations.

This article aims to investigate students' drawings as a valuable tool for capturing and analysing intuitive elements in their understanding of a scientific phenomenon, heat transfer.

The research question that we are investigating is "What intuitive elements in students' understanding of heat transfer can be captured and analyzed through their drawings?" We do this by analysing scientific drawings about heat transfer phenomenon by grade 11 students. In this study we analyse different elements represented in the drawings and how they have been depicted to influence the heat transfer process using a coding mechanism(see Table I). Understanding how these elements interact to foster the creation of drawings for scientific explanations can inform the design of technology-assisted environments. By incorporating insights from research on students' intuitive reasoning and the role of drawings in capturing intuitive elements, we can develop technology-assisted environments that effectively support students' intuitive thinking. This study offers valuable insights into modifying technology-driven instructional designs and supporting teachers in facilitating students' scientific explanations. The findings are particularly useful for implementing scaffolds and prompts within existing drawing tools or technology-enhanced learning environments (TELs) and developing new TEL environments to enhance students' scientific explanations by leveraging their intuitive ideas.

II. LITERATURE REVIEW

A. Analytical approaches to understanding student drawings

Different iterations of the drawings can help us to contrast between student's prior knowledge and the acquired knowledge as part of different interactions [16]. Drawings have also helped display student's levels of conceptual understanding, promoted their construction of knowledge, and motivated them to learn. All these skills help students continue learning beyond schooling and support them in their lifelong learning process [16]. Hence, it becomes crucial to closely analyze student drawings to guide us in refining our instructional strategies. A few analytical approaches exist to aid our understanding of student drawings. Some frameworks focus on classifying representations [17], analyzing science textbook images [18], studying multimodal representations in classrooms [19], and assessing students' combined drawings and writings [20]. However, these approaches lack specific methods for analyzing the drawings. An ideal framework for analyzing student drawings as suggested by literature should encompass the following [21]: comprehensive categorization of a wide range of student ideas, a systematic and holistic approach for examining drawings and the ideas they convey, and assisting in revealing students' reasoning and understanding within specific contexts. Such a framework would enable the development of appropriate tools to support teachers and students in their scientific practices. By understanding how students employ drawings to derive scientific meanings, teachers can design suitable instructional scaffolds to enhance students' comprehension of scientific concepts [21].

B. Methods of categorizing drawings

Previous research has shed light into how we can make sense of students' drawings. Classification of drawings into different categories have been largely employed to do this. [21] [22] Drawings have been classified into representational styles (realistic or schematic) and were also examined for inclusion of formal elements such as the use of arrows while depicting energy flow. The categorization also considered the situation depicted in the drawing, including elements like the presence of ground or radiator and the depiction of their impact on the given phenomenon [23]. Drawings related to photosynthesis were classified based on sophistication, ranging from no drawing to comprehensive representations, including categories for misconceptions, partial understanding, and realistic drawings [24]. Other categories used for analysing drawings included association, spatial orientation, abstraction, textual contextualization, and connectivity [21]. A rubric focusing on chemistry drawings assesses understanding levels (macroscopic, submicroscopic, process, and symbolic), complexity, accurate representation of scientific terms, and the description of the system and its surroundings [25]. Another study identifies salient characteristics of students' conceptual understanding of the greenhouse effect through drawing analysis, resulting in four categorized models [22]. For the analysis of student drawings about the marine environment, researchers developed the DAME-R (Draw a Marine Environment-Rubric) to assess the relationship between marine elements [26]. Although these drawing analysis methods have helped elucidate students' conceptual understanding, they fall short in fully revealing the implicit thought processes reflected in their drawings. Nonetheless, the importance of these established methods becomes apparent as they aid us in scrutinizing and comprehending the scientific illustrations produced by students. By conducting a thorough examination and interpretation of these drawings, researchers and educators can extract valuable insights that can serve as an initial stepping stone towards understanding the ideas of students. Through this initial analysis, we can begin to uncover the underlying patterns, representational styles, and conceptual understanding expressed through the drawings. It provides a foundation for further exploration and deeper investigation into the rich information conveyed by students' visual representations, leading to a more comprehensive understanding of their learning experiences and scientific comprehension.

C. Role of technology in supporting student drawings

Technology provides opportunities for dynamic representation of student drawings, such as the use of simulations to support drawings [23] and the creation of animations from drawings [27]. Existing technology for supporting drawings utilizes computers and tablets, offering basic functions like labelling, adding objects, voice recording, and creating animations [28] [23]. Computer simulations have been employed to support computer-based drawings, allowing manipulation of observable scientific phenomena [28] [29]. These simulations have proven beneficial in enhancing students' understanding of different variables and their effects on the phenomena [23]. Analysis of students' dynamic representations derived from their static drawings has also been used to capture their

alternative conceptions and explain scientific concepts [30]. In technology-assisted environments, educators may need to assist students in applying effective explanation patterns in their scientific explanations [28]. Technology-assisted approaches provide promising avenues for supporting and enhancing students' drawing-based scientific explanations, enabling dynamic representations, and capturing alternative conceptions.

However, it is important to note that these tools do not yet fully consider students' use of intuitive elements during their scientific explanations. By recognizing the influence of intuitive thinking and incorporating it into technology-assisted environments, we can foster a more comprehensive and effective approach to supporting students' creation of drawings for scientific explanation. This understanding has the potential to enhance the learning experience and facilitate better conceptual understanding of scientific phenomena.

III. MATERIALS AND METHODS

A. Study Setting

A total of thirty-five grade eleven students from a school in Mumbai, India, grouped into groups of 3-4 students each, took part in the study. The school follows a senior secondary school certificate curriculum and students were enrolled in math, physics, chemistry, and biology courses. None of the students had undergone any formal training for the chapter related to heat, temperature or heat transfer in their syllabus during the time of the study. The application of the research study was done in a 3-hour activity session, where the student groups were asked to discuss amongst themselves and draw a scientific explanation as a group about how coffee cooled in a cup. moderated by 5 researchers. The researchers were present to answer any technical doubts that arose due to the activities. The activities were constant throughout the groups with certain modifications in a few groups due to lack of resource availability. The overall flow of the activity is represented in Fig 1.

The activities were designed around the three levels of representation (macro, micro and symbolic) to accurately elicit and analyse student understanding at a more nuanced level.The explanatory models that students were building were at the symbolic representational level. For the macroscopic levels, the following activities were done:

- The researchers poured hot water/coffee in front of the entire class asking them to discuss and build an explanatory model about how heat transfer occurs in a coffee cup.The student groups were given pen and paper to draw their explanatory models.
- As part of another macroscopic level activity, the student groups were given sets of different coffee cups and asked to choose the one that cools down faster while updating their model if they want to.
- For the microscopic level activities, the student groups were asked to draw the molecular view of their scientific explanations. A few of the groups were also given molecular workbench simulation of heat and temperature to play around at this point. All groups also shared information notes about the three types of heat transfer-conduction, convection and radiation. The notes explained the process of the types of heat transfer along with examples and a few diagrams. During these activities, the researchers were only present to explain the activities and to clarify any doubts that the students may have. The class teachers were not present during the study.

TABLE I
SUMMARY OF CODES

	Codes	***Explaination***
1	Abiotic elements coded as system elements	Drawings including any abiotic elements like clouds, wind, sun, human, windows, fans, table, house
2	Perceived Movable or immovable elements: water, vapor, wind	Drawings representing different elements as moving or non-moving macroscopically. Like water in a cup will be perceived as immovable while vapours from the cup will be seen as a moving element
3	Level of complexity: very low to high level	Drawings labelled as very low complex to highly complex based on the extent of different elements drawn and their interactions explaining the heat phenomenon
4	Cup emitting or taking something	Drawings that depict the cup emitting something (like vapours) or taking in something from other elements (like air)
5	Other abiotic elements emitting something	Drawings that depict the other abiotic elements like fan or window emitting something (like air) or taking in something from other elements (heat molecules)
6	Vapours emitting absorbed or transformed by atmosphere	Drawings that specify how the vapours are emitted, absorbed or transformed
7	Spatial: position of cup, cup on table, cup alone, cup near window, near fan	Position of the cup: touching the table, positioned above the table, positioned near other elements in the drawing
8	Connective: Flow of energy or heat, temporal sequence, comparison	Flow of energy or its other forms shown in the drawing by moving arrows, temporality of the flow, comparing different images/representation side by side
9	Representation of elements at different temperature	How the temperature difference in the different elements are depicted
10	Representation of vapours, coffee, wind: molecular, streamline or continuous, discreet	The type of representation: using dots, continuous lines, circular, moving circular, etc
11	Perspective: dimension of the matter represented, angle (top view, oblique, side view, mixed, projected) and abstraction (macroscopic, microscopic, symbolic)	The different perspectives used while representing the phenomenon. Front view of the cup, zoom out, zoom in(micro view), etc
12	Agency: which element is seen to control the phenomenon (air, cup, natural, fan)	How the elements are depicted to control the phenomenon. Highlighted with labels and arrows(directionality)

Based on the goal of this study, we focused on characterizing and analyzing the drawings that student groups

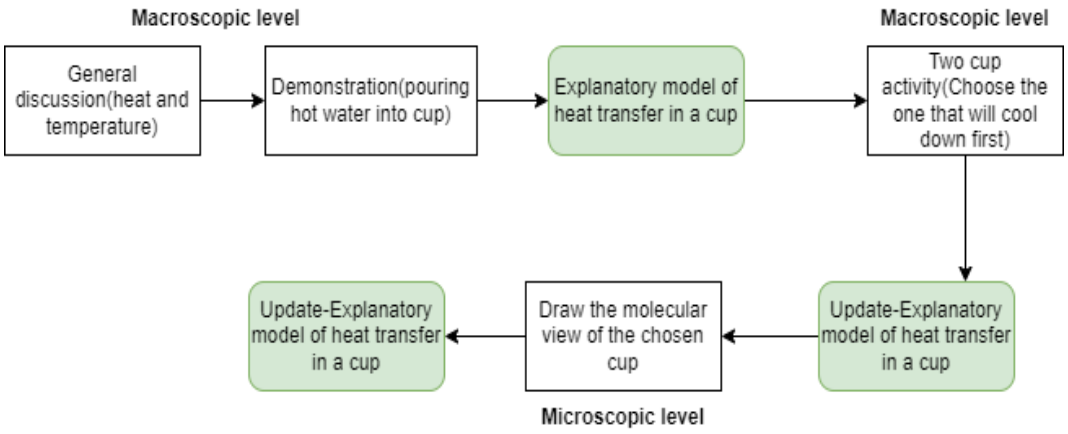

Fig. 1. Overall flow of the study.

drew. The additional explanations that the students gave as the description were considered to clarify our analysis where needed but the explanations themselves were not evaluated. We analyzed a total of 8 student groups' drawings. A total of 15 drawings were evaluated.

B. Coding mechanism

For our research study, we have borrowed parts of the coding schemes and methods from the existing analytical approaches reported in the literature. To summarize, we have considered the following aspects closely while analyzing our drawings:

- Use of representational styles, where formal elements like use and direction of arrows, extent of situation represented (doors, sun, etc.) [23]
- Broadly categorizing drawings as partial understanding, misconceptions or comprehensive understanding based on the number of elements and their relationships [24].
- Looking at spatial aspects of the elements like cup in the drawing (position, alignment) [21]
- Special attention was also given to the students' description of the system and the surroundings. Looking at the drawings through the three levels of representation and checking for scientific accuracy and use of scientific terms like temperature, pressure, position, shape, distance of molecules in the drawing, etc. [25]
- Closing looking at different elements of the heat transfer phenomenon and comparing contrasting them to existing textbook taught models related to such phenomenon. [22]

We first went through all drawings to determine meaningful and unique characteristics using existing codes, some with modifications and other by creating. All drawings were analyzed by one researcher of this study and again by an experienced chemical engineering researcher well versed with heat transfer. We included an external to ensure accuracy of our coding procedure. After independently analyzing the codes, a consensus meeting was held with the external researcher where the coding results were discussed and deliberated iteratively until a consensus was reached on the final codes. A total of 12 codes emerged from the drawings (summarized in Table I). These codes represent the salient features that students have included in their drawings that helped us uncover the work of implicit(intuitive) processes in their explanation building.

The codes were then combined into six themes as explained in the next section. Codes (e.g., number 1, 5, 10) that informed us about the different elements students considered in their scientific reasoning were categorized together into a single theme(drawings ranged from simple depictions of cups to detailed representations). The same was done to develop the other themes too. Another example is how Codes (8, 10,11 and 12) that informed us about the characteristics of the vapors were categorized into a single theme(vapor was frequently depicted in the drawings, with its presence and movement use to symbolize cooling and heat loss). The details of the remaining findings are elaborated in the next section.

IV. Findings

The findings were categorized into the following:

1) Drawings ranged from simple depictions of cups to detailed representations of classrooms, rooms/houses, and external factors like humans and the sun:

While analysing the drawings, we paid special attention to what elements students included in their drawings. These elements would help us understand the visualization space the students might be using while building their explanations about heat transfer. A few drawings depicted only cups while explaining the phenomenon. Other drawings included all elements that were part of the classroom that the activity was situated in-cups, fan, air, vapours, table and windows(see Fig.2). Some students went on to draw the entire room/house that the cups were in, including the surrounding of the house, a human and the sun.

Looking at what different elements the students drew may indicate the possibility that the students might have considered its role or importance in the phenomenon but may not truly

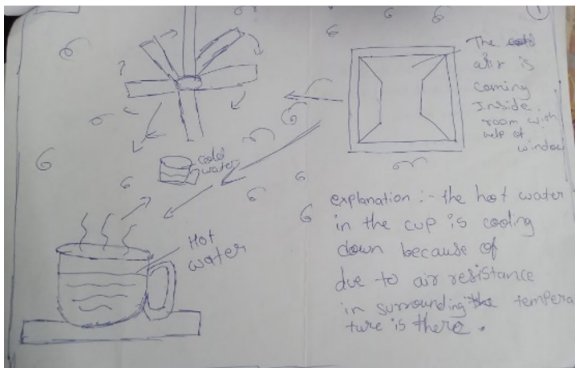

Fig. 2. Representation of different elements like fan, windows, etc

understand the causality behind its influence. These activated elements become important points for the teacher to understand the extent of a students' thinking about the phenomenon.

2) Drawings revealed how moving states of matter as depicted as streamlined flows, while stationary states are represented as individual molecules:

The drawings revealed how students think about different states of matter. Elements such as vapours that were visible to be moving to the students were always represented in a flowy, wavy depiction. This form of matter was represented to be a steady continuous flow as represented in Fig.3. While air is another element which fits in the "flowy" category, it was not represented in the way the vapors were. Air was mostly drawn as swirl like moving images or horizontal swirl lines. Similarly, the coffee was sometimes represented as a continuous liquid and sometimes as molecules moving around. Coffee evaporating was represented as molecules too. Overall, it was observed that moving images or experiences (vapours) are represented as streamlined versions while stationery experiences are represented as molecules (like water).

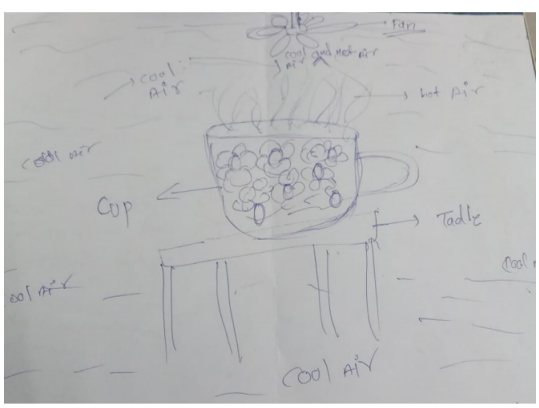

Fig. 3. Representation of moving and stationary states of matter

3) Student drawings showed inconsistent representations of elements like vapor and coffee :

An important observation that came out of the analysis was the way the students represented the same elements such as vapor or coffee differently in the same context or setting. For example, when representing coffee, students would either use a continuous streamline like representation or a discreet molecular representation(see Fig.4(marked 1 and 2)). While representing vapours, the students uniformly used streamlined continuous lines to represent it. And while representing the vapours after being dissipated into the air, they again switched to molecular or discreet representation (see Fig.4(marked 3 and 4)). This highlights the possibility of how students consider the water, vapours and air as non-interacting or non-causal entities in heat transfer.

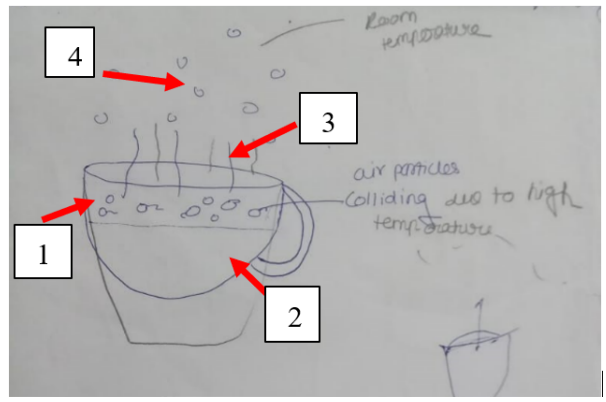

Fig. 4. Inconsistent representation of elements

4) Vapor was frequently depicted in the drawings, with its presence and movement used to symbolize cooling and heat loss:

Vapor was the most represented element in the drawings. 12 out of 15 drawings included vapor as a component of heat transfer. The drawings represented the presence of 'more' or 'less' vapor coming out of the coffee cup as a cue of the coffee cup getting cold or losing heat. Other drawings show a flow where there is movement of vapors into the air and the movement of air to vapor, to depict how cooling occurs, highlighting the fact that the students may see the heat loss caused by and only through vapors. An association of vapor and heat is generated to the extent that vapor is represented to control the entire process of heat transfer.

5) Drawings revealed how cups and its aspects such as shape, sizes were represented differently:

How a student has depicted the cup in her drawing is important for us to understand the extent of cup's characteristics considered by the student to be affecting the phenomenon. Some diagrams showed only cup, while others showed cup placed on or near a table. Some drawings showed designs of multiple different cups. Other aspects such as considering the shape of the cup in determining its role in heat transfer is visible in the drawings. Although different shapes and designs of cups were drawn by students while explaining the phenomenon, they could not explicitly comment on its impact on the transfer rate, except when they were given the same cups of different sizes to choose from. Despite drawing different surface area and height of the cup, students did not include them in their explanation. One of the groups, designed

multiple designs of cooling and heating a cup. Even while focusing on the design aspect of cup, they could not focus on the size aspect of the cup that plays a huge role in the heat transfer process as can be seen in Fig.5.

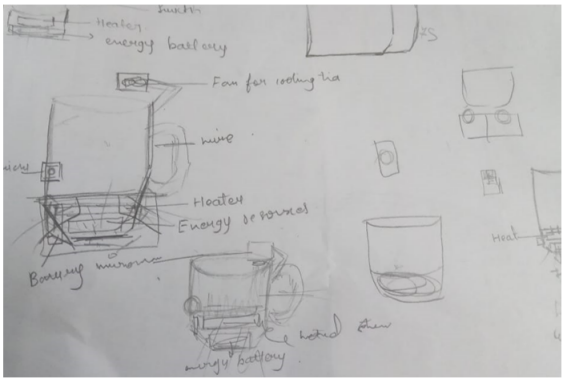

Fig. 5. Representation of cup with different designs but no consideration of size in heat transfer

6) Other aspects: The drawings showed a lack of students' understanding of equilibrium in scientific processes:

Equilibrium is an important aspect of any scientific phenomenon. But what was evident in the drawings was a lack of it in students' conceptions. No drawings touched upon the concept of equilibrium to explain how the cup ultimately cools down. This became more evident in one of the group's drawings where the students use the representation of (+) and (-) to explain hot and cold temperature (see Fig.6). Even though they explained the process of how the energy gets transferred, they showed an exchange of the hot and cold molecules but nothing about the equilibrium.

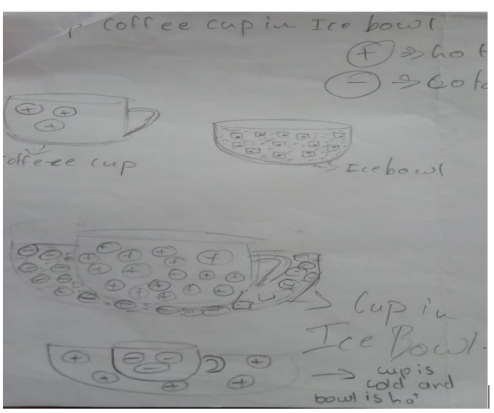

Fig. 6. Representation of transfer of energy without understanding the concept of equilibrium

V. Discussions

The analysis of student drawings provides valuable insights into their understanding of heat transfer phenomena. By examining the elements included in their drawings, we can gauge the extent to which students consider the role and importance of various factors, although their comprehension of the underlying causality may be limited. These activated elements serve as important reference points for teachers to understand students' thinking and provide necessary explanations that establish connections and elucidate causal relationships. Scaffolding in learning environments can also prompt students to consider additional elements they may have overlooked, fostering a more comprehensive understanding. The varied representations of matter in science classrooms, where water is typically portrayed as molecules while vapor is seldom depicted at the molecular level, may hinder students' perception of how phenomena unfold. When students represent coffee as molecules and vapor as streams, the crucial boundary interactions that contribute to heat loss or transfer may be overlooked. To mitigate such confusion, it is crucial to monitor and clarify different models of matter, ensuring students grasp the role of drawings as dynamic representations in scientific explanations.

Vapor, being the most easily observed element in everyday life during heat transfer, is frequently activated in student drawings. Drawing upon their phenomenological experiences, students often depict instances involving boiling hot water and coffee in cups, connecting them to the concept of rapid vapor formation through evaporation. This idea along with daily encounters like knowing a cup of coffee is hot because they see vapor coming out becomes activated in such scenarios. However, it is essential to expand their understanding beyond these observations and encompass the other modes of heat transfer, including conduction and radiation. Depicting cups placed on tables facilitates conceptualization of conduction, while recognizing the involvement of external systems in the heat transfer process broadens students' comprehension of heat transfer, paving ways to build on other modes of heat transfer like convection and radiation.

To support students in their explanations, drawing tools can be used as prompts for manipulating cup shape and size, allowing them to observe and incorporate the effects into their diagrams and verbal explanations. Introducing the concept of equilibrium becomes crucial, with scientific drawing tools offering a separate column to encourage students to depict both the dynamic and equilibrium states of the phenomenon. By incorporating these strategies, teachers can enhance students' understanding of heat transfer processes and foster a more comprehensive conceptual mental model.

VI. Implications

The findings from the analysis of students' drawings provide insights into various aspects related to intuitive thinking and understanding of scientific concepts. Firstly, the diverse range of physical elements depicted in the drawings reflects the activation of different concepts during scientific explanations. Looking at what different elements the students drew may indicate the possibility that the students might have considered its role or importance in the phenomenon but may not truly understand the causality behind its influence. These activated elements become important points for the teacher to understand the extent of a students' thinking about the phenomenon.

The teacher can provide necessary links that may connect the elements and explain their causality in the phenomenon. On the other hand, learning environments may include scaffolds to prompt the students to consider other necessary elements that they may have missed and to encourage them to include its effects in the explanations. The inclusion of these elements in the drawings allows teachers to understand the extent of students' thinking about the phenomenon and provide necessary links to explain causality.

Secondly, the representation of different forms of matter in the drawings suggests how students perceive their interactions and roles within a system. Understanding these perceptions can inform the positioning of scientific learning in the classroom and the need for simulations to showcase different representations of matter and their interactions.

Thirdly, changes in the depiction of the same matter indicate the presence of misconceptions related to the properties or behavior of matter. Teachers should monitor and clarify different models of matter to prevent confusion and help students recognize the role of drawings in scientific explanations.

Fourthly, moving entities, such as vapor, are attributed with agentic characteristics when students explain phenomenological phenomena like heat. Vapor is often represented as controlling the entire process of heat transfer, hence clarifying the role of other factors is necessary.

Lastly, the representation of a cup in the drawings reflects how students perceive the process of heat transfer. Consideration of aspects such as cup placement, shape, and size can enhance students' understanding of conduction, convection, and radiation. Additionally, the lack of understanding of the concept of equilibrium in scientific processes is evident in the drawings, highlighting the need to introduce and incorporate this concept in students' explanations.

These insights from the analysis of students' drawings help us uncover the tacit aspects of students' conceptions about heat transfer, which were not evident from students' discourses before. They have implications for how we use findings from students' conceptual understanding to improve science learning and teaching in classrooms. In this article, we focus on expanding a bit on how the findings of this study can help modify technology-driven instructional designs, and how teachers can scaffold students' learning of scientific phenomenon.

A. Technology-driven instructional designs

Analyzing the drawings for implicit (intuitive ideas) has provided us with useful insights that can be applied in modifying technology driven instructional designs. Learning environments can incorporate supports or frameworks to encourage students to consider additional elements like the cup's saucer, human hand that they might have overlooked, prompting them to include the effects of those elements in their explanations. Simulations that allow students to manipulate different representations of matter can be beneficial for their comprehension of states of matter and their involvement in heat transfer [28] [29]. This way, students can observe how the same matter can be represented differently and how interactions produce consistent outcomes, even though the appearances may vary. To ensure students considered the concept of equilibrium in their explanations, scientific drawing tools could include a separate section to encourage students to depict both the dynamic and equilibrium states of the phenomenon. Students often view drawings as static representations without recognizing the role of each element in explaining the phenomenon. Tools that support conversion of static images to dynamic animations can help in overcoming this barrier [30]. Drawing tools can also provide prompts that enable students to modify the shape and size of a cup and observe the resulting effects [28] [29]. Another approach could involve providing pre-made cup templates with measurements, making it explicit for students to include them in their diagrammatic or verbal explanations.

B. Teaching and Learning science in classrooms

Different representations of the same matter in drawings may indicate misconceptions or incorrect notions about the properties and behavior of matter in a system, potentially hindering understanding of related phenomena. Monitoring and clarifying students' conceptual models of matter, as well as emphasizing the role of drawings in scientific explanations, are crucial for addressing these misconceptions [28]. It is important to explicitly teach students the significance and effectiveness of drawings in scientific explanations. When explaining heat-related phenomena, students attribute agentic characteristics to moving entities like vapor. Vapor is prominently represented in the drawings, associated with heat transfer and considered as the controlling factor in the process. The presence or absence of vapor is depicted as an indication of the cup's temperature change, potentially indicating a limited understanding of heat loss through vapor. The representation of a cup in students' drawings reflects their perception of the heat transfer process. Depicting a cup on or near a table indicates an understanding of conduction, while failing to consider external factors suggests a limited understanding. Students often focus on convective or evaporative processes, neglecting the impact of cup shape and size. Providing prompts or templates can help students consider these factors in their explanations. The teacher can also provide links and scaffolds to enhance students' explanations and consider additional elements involved in the scientific phenomenon. They could offer relevant links that can establish connections between different elements and clarify their causal relationships within the phenomenon. The drawings revealed a lack of understanding of equilibrium in scientific processes, as none of them addressed the concept to explain how the cup ultimately cools down. Students focused on the transfer of energy without considering the equilibrium state, highlighting the need for teachers to introduce and emphasize the concept when they introduce such phenomenon in classrooms. Other ways in which teachers can use drawings is to diagnose conceptual inconsistencies in students' understanding and explicitly clarifying them early on either through group discussions other experiment alike activities [31].

VII. Conclusion

The study findings demonstrate that students rely on their intuitive ideas when constructing scientific explanations, as revealed through the analysis of their drawings. These insights inform guidelines for technology-driven instructional designs that incorporate students' implicit ideas, enhancing their ability to develop scientific explanations. Further research can explore different contexts to uncover additional implicit ideas, and instructional designers can use these findings to enhance drawing tools and science instruction. While the current study has limitations in terms of participant numbers, scope of the topic, and reliance on drawings alone, future analysis of student discourses during drawing activities can strengthen the findings and provide further insights for science education. We have also not analyzed the impact of the different levels of activities on students' drawings and the possible effect of the prompts on the creation of the drawings. This direction holds significant potential for future research and can prove to be highly valuable.

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MWP-T5: Fine-tuning with Numeracy for Math Word Problem Generation

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***Abstract*—Language models have been fine-tuned t o generate math word problems (MWPs) from a provided context representing a premise. Approaches have also been made to control the difficulty o f t he g enerated M WPs b y c ontrolling the number and type of underlying equations of the given MWPs. Additionally, attempts have also been made at generating only univariate MWPs since multivariate MWPs represent complex relationships between various entities and thus can prove to be a challenging task. However, existing approaches are prone to generating semantically impossible or mathematically invalid MWPs with unsatisfactory language quality. They also tend to generate MWPs that do not represent the expected equations either by having an incorrect number of equations, missing operands or by having a completely incorrect equation. This leads to a loss of control over the MWP generation due to a lack of a guiding metric that allows the language model to learn mathematically valid MWPs that represent equations accurately. In our work, we propose a novel conditional fine-tuning strategy to inject numeracy and MWP solvability into a Text-To-Text Transfer Transformer (T5) to create MWP-T5, an effective model capable of generating mathematically valid MWPs offering greater control over difficulty w ithout compromising language quality. We perform our experiments on real-world MWP datasets and achieve State-of-the-Art by significantly outperforming all existing quantitative and qualitative baselines.**

Index Terms*—*math word problem generation, transformer, Text-To-Text Transfer Transformer

I. Introduction

Math word problems (MWPs) play a vital role in mathematical education, enabling students to apply mathematical concepts to real-world scenarios and helping analyze a student's proficiency w ith m athematical c oncepts a nd problem-solving skills. A MWP comprises underlying *equations* which are represented using real-world entities that require a student to understand and solve the problem. MWPs may comprise a single equation or a higher number depending on the number of unknown variables involved. To make problems interesting and to challenge the student, MWPs are created using various topics or *contexts*, to ensure the student can use their problem-solving skills to understand and solve real-world scenarios.

TABLE I
An example of a provided equation and context being used to construct a MWP. See Table II for more information on the datasets used in our work.

Equation	$N_00 + N_01$
Context	`fruits oranges apples`
MWP	Alice bought N_00 oranges from the supermarket. She already had N_01 apples at home. How many fruits does she have now?

Automatic MWP generation finds application in aiding instructors and teachers to speed up the process of creating questions of varying difficulties, which is often costly and laborious. It also allows them to create a wide variety of engaging MWPs and reduce plagiarism attempts by students.

One of the desired features of any real-world application is *customizability* and *configurability*. Depending on the number and type of underlying equations, a MWP can be customized to varying degrees of difficulty. For example, simpler mathematical operations such as addition and subtraction are preferred for students in lower grades, while higher grades will not only focus on combining possible mathematical operations and include multiple unknown variables, making the MWP challenging to solve. Thus, the automated generation of MWPs needs to account for the requirement of customization both in terms of context as well as underlying equations.

However, this has posed a challenging task for researchers due to the difficulty of accurately representing numerical values and ensuring mathematical validity and consistency in the generated problems. Existing approaches suffer from learning inaccurate representations, leading to numerically invalid MWPs with unsatisfactory language quality. Although some approaches use conditional fine-tuning with state-of-

the-art language models, they still generate incomplete or mathematically invalid MWPs due to a lack of a guiding metric for numerically valid generation.

Contributions. Our work leverages the Text-To-Text Transfer Transformer (T5) model, a more powerful text-to-text generation model, for MWP generation. Unlike previous approaches that used decoder-only Transformer architectures, such as the GPT-2, we utilize both the encoder and decoder Transformer layers of the T5 to convert MWP parameters such as equations and context, into well-formed MWPs.

We also propose a novel conditional fine-tuning strategy based on the architecture proposed by Wang *et al.* [1] to include multiple grounded objectives to inject numeracy and knowledge about MWPs which help the model learn better representations and mathematical constraints that allow for a more effective generation of problems.

We display the effectiveness of our approach on two real-world MWP datasets and significantly outperform all existing baselines on both quantitative and qualitative metrics. Specifically, we improve upon the existing work by introducing the following.

1. We conditionally fine-tune a larger language model – the T5, on equations and context keywords for the controlled generation of MWPs.
2. We propose a novel *Solvability Checker* (SC) component with multiple supervised objectives that relay back to the generator how *solvable* a given math word problem is to increase the mathematical validity and consistency of the generated problems.
3. We display our approach's effectiveness in generating univariate MWPs and multivariate MWPs and significantly outperform all existing baselines.

II. Related Work

Math word problem generation is a topic that has become increasingly popular over the years with previous works in this domain focusing on generating MWPs based on topic and equation templates. Heilman *et al.* [2] proposed a parser to generate a tree and a rule-based system is used to transform the tree into the corresponding question. Koncel-Kedziorski *et al.* [3] proposed a method to generate new MWPs from existing ones by replacing nouns and verbs with words corresponding to the new topic. The model proposed by Zhou *et al.* [4] dealt with generating MWPs using a fusion mechanism to capture both equation and context using BiGRU with a GRU decoder for text generation. An additional Entity enforced loss which was used to ensure relevance between the generated question and the equation, helped it to outperform the existing baseline models.

Further, [1] proposed a novel state-of-the-art MWP generation approach that focuses on generating more coherent and consistent MWPs by guiding the generation using a consistency metric that forces the model's MWP to be constrained by the equation, allowing more control over the type and difficulty of problems generated, along with the validity of the problem. It leverages pre-trained language models and attentive context selection to improve the language quality of the problems generated. However, it is limited to equations in one variable. Additionally, the equation loss described in this paper does not take into account the structure of the equation.

Most of these works focus on constraining the text generation model to adhere to the given context and equation but do not directly account for the solvability of the generated problem. Hence, we propose an architecture that handles multi-variable equations as well as ensures that the generated math word problem has all the numerical quantities necessary to generate an equation from it.

III. Methodology

We formulate the task of controllable MWP generation as a conditional generation problem. In this paper, we work with datasets in the form of D (M_i, E_i) pairs where M_i and E_i represent MWP and its associated equation set respectively. Our fine-tuning strategy assumes that each MWP in our dataset is labeled with its underlying equations but its context is unknown. In our work, we represent $M = \{m_1, ..., m_T\}$ as a MWP with a sequence of T tokens, which is conditionally generated using an equation set $E = \{e_1, ..., e_N\}$ consisting of N equations and context $c = \{c_1, ..., c_K\}$ consisting of K tokens.

A. Context Selector and Language Model

Given a MWP M, we compute the context c using KeyBERT[1]. This context is used to drive the generation process to create MWPs with the same underlying topic as the selected tokens. We also shuffle these tokens while training the language model.

We use a pre-trained T5 model as our generator. The input to our generator includes the set of equations E for a given math word problem, along with the context c. The expected output from the generator is a complete MWP M that ensures consistency with the underlying equation and context. We train our generator using the negative log-likelihood objective.

$$\mathcal{L}_{LM} = NLL(M|E, c) \tag{1}$$

However, we cannot control the numerical validity of the MWPs being generated for the following reasons. First, there is no way for the T5 to verify if the generated problem contains the same number of equations as in the expected equation E. Second, based on the equations, the generated problem needs to also contain the same operands as well as operators for the problem to be solvable. Hence, we must ensure that the generated MWPs adhere to the equations present in E to be numerically valid without losing language quality.

B. Solvability Checker

We propose a fine-tuning strategy that introduces a solvability-checking constraint that uses supervised metrics to ensure that the generator can produce mathematically solvable and numerically valid MWPs.

[1] https://maartengr.github.io/KeyBERT

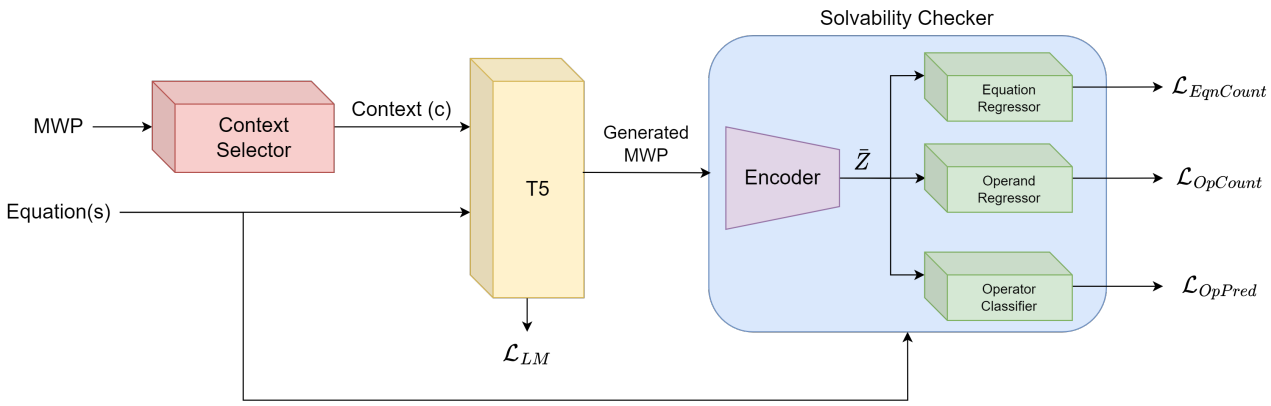

Fig. 1. **The architecture of our proposed fine-tuning approach MWP-T5:** The input MWP M is passed to the Context Selector to obtain the underlying context c. The Equation set E and c are used to conditionally fine-tune the T5 and control the equation as well as the underlying topics of the generated MWP. The Solvability Checker is used to constrain the T5 to generate a mathematically valid MWP that is consistent with E. The two regressors and the classifier are used to penalize the T5 if the generated MWP is unsolvable or cannot represent E. The entire approach has been explained in section III.

Solvability Checker Encoder. Our solvability checker encoder maps the input generated MWP $M = \{m_1, ..., m_T\}$ to a matrix of feature representations $Z \in \mathbb{R}^{T*h}$ where T is the number of tokens in the MWP and h is the hidden feature size.

$$Z = encoder(M) \tag{2}$$

The representation vector corresponds to each token in the MWP, which will be used to evaluate and improve the solvability of the generator model. These representations from the encoder are fed to three supervised fine-tuning objectives, each tackling a different aspect of mathematical and numerical validity to ensure the generated MWP adheres to the expected equation E. Our encoder implementation combines the T5's encoder layers with a BERT model to obtain the final feature representation matrix. More details can be found in Section IV.

Feed-forward Network (FFN). We use a standard feed-forward network template consisting of three fully connected layers for each fine-tuning objective. The final layer is either a ReLu activation for regressive objectives or a Sigmoid for classification objectives, with the final output shape being a single value for regressive objectives and a 4-dimensional vector for the classification objective. The input to the FFN is the mean vector of Z, which is a single vector representing the encoder's overall representation of a MWP denoted by $\bar{Z} \in \mathbb{R}^h$.

$$\hat{y} = FFN(\bar{Z}) \tag{3}$$

Equation Counting. One of the fine-tuning objectives is to predict the number of equations that are present in the generated MWP. This aids the model in developing a basic understanding of the difficulty of a given MWP with the help of the number of equations required to solve it. This especially guides the model to learn effectively on datasets that contain multivariate MWPs and allows it to distinguish between univariate and multivariate MWPs. We use a regression loss between the expected and predicted number of equations in the generated MWP and reduce the Mean Square Error (MSE) between the two quantities.

$$\mathcal{L}_{EqnCount} = MSE(FFN(\bar{Z}), N) \tag{4}$$

where N is the expected number of equations in the original MWP.

Operand Counting. The second fine-tuning objective is to predict the number of operands in the generated MWP. This helps the generator to draw a relationship between the number of operands and the number of required entities to represent an operand and constrains the model to generate the required number of entities and operands in the MWP as in the expected equation. Similar to Equation Counting, we use a regression loss between the expected and the predicted number of operands in the generated MWP and reduce the MSE between the two quantities.

$$\mathcal{L}_{OpCount} = MSE(FFN(\bar{Z}), Q) \tag{5}$$

where Q is the expected number of operands in the original MWP.

Operator Prediction. The final fine-tuning objective is to predict the operators that are present in the generated MWP. This helps the generator to draw relationships between the entities themselves and guides the model to generate a MWP where the entities are related the same way as in the expected equation. This final objective also ensures that the underlying equations and the expected equations match both in cardinality as well as the number of operands and operators between them. We use a classification objective to construct a boolean label distribution indicating the presence or absence of an operand and predict the probability distribution of the following operators: $+$, $-$, $*$, and $/$ and minimize the Binary Cross-entropy loss between the two vectors.

$$\mathcal{L}_{OpPred} = BCE(FFN(\bar{Z}), \{B_+, B_-, B_*, B_/\}) \tag{6}$$

where B indicates the occurrence of an operand in the original MWP.

TABLE II
NUMBER OF EXAMPLES IN EACH TRAINING DATASET

Dataset	Number of MWPs
MAWPS	2,373
PEN	3,581

The final loss from the solvability checker $\mathcal{L}_{SC}$ is then obtained as a weighted aggregate using empirical hyperparameters ζ, γ and η for each of the formulated individual fine-tuning loss functions defined in equations (4), (5) and (6) respectively.

$$\mathcal{L}_{SC} = \zeta\mathcal{L}_{EqnCount} + \gamma\mathcal{L}_{OpCount} + \eta\mathcal{L}_{OpPred} \quad (7)$$

C. Training

We fine-tune the T5 and the SC in two stages. In the first stage, we fine-tune only the SC using valid MWPs as the inputs to the encoder and minimize the solvability checker loss defined in Eq (7). In the second stage, we freeze the SC's encoder before loading it with the T5 for joint fine-tuning. Each component is optimized using their overall loss objectives defined in Eq (1) and (7) respectively. The final loss objective for the entire model is formulated as below in Eq (8):

$$\mathcal{L} = \beta\mathcal{L}_{LM} + \mathcal{L}_{SC} \quad (8)$$

IV. EXPERIMENTS

We perform a series of experiments to validate the effectiveness of our proposed fine-tuning strategy for MWP generation. Quantitatively, we compare our approach to several baselines on various automated language quality metrics namely BLEU-4 [5], METEOR [6] and ROUGE-L [7]. Additionally, we pre-train a solvability checker on all our datasets and use it to compute the mean solvability loss of each model when provided the same inputs. Qualitatively, we showcase the capability of our approach in generating highly controllable as well as mathematically and numerically valid MWPs.

Datasets. We show the effectiveness of our fine-tuning strategy on MWP generation datasets in the English language. Extension of the model to languages other than English is left for future work. We focus on both univariate as well as multivariate datasets to show how well our model can generalize to the respective types of problems. For univariate MWPs, we consider the **MAWPS** [8] dataset and for multivariate MWP generation, we consider the **PEN** [9] dataset. We follow the preprocessing steps in [4] by first replacing all numbers in both MWPs and equations with special tokens like N_0, N_1, and so on. Additionally, we also use the infix translation of the equations to train our model. Table II shows the number of training examples in each of the datasets used in our experiments.

Implementation Details. We fine-tune our models on a single NVIDIA TESLA T4 graphic card offered by Google Colaboratory or a single NVIDIA TESLA P100 graphic card offered by Kaggle. We use the pre-trained English MWP-BERT model[2] for the solvability checker's encoder since it is already pre-trained on multiple English MWP datasets and will possess more accurate and refined feature representations compared to a generic BERT model. We fine-tune the SC in the first stage on a randomly shuffled collection of MWPs from both datasets using a batch size of 8 and the AdamW [10] optimizer is applied with an initial learning rate of 1e-5 for 20 epochs. We also use a scheduler to reduce the learning rate by a multiplicative factor of 0.1 if the loss plateaus.

During the second fine-tuning stage, we load the SC from the previous step along with the T5 for joint fine-tuning. We additionally freeze all the layers of the MWP-BERT model to avoid gradients from affecting the learned representations. In our encoder implementation, we use T5's encoder layers to first obtain an initial feature representation which is then passed to the layers of the MWP-BERT's encoder in succession to obtain the final feature representation for a MWP. This is done to ensure the entire network is end-to-end differentiable. We set the values of weights γ, θ and ζ to 0.5, β to 10 and η to 2 across all our experiments and datasets.

We use Google's pre-trained flan-t5-base model [3] for the T5 generator model because it is already pre-trained for MWP solving tasks and can adapt to MWP generation far more effectively than an ordinary t5-base model. We add nine number tokens ranging from `N_00` to `N_09` to the tokenizer along with two other tokens: `<BRG>` and `<keywordtext>`. We combine the equations in the equation set E with the `<BRG>` token and all the tokens in the context c with whitespace. We also perform prompt tuning by using the `mwp:` token for tuning. Our final prompt to the T5 model is a text of the form `mwp: E <keywordtext> c`.

The MWP-T5 model is jointly fine-tuned for 5 epochs on the MAWPS dataset and for 10 epochs on the more complex PEN dataset. Fine-tuning is performed with a batch size of 2 and the AdamW optimizer is applied with an initial learning rate of 1e-3 and a scheduler with a multiplicative factor of 0.1. During inference, we set the value of top-k-filtering to 0, the top-p probability threshold to 0.8, the temperature for the generation to 1.0, and a repetition penalty to 1.0.

We compare the effectiveness of our approach to just a vanilla T5 as well as a T5 with the solvability checker that utilizes just the T5's encoder (instead of the proposed MWP-BERT encoder). Our code and data have been open-sourced on GitHub[4].

Metrics. To analyze the language quality of the generated MWPs, we use the following three evaluation metrics: BLEU-4, METEOR, and ROUGE-L. We implement these metrics using the evaluate package [5]provided by HuggingFace. A higher score for the language quality metrics indicates a more coherent as well as grammatically complete MWP (although it is to be noted that this also indicates how well it matches the

[2]https://huggingface.co/invokerliang/MWP-BERT-en
[3]https://huggingface.co/google/flan-t5-base
[4]https://github.com/yashichawla/mwp-t5
[5]https://github.com/huggingface/evaluate

TABLE III
A COMPARISON OF LANGUAGE QUALITY METRICS FOR MWPS GENERATED USING OUR METHOD TO VARIOUS EXISTING BASELINES [1] ON THE **MAWPS DATASET**.

Model Name	BLEU-4	ROUGE-L	METEOR
seq2seq-rnn [11]	0.153	0.362	0.175
seq2seq-rnn + GLoVe [12]	0.592	0.705	0.412
seq2seq-tf [13]	0.554	0.663	0.387
GPT [14]	0.368	0.538	0.294
GPT-pre [14]	0.504	0.664	0.391
GPT2-mwp2eq [1]	0.596	0.715	0.427
MWP-T5 (ours)	**0.885**	**0.930**	**0.930**

input MWP from the training dataset and thus could be taken as a measure of overfit). Additionally, we measure the degree of solvability by measuring the solvability loss of each variant model using a pre-trained solvability checker that has been fine-tuned on a combination of all datasets. A lower solvability loss indicates a quantitative measure of how much a model's generated MWPs are mathematically and numerically valid and provides a measure of the degree of solvability. All scores indicate the highest score obtained over multiple runs.

V. RESULTS

A. Quantitative Results

1) MAWPS: Table III shows the quantitative results of our experiments on the *univariate* MAWPS dataset. This dataset is arguably easier to tackle compared to the PEN dataset since it focuses on students in lower grades and comprises an easier vocabulary to comprehend. Numbers in bold red indicate the highest score obtained by our models and the new State-of-the-Art. We observe that our MWP-T5 model significantly outperforms the existing baselines on all three metrics by **0.29** points for BLEU-4, **0.21** points for ROUGE-L and **0.50** points for METEOR. We can conclude that our approach can generate semantically valid, understandable, and coherent MWPs with significantly better language quality compared to previous approaches.

TABLE IV
A COMPARISON OF LANGUAGE QUALITY METRICS FOR MWPS GENERATED USING OUR METHOD TO VARIOUS EXISTING BASELINES ON THE **PEN DATASET**

Model Name	BLEU-4	ROUGE-L	METEOR
MWP-T5 (ours)	**0.669**	**0.768**	**0.772**

2) PEN: Table IV shows the quantitative results of our experiments for our model on the *multivariate* PEN dataset. Since this dataset focuses on students in higher grades by testing their mathematical problem-solving skills by solving a higher order of equations and using a combination of equations, it comprises problems with significantly higher difficulty as well as a richer language quality, thus proving a difficult challenge for MWP generation. At the time of conducting our experiments, we could not find any other existing work that focused on multivariate MWP generation and thus did not find any existing baselines for this dataset.

This draws us to believe that our MWP-T5 approach is the first of its kind to handle multivariate MWP generation. Numbers in bold red indicate our results, which are also currently the only existing baseline metrics for this dataset. Although the language quality metrics are slightly lower compared to the MAWPS dataset, we observe they are still really strong baselines and are significantly better than previous approaches on the easier dataset. Thus we conclude that MWP-T5 is adept at not only univariate but also multivariate MWP generation while comparing language quality and fluency.

B. Qualitative Results

We perform a set of case studies similar to Wang *et al.* [1] to investigate the effectiveness of our approach at equation and context control while generating *novel* MWPs. We focus solely on the ability of the approach to generate unseen problems or from contexts that are not present in any of the training datasets to display the robustness of our approach at generalizing to different underlying topics and contexts.

Additionally, we form permutations of context and equations by firstly keeping the context the same and changing the input equation, and second, by keeping the equation the same and changing the context. For multivariate problems, we also permute the order of the input equations with the context. We draw comparisons of our approach against the currently existing State-of-the-Art baseline approaches. All univariate comparisons shown are trained on the MAWPS dataset and all multivariate examples have been trained on the PEN dataset.

1) Fixed Context, Changing Equation: Table V shows that our approach generates MWPs with high diversity and creativity while maintaining mathematical validity and language quality. Other approaches generate similar or semantically invalid MWPs due to overfitting on the small MAWPS dataset, resulting in a lack of diversity and creativity. The GPT2-mwp2eq baseline produces high-quality MWPs, but they often have paraphrased versions of the training examples. Our approach consistently generates vastly different yet related MWPs and is unaffected by the dataset size. We conclude that our MWP-T5 approach is far more effective than other baselines at generating diverse and creative MWPs.

2) Changing Context, Fixed Equation: Table VI shows the MWPs generated by each approach using a fixed equation but with changing contexts. While the GPT-pre approach generates mathematically valid MWPs, they are irrelevant to the provided context. Both the GPT2-mwp2eq and MWP-T5 approaches generate similar MWPs, but the nature of problems generated with the GPT2-mwp2eq suffers a greater decrease in diversity with the increase in complexity of the provided equation. However, our MWP-T5 approach captures the required context well and generates mathematically valid MWPs with high language quality even when the complexity of the equation increases without compromising on diversity and creativity. This is in contrast to other approaches, which

TABLE V
GENERATED MWP EXAMPLES WITH FIXED CONTEXT AND VARYING EQUATIONS FROM THE MAWPS DATASET

Context: `candies`	
Equation #1: $x = N_00 + N_01$	**Equation #2:** $x = N_00 - N_01$
GPT-pre: There are N_00 scissors in the drawer. Keith placed N_02 scissors in the drawer. How many scissors are now there in total? (irrelevant to context)	**GPT-pre:** Joan has N_01 blue balloons but lost N_02 of them. How many blue balloons does Joan have now? (irrelevant to context)
GPT2-mwp2eq: Mildred collects N_01 candies. Mildred's father gives Mildred N_02 more. How many candies does Mildred have? (similar to training data)	**GPT2-mwp2eq:** There are N_01 candies in the jar. N_02 are eaten by a hippopotamus. How many candies are in the jar? (semantically invalid)
MWP-T5: There are N_00 candies in Kathy's candy collection. If the candies are mixed with N_01 candies, how many candies do they have in all?	**MWP-T5:** Mrs. Hilt wants to have N_00 candies. She has N_01 candies. How many candies can she buy?
Equation #3: $x = N_00 * N_01$	**Equation #4:** $x = N_00/N_01$
GPT-pre: Joan has saved N_01 quarters from washing cars. How many cents does Joan have? (inconsistent with equation)	**GPT-pre:** Joan has N_01 blue marbles. Sandy has N_02 times more blue marbles than Melanie. How many blue marbles does Joan have? (inconsistent with equation)
GPT2-mwp2eq: Each child has N_01 candies. If there are N_02 children, how many candies are there in all? (similar to training data)	**GPT2-mwp2eq:** There are N_01 candies in the candy collection. If the candies are organized into N_02 groups, how big is each group? (similar to training data)
MWP-T5: There are N_00 calories in a candy bar. How many calories are there in N_01 candy bars?	**MWP-T5:** For Halloween Bianca received N_00 pieces of candy from neighbors. If she only ate N_02 pieces a day, how long would the candy last her?

TABLE VI
GENERATED MWP EXAMPLES WITH FIXED EQUATION AND VARYING CONTEXT FROM THE MAWPS DATASET

Equation : $x = N_00 + N_01 + N_02$	
Context #1: `violin piano acoustic guitar`	**Context #2: `beets eggplant`**
GPT-pre: There are N_01 dogwood trees currently in the park. Park workers will plant N_02 dogwood trees today and N_03 dogwood trees tomorrow. How many dogwood trees will the park have when the workers are finished? (irrelevant to context)	**GPT-pre:** There are N_01 orchid bushes currently in the park. Park workers will plant N_02 orchid bushes today and N_03 orchid bushes tomorrow. How many orchid bushes will the park have when the workers are finished? (irrelevant to context)
GPT2-mwp2eq: Mike joined his school's band. He bought a clarinet for $ N_01, a music stand for $ N_02, and a song book for $ N_03. How much did Mike spend at the music store?	**GPT2-mwp2eq:** Sara grew N_01 beets, Sally grew N_02 beets, and Fred grew N_03 beets. How many beets did they grow in total?
MWP-T5:: Alyssa joined her school's band. She bought a trumpet for $ N_00, a music tool for $ N_01, and a songbook for $ N_02. How much did Alyssa spend at the music store?	**MWP-T5:** Sally grew N_00 eggplants, Dan grew N_01 eggplants, and Jessica grew N_02 eggplants. How many eggplants did they grow in all?
Context #3: `fruit bag`	**Context #4: `cake cupcake pastry chocolate`**
MWP-T5: Maria ate N_01 pieces of fruit the first night, N_02 pieces the second night, and N_03 pieces the third night. How many pieces of fruit did Maria eat in total?	**MWP-T5:** A restaurant served N_00 cakes during lunch and N_01 during dinner today. The restaurant served N_02 cakes yesterday. How many cakes were served in total?

tend to generate very similar to the existing training examples in such scenarios.

3) Fixed Context, Changing Equation Set: Table VII shows the MWPs generated by our approach using a fixed context with a random combination of equations in each equation set. We again observe that our MWP-T5 approach can capture the required context easily and is capable of generating semantically related as well as mathematically valid multivariate MWPs. Since no other approaches have been tried on this dataset, we are unable to perform a true qualitative analysis of our generated examples. We conclude that our MWP-T5 approach is capable of generating a wide variety of multivariate MWPs with a fixed context across multiple combinations of equation sets. However, we have also noticed that our approach is not very consistent on the PEN dataset and occasionally is prone to generating multivariate MWPs, which are mathematically valid but not consistent with the required equation set. Although they are mathematically solvable, they do not obey one or more of the required equations and hence can be considered a limitation of our approach. Comparison of our approach against other baseline approaches has been left to future work.

VI. ABLATION STUDY

We perform extensive experiments to investigate the effectiveness of each component in our approach and to figure out how each component contributes to the overall success. Specifically, we are interested in how our novel solvability checker performs and contributes during MWP generation.

A. Effectiveness of Solvability Checker

We compare the effectiveness of our Solvability Checker after removing the Solvability Checker completely, as well as by using just the T5 encoder layers for the encoder model.

TABLE VII
GENERATED MWP EXAMPLES WITH FIXED CONTEXT AND VARYING EQUATION SETS FROM THE PEN DATASET

Context: `chocolate bakery cookie`	
Equation set #1: $N_00 + N_01, N_02 - N_03$	**Equation set #2:** $N_00 + N_01, N_02 * N_03$
MWP-T5: Mary is baking a cake. The recipe wants N_00 cup of chocolate candy for the frosting and N_01 cup of chocolate candy for the cake. She already has N_02 cups of chocolate candy. How many more cups of chocolate candy does she need?	**MWP-T5:**A bakery sold some bars and N_01 cookies to make a profit of N_02 dollars. If the chocolate bars were sold for N_03 dollars and the rest were sold for N_04 dollars each, how many bars did the bakery sell?
Equation set #3: $N_00 - N_01, N_02 * N_03$	**Equation set #4:** $N_00 - N_01, N_02/N_03$
MWP-T5: Adam bought N_00 boxes of chocolate candy and gave N_01 to his little brother. If each box has N_02 pieces inside it, how many pieces did Adam still have?	**MWP-T5:** A bakery had N_00 cookies in stock. They ended up putting them on sale and getting rid of N_01 of them. They put the ones they still had into baskets, with N_02 in each basket. How many baskets did they use?

TABLE VIII
A COMPARISON OF THE EFFECTIVENESS OF OUR SOLVABILITY CHECKER ON MWP GENERATION USING ALL QUANTITATIVE SOLVABILITY METRICS

Model Configuration		**MAWPS**				**PEN**			
Solvability Checker	**Encoder Type**	**BLEU-4**	**ROUGE-L**	**METEOR**	**Solvability Loss**	**BLEU-4**	**ROUGE-L**	**METEOR**	**Solvability Loss**
-	-	**0.885**	**0.930**	**0.930**	**0.370**	**0.669**	**0.768**	**0.772**	**1.055**
✓	T5	0.823	0.876	0.876	0.690	0.620	0.743	0.733	1.121
✓	T5 + MWP-BERT	0.844	0.895	0.895	0.419	0.612	0.719	0.725	1.302

Table VIII shows the effectiveness of our solvability checker across both language quality and solvability metrics.

We initially observe that although all variations perform similarly and outperform the existing approaches, our MWP-T5 approach outperforms without the need for a solvability checker and even performs slightly better without it. Although this is contrary to our assumption that grounded solvability objectives benefit the generator model, we can explain this phenomenon on closer inspection of the *type* of generated problems. Since the solvability checker used to measure the baselines was trained on examples from the MAWPS and PEN dataset only, it is unable to generalize to computing accurately for problems that show a great amount of diversity from those already present. We have already shown in Table V and VI that our approach is capable of being creative and using the provided context to generate a MWP that is entirely different from the training examples.

B. Dataset Overlap

Since our approach employs a T5 over a GPT-2 unlike other existing approaches, we are aware of the larger and more powerful language model suffering the risk of memorizing the training dataset. We compare the overall dataset overlap of our models using the median of three metrics: absolute overlap – which indicates if a MWP in the generated set has been picked directly from the training dataset, Jaccard Index – which measures the similarity between a pair of MWPs as the percentage of common words between the pair, and semantic similarity which comprises the cosine similarity between the pair of MWPs. We compute these metrics for each generated problem, taking into account each combination of components in our approach. Table VIII shows the effectiveness of our approach in generating novel MWPs.

1) MAWPS: Our experiments on the MAWPS dataset initially show that our approach does not have any absolute overlap with the training examples, indicating that all the MWPs generated by each model are novel. However, higher Jaccard's Index scores emphasize that although the generated problems are not from the dataset, there is significant overlap with the original MWP used to train the model and thus can be considered to be paraphrased from the dataset. This hypothesis is further confirmed by the semantic similarity scores, which show that most generated MWPs are contextually similar to the training dataset.

2) PEN: Experiments on the multivariate PEN dataset initially show that our approach suffers from memorization and although uncommon, can generate MWPs which are found in the training dataset. However, unlike the MAWPS dataset, we observe much lower Jaccard's Index and lower semantic similarity scores with the training examples enforcing that the problems generated are more novel and contain minimal paraphrased content. Although our approach sometimes picks problems from the dataset, we can conclude that our approach is adept at multivariate math word problem generation with a higher chance of generating novel word problems.

Across both datasets, we observe the effectiveness of our Solvability Checker in generating novel MWPs. The approach with the MWP-BERT Solvability Checker encoder consistently outperforms all other experiments on all three aforementioned dataset overlap metrics. Although our experiment without a Solvability Checker obtains significantly higher language quality metrics, we see that this approach suffers the most from memorization and produces near-identical word problems to the training examples. Combining the conclusions from Table VIII and VIII, we establish that a T5 coupled with the MWP-BERT Solvability Checker encoder proves to be a robust approach for math word problem generation exhibiting *superior language quality*, *variety* and *degree of solvability* along with great *mathematical validity* and *consistency*. Further experiments to investigate the Solvability Checker with

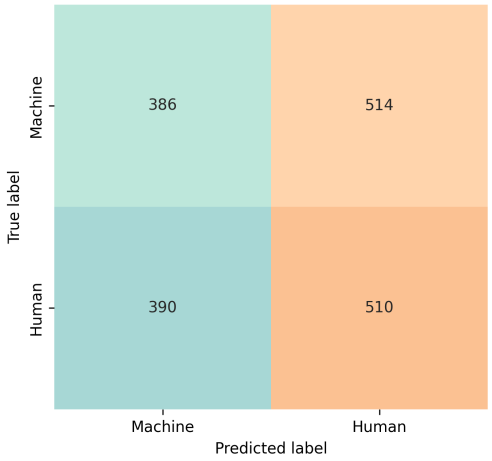

Fig. 2. A split up of the demographic of the 150 respondents as a Confusion matrix from the Turing Test.

other language models have been left to future work.

VII. User Study and Feedback

A total of 150 respondents undertook a survey to provide feedback on the problems generated with about 1% of the feedback from students in the 2nd-4th grades, 2% in the 5th-8th grades, 13% in the 5th-9th grades, and the rest in undergrad or above, with the majority of the respondents (63%) being undergraduate students.

Turing Test. Users were presented with a randomized set of six problems culled from the MAWPS and PEN datasets and six machine-generated problems by the MWP-T5 after it was trained. They were asked to identify the origin of each problem while the original labels were obscured from them. A confusion matrix of the responses for the selected problems is presented in Fig. 2. We found that respondents labeled 57.1% of all machine-generated problems as written by humans and 42.9% as machine-generated. We also observe that all our machine-generated problems individually pass the Turing Test, thus demonstrating that the problems generated by the machine were not distinguishable from manually designed problems.

VIII. Conclusion and Future Work

In this paper, we propose a novel fine-tuning strategy that uses several supervised objectives to perform controlled MWP generation using the underlying context and equation set as parameters. We leverage the use of a larger language model to improve the language quality of generation and propose a novel Solvability Checker component to provide a guiding metric to constrain the validity of the generated MWPs. Our experimental results and ablation studies show that our approach significantly improves over the current State-of-the-Art on existing real-world datasets at several quantitative and qualitative metrics. Unlike previous work, we show that our approach is not limited to the number of equations and thus can handle multivariate equation sets without compromising on contextual relevancy, mathematical validity, and language quality. We are confident that our MWP-T5 approach combined with a clean, lightweight, and accessible user interface for mobile devices will bring a widespread positive impact to teachers, students, and the education industry.

Generating MWPs automatically remains a challenging problem and our work opens up multiple opportunities for future work. First, we are yet to discover the full potential of our model-agnostic Solvability Checker to identify how effective it can be at improving existing approaches to controlled language generation. Second, since our work is the only existing work for multivariate problems, we believe that it could potentially pave the way for multivariate MWP generation. Finally, an interesting future direction would be to control other qualitative parameters such as linguistic complexity as well as extend functionality to word problems in scientific courses involving their respective concepts.

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Promoting Personalized Learning: The Effectiveness of Peer Teaching Pedagogy

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***Abstract*—Student-centered learning is gaining traction in India's education landscape, but the potential of Peer Teaching remains largely untapped. Involve Learning Solutions Foundation promotes peer-based pedagogies to tailor education to individual needs, enhancing outcomes, engagement, and student ownership of learning. This study investigates the effectiveness of Peer Teaching in fostering personalized learning and improving students' foundational numeracy skills. The research employs cross-age Peer Teaching, with senior students (Student Leaders) instructing small groups of junior Learners. It addresses two key questions: a) Does Peer Teaching impact students' learning outcomes? b) How does Peer Teaching adapt to student learning? Standardized numeracy assessments and classroom observations are used for data collection. Quantitative analysis shows that students involved in the year-long Peer Teaching program make significant improvements in end-line assessments. There's a strong correlation between the number of Peer Teaching hours and score improvements. Classroom observations reveal that Peer Teaching offers personalized instruction, immediate feedback, social interaction, and adaptive skills development. Particularly in government schools with large classes and diverse students, Peer Teaching adapts to language and cultural contexts, reducing learning gaps and aiding teachers in introducing new concepts. This study sheds light on the personalized learning potential of Peer Teaching in India, substantiating its ability to enhance learning outcomes and holistic student development. However, further exploration is needed to create peer-based online platforms prioritizing student-centered education. The study paves the way for developing such platforms, addressing the demand for effective and student-centric educational technologies.**

***Index Terms*—Peer Learning, Pedagogy, and Foundational Numeracy**

I. Introduction

Involve Learning Solutions Foundation (henceforth referred to as Involve) is a non-profit organization based in Bengaluru, India. Involve works with government schools and communities, creating Peer Teaching/ learning spaces towards building Foundational Literacy and Numeracy (FLN) in students. It also creates opportunities for students to build skills like communication, collaboration, problem solving through participation in the Peer Teaching program. In India almost 200 million students' study in government schools. Data from the Annual Status of Education Report, 2018 and the Learning Loss During the Pandemic by Azim Premji University, 2021 have found that 48% 5th graders cannot do basic reading and Maths [1] and that during the pandemic 80% students lost at least one language and mathematical ability [2]. These learning gaps are exaggerated by teacher shortages and multi-grade multi-level classrooms leading to students not receiving enough personalized attention to significantly shift their learning levels [3]. Involve designed a Peer Teaching program that addresses these challenges by creating shared ownership of learning between the teacher and students themselves. In the Peer Teaching program, students from senior grades (grades 7-8) are selected as Student Leaders and paired with 4-5 Learners from grades 3-8. These Leaders teach their Learners for 40-minute classes, 3-4 days a week. The students teach using content that is designed specifically for the purpose of Peer Teaching and Learning, which includes activities, games and student-friendly worksheets. Since 2018, over 20,000 students have participated in Involves Peer Teaching program. This study is an attempt to understand what type of influence the Peer Teaching program has on student learning outcomes and student engagement in learning. It hopes to provide evidence and advocate for the use of more peer based pedagogies in government school classrooms in India as a potential method to address some of the aforementioned challenges that the system currently faces.

II. Literature Review

A. The sociocultural theory

Vygotsky's perspective on cognitive development highlights its social nature, emphasizing that children learn from experienced adults within their social and cultural contexts.He refers to two principles: More Knowledgeable Other (MKO) and Zone of Proximal Development (ZPD). MKO refers to a teacher, peer, or someone who has a deeper understanding of a concept than the Learner. ZPD represents the gap between what a child can accomplish independently, and what they can achieve with the guidance and encouragement of a skilled partner. Therefore, according to Vygotsky, cognitive development arises from social interaction involving guided learning where children and partners co-construct knowledge [4]. Peer Teaching is a pedagogical approach that aligns with Vygostky sociocultural theory. It emphasizes the importance of social interaction, engaging in dialogues to co-construct knowledge, and collaboration which enables learning from one another.

Peer Teaching also aligns with the concept of ZPD, as it allows Learners to support and guide their peers creating a supportive learning environment where students can develop their knowledgeable skills.

B. Student centered pedagogies

Various pedagogical techniques are used worldwide to enhance student engagement in classrooms. Flipped learning involves students acquiring subject knowledge outside of class and allowing in-class time for problem-solving and peer interaction [5]. Project-based learning engages students in complex projects, fostering independent work and realistic outcomes. [6]. Cooperative learning promotes peer collaboration, either formally or informally, to achieve shared objectives [7]. Brainstorming encourages active participation and the generation of innovative ideas [8]. Gamification introduces game elements to educational settings, increasing engagement and personalized learning [9]. All these approaches create a collaborative learning environment, enhancing student engagement & promoting active learning experiences. Collaborative learning (CL) is an approach in which individuals work together in groups, respecting each other's abilities & contributions [10]. It is widely used in education, involving grouping & pairing students of different performance levels to achieve shared learning goals [11]. CL offers social benefits by establishing a support system and fostering diversity and understanding. It also provides psychological benefits by boosting self-esteem, reducing anxiety, and cultivating a positive attitude towards the facilitator. Academically, CL promotes critical thinking & active student engagement, improved classroom results, problem-solving modeling, personalized classes, and various teaching & assessment techniques [10].

C. Peer Teaching & its outcomes

Peer Teaching is a form of collaborative learning where students collaborate with their peers to achieve meaningful learning experiences. Various forms of Peer Teaching include same-age peer tutoring, cross-age peer tutoring, class-wide peer tutoring, and reciprocal peer tutoring. Same-age peer tutoring pairs students of similar or different skill levels, while cross-age peer tutoring involves older students teaching younger ones. Class-wide peer tutoring involves grouping students of varying proficiency levels, and reciprocal peer tutoring involves taking turns as tutors and tutees [12]. Peer tutoring has benefits in academic, social, and personal development, expanding knowledge, developing skills, fostering friendships, and building confidence [13]. Peer-assisted learning (PAL) has been shown to have a positive impact on students' academic performance. In a study with a population of 154 first-grade students, PAL was found to improve mathematical development. The group participating in PAL showed an average improvement in achievement of 18.86, compared to 16.37 in the non-PAL group [14]. Michale Parkinson did a similar study in enhancing student performance in mathematics and chemistry among first-year biotechnology students [15]. Another study by [16] investigated the impact of PAL on academic performance in specific subjects in their research. These studies provide evidence of the positive effects of PAL on students' marks and academic performance, highlighting its potential as an effective learning approach. However, the literature is lack studies conducted in non-Western contexts, particularly among school students and within the Indian context.

Significance of the study: Studies around the world have shown Peer Teaching and learning to be effective in improving learning outcomes, bridging learning gaps and building student confidence. The pandemic has further increased the need and urgency to adopt such innovative methods to bridge the widening learning gaps among our young Learners. Recently in India, this pedagogy has found mention in the New Education Policy 2020 [3]. Under the section on Foundational Literacy and Numeracy, the policy advocates for the use of Peer Tutoring as a method to improve both Learner and tutor levels. However, there is a lack of evidence on Peer Teaching pedagogy technique in Indian cultural context. Also, most of the research studies on Peer Teaching have focused on high-school or university students. Hence, considering the mention of the pedagogy in the Indian education policy, and to eliminate the literature gap of this study in the Indian context, this study is highly significant for the time.

III. Research Questions and Methodology

The study was conducted over a timeline of one year, from July 2022 to February 2023. During this period, assessment data, and classroom observations were collected from students and classrooms at different stages of the program..

A. RQ1: Is Peer Teaching associated with changes in students' learning outcomes?

1) Study Design: This research employed a quasi-experimental research design to investigate the research question. Four schools with similar characteristics, i.e. a semi-urban nature, student population, student-teacher ratio, infrastructure, and other school resources, were selected. Two of these schools were the experimental group, where Involves Peer Teaching program on foundational numeracy was being implemented. The other two schools formed the control group, where no Peer Teaching program was introduced. The researchers conducted a baseline test in both groups to assess the numeracy level of the students before the intervention of the program. Following the program intervention at the end of the year, an endline test was conducted in both groups using the same set of questions to assess the numeracy level.Of note, this paper focused only on numeracy (and not literacy) for two key reasons, a) the Peer Teaching program had been implemented for improve student learning outcomes for numeracy and a robust program design for literacy had not yet been defined and b) numeracy outcomes have more standardized tools for monitoring and evaluation therefore making the study design easier to implement.

2) Population & Sample: The target population for this study includes the students in the schools of the Anekal block. The sample frame consists of students from grade 3rd to grade 8th in the selected four schools. The sample size for the study was determined as 60 through random selection of children from multiple grades.

3) Data Collection Instruments: A standardized numeracy assessment paper was used as the data collection instrument due to the quantitative nature of the data to be collected. The paper consisted of 12 questions that assessed the students' basic foundational knowledge in numeracy skills. Inspired by the ASER test format, the assessment questions led students through a progression, starting with numerical problems transitioning to pictorial problems and advancing to intricate word problems. Baseline assessments were collected in the month of July-August and the endline assessments were collected in the month of February.

4) Data analysis technique: The assessment was conducted on pen and paper. The answer sheets were corrected by Involve staff, who then recorded the scores onto Google Sheets. The data was filtered to remove any duplications of students. For maintaining the quality of data, the study only considered student data where both baseline and endline scores of the student were collected. Data was analyzed using GraphPad Prism version 9.5.1 for Windows, GraphPad Software, San Diego, California USA, www.graphpad.com. Details of the statistical tests are presented in the results section of the paper.

B. RQ2: How does Peer Teaching pedagogy personalize and adapt to student learning?

1) Study Design: A comparative study design was employed to observe and analyze the prominent classroom interaction patterns, factors influencing student participation, and non-participation in Mathematics classrooms led by a teacher compared to a Student Leader in a Peer Teaching circle. The classroom observation focused on the following variables in both classroom settings: Ownership taken by the facilitator, Student engagement with the learning content, Collaboration with facilitator and peers, Learning progression, Learners asking questions, Student participation in the class, Instructions & feedback provided, Classroom energy.

2) Sample Selection:: A stratified sampling technique was used to select the sample for observation, ensuring representation from all grade levels between 4th and 7th standard. Four random peer groups with diverse populations were selected from each school. From these peer groups, a larger population of students belonging to the same class was chosen for observation. The sample size for observation was 33, and the same students were observed during their teacher-led Mathematics classroom and Peer Teaching Mathematics classes during the months of December and January

3) Observation Protocol: A structured observation protocol designed for the study was used to conduct the classroom observations. The protocol captured the variables of interest and facilitated a focused comparison between the regular and Peer Teaching classrooms. Each observation session encompassed a full class period of 40-50 minutes in accordance with the school timetables. Each observer observed a group of two to three students at a time. To increase reliability and reduce possibilities of bias, the same students were observed by a second observer within a one-week interval.

4) Data Collection Method: Trained observers conducted the classroom observations to assess the variables. Prior to data collection, observers underwent a training program, including trial classroom observations and debrief sessions. During training, observers familiarized themselves with the research study objectives, observation protocol, data collection techniques, and ethics. Observations were recorded by taking written notes.

5) Data Analysis Process: The recorded observations were transcribed and analyzed using qualitative coding techniques. The data were systematically coded to identify recurring themes, patterns, and differences in teaching patterns and student behaviors between the regular classroom and Peer Teaching class. The coded data were then subjected to thematic analysis to generate insights and identify key findings related to student engagement.

IV. Findings and Analysis from Numeracy Assessments

The findings in this section are based on the numeracy assessment of students. The assessment was conducted once at the beginning of the academic year (baseline) and then at the end of the year-long program (endline). Due to the nature of school schedules, not all students who were present during baseline may have been present during endline. In order to ensure high quality of data the study only considered those students for analysis where both baseline and endline data was available. Figure 1 shows the delta (percentage scored on endline - percentage scored on baseline) score of students who participated in the Peer Teaching program compared to students who did not participate in the program. Students in the sample were from grades 3-8. The distribution of students across grades categories in each group is provided in Table I. As illustrated in Figure 1, the study found that students who participated in the year-long Peer Teaching program performed significantly better at Numeracy assessments compared to students who did not participate in the program. While it is challenging to attribute causality using this data, the correlation between participation in Peer Teaching and improvement in academic scores is evident through it. The Study then analyzed student endline data from all our schools where the Peer Teaching program was conducted. After filtering we were able to analyze the data of 988 students from 27 schools (including 2 schools where 0 Peer Teaching classes were conducted; control group). Government schools often face the challenge of unforeseen changes in timetables, school closures, unplanned events, visits etc. This leads to changes in school and student schedules. Involves' Peer Teaching program was designed to be conducted 3 days per week (40 minutes per day), but due to the above-mentioned factors, there was significant variability in the number of classes across schools. This

TABLE I
GRADE WISE DISTRIBUTION OF NUMBER OF STUDENTS WHOSE DATA WAS COLLECTED FOR OUR ANALYSIS FROM BOTH PEER-TEACHING (P.T.) CLASS AND NON PEER-TEACHING CLASSES.

Grades	Non P.T. class	P.T. class
Primary (3-5)	31	34
Upper Primary (6-8)	26	21

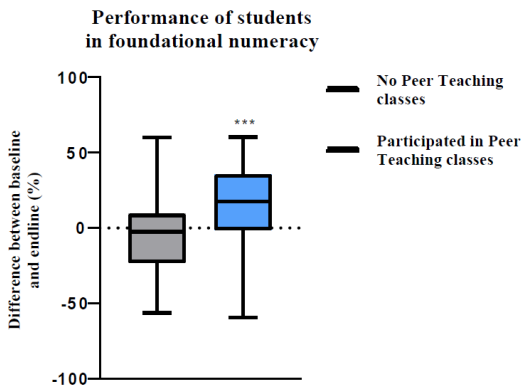

Fig. 1. Comparison of numeracy scores of students who participated in Peer Teaching classes over the year and students who did not. We analyzed the difference between baseline and endline scores of the students on a standardized assessment. The Y-axis represents the delta of the scores. The average change in students who did not participate in Peer Teaching was -4.05% while the difference for students who participated in Peer Teaching program was +15.25%. This difference was found to be statistically different using a One-way ANOVA, p-value < 0.0001 n=57 and 54 for the 2 groups respectively

variability provided a unique opportunity for the researcher to study the impact of the number of Peer Teaching classes on the student outcomes. For this we collected student data from 27 schools where Involves' Peer Teaching program was being executed. We plotted the endline data of students from each of these schools against the number of Peer Teaching classes for that school (as shown in Figure 2), and conducted a simple regression analysis on the data. While the missing data points and high variability does not provide the most accurate fit (R2 = 0.03730), the positive slope (+0.08730) of the fit point towards a positive correlation between the number of Peer Teaching classes and the endline scores of students. Both these data indicate that the Peer Teaching classes (in addition to the regular classroom teaching) are effective in improving student learning outcomes for numeracy. The reason for this could be related to the personalized nature of the program, where the senior students are able to tailor instructions and support for their Learners based on their previous understanding. Classroom observations discussed in the upcoming sections, provide some explanations on why Peer Teaching appears to be a useful tool to improve student learning outcomes.

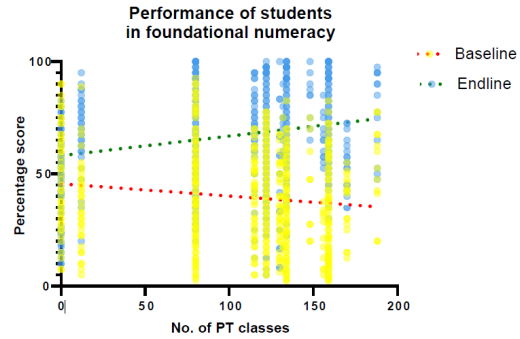

Fig. 2. We analyzed student scores (baseline and endline) in relation to the number of Peer Teaching classes attended by the student. Each point on the graph represents an individual student. We ran a Simple Linear Regression to study the correlation between student scores and the number of classes. The slope (+0.08730) of the fit of the endline data (in blue) indicates a positive correlation between the student scores on the endline and the number of Peer Teaching classes attended by them. n=988 students

V. FINDINGS AND ANALYSIS FROM CLASSROOM OBSERVATIONS

The findings in this section were analyzed based on the themes noted from the Peer Teaching classroom observation focusing on the possibilities of personalization of learning in peer led learning spaces. Classroom observations demonstrated that Peer Teaching environments provide personalized instructions, responsiveness to student needs, room for immediate feedback, social interaction & the development of adaptive skills in students.

A. Responsiveness to student needs creating a supportive learning environment

The Student Leader demonstrated a deep understanding of their peers' abilities, preferences and feelings during the class and utilized this knowledge to provide needed support for them.

> *Anecdote 1:* In the middle of one of the classes, the Learners seem to be distracted, and not interested in learning. Sensing the boredom the students felt with the content and the session, the Leader asked them to close their books and made them do a small movement activity for a while. After this short activity, the Learners were found to be more focused on the content.

Government schools commonly have students coming from other parts of the country who are unfamiliar with the local language (Kannada). After explaining the topic in general to all the Learners, Student Leaders sit with these Learners individually and explain the problem or activity helping them to read, understand Kannada and solve the Maths problem.

B. Providing contextualized examples relatable to students

Student Leaders incorporated additional examples out of their guide book to help the Learners understand the Maths concepts.

Anecdote 2: While teaching the topic of subtraction the Leader explained the concept using stones as chocolates, "You have 5 chocolates in your hands, I took 2 chocolates from it. How many do you have in your hands now?" In another class while teaching division, the Leader explained the concept by bringing the example of land division and drawing them on the floor, "A mother has 4 children , they have 2 (pieces of) land, then how can it be divided among all?"

Using such local examples the content became more meaningful and relevant to the students.

C. Personalized instructions and feedback give customized learning experience

From the observations it was evident that personalized instructions played a major role in promoting individualized learning experiences for the student Learners. Student Leaders were seen adopting various strategies to personalize the instructions including providing extra questions to students facing difficulty in specific topics, reducing the pace of teaching on topics based on students' progression, taking extra time to help students who found learning hard, and pairing the students with their peers for support.

Anecdote 3: Ajay, a learner, was having a hard time understanding a Math activity. The Leader sat with him and explained the activity slowly with patience and did the activity with him while other Learners were paired in groups to do the same.

In most of the classes it was observed that in addition to the practice and revision questions given in the Leader guide book, the Leaders made question papers personalized to their Learner group levels and conducted formative assessment model tests in between the sessions. The Leader also gave new problems to the students who completed the problems in their workbook earlier.

D. Peer Teaching through personalized instruction promote collaboration and social skills

Collaboration is the key to an engaging classroom. In the Peer Teaching classes it was observed that the Learners after completing their work voluntarily help their peers who are facing difficulties in solving the problem, without the Leader assigning them. In one of the classes, two Learners were observed helping their peers in the group multiple times to solve the problem. They voluntarily engage in this, when they see their Leader busy and engaged in helping someone else. In multiple classes the Learners were also observed seeking help from their peers when challenged by any questions. Student Leader and Learner collaboration was also observed in classes. The Leader explained a problem to the Learners and asked two of the Learners to volunteer and explain the next problem to the group. This allowed the Leader to assess understanding and encourage the participation of the Learners, who are eager to collaborate and volunteer. It was observed in the Peer Teaching class students asked questions to Leaders in the form of doubts, significantly more times they asked doubts to their teachers in their Maths class. Similarly, peer to peer collaboration was also observed more in a Peer Teaching classroom compared to a regular classroom.

E. Peer Teaching encourages self-reflection and individual learning progression

In the Peer Teaching class, the students have their individual learning track and level of progression. In the same class while some Learners/ groups were working on basic operations, a few of the Learners who were familiar with the basics moved onto higher rigor work like word problems. In a Peer Teaching class unlike their regular Math class, they do not have to wait until all their peers finish solving the question. Having smaller groups and individual workbooks, they can move from one stage to the other within a concept/ level according to their pace of learning with support from their Student Leaders. Hence the students take ownership and actively engage in shaping their learning path.

VI. Discussion

This research focuses on the impact of Peer Teaching on students' learning outcomes and its positive influence on student engagement with the content and their peers during their learning process. Previous studies conducted in various cultural contexts have consistently shown the effectiveness of the Peer Teaching model in improving student learning outcomes. A study conducted in Israel analyzing the existing model for Peer Teaching in Tzemach school developed a model integrating Peer Teaching in any age group and subject [17]. However, there is a lack of research on Peer Teaching, specifically in school-age students and the Indian context. This pioneering study aims to fill the gap by validating the benefits of peer-based learning in enhancing student learning outcomes in India. The research examines the effect of the Peer Teaching program implemented in Maths classes by Involve. The findings indicate that the Peer Teaching program increased students' academic scores, and created an environment where peer Learners actively assist their struggling peers, proactively seek assistance from peers, tackle complex Maths problems together, and exhibit increased engagement by asking questions and collaborating with peers. The study also highlights personalized learning aspects of Peer Teaching and its positive impact on student learning. In light of these findings, the discussion focuses on two interesting aspects of Peer Teaching that are mentioned as follows.

A. Peer Teaching shows positive impact on students learning outcome

Approximately 200 million students in India attend government schools. Research conducted by ASER and Azim Premji University reveals concerning statistics indicating that less than 50% of the students possess the ability to perform basic mathematical operations [1]. This shows a significant gap in the foundational skills that requires urgent attention. One

of the contributing factors to this learning gap is the shortage of teachers in government schools. With the limited resources and large student population it is challenging for the teachers to provide personalized attention to all the students. In addition to this, learning variabilities in the class further elevates the challenge as the teachers struggle to address the needs of students with varying abilities and knowledge levels at the same time. It becomes increasingly difficult for the teachers to provide personalized instruction in such a diverse classroom environment. Addressing these issues, the current solutions have centered around teacher training and development, and bringing changes in the curriculum incorporating project and activity-based content. This research study offers compelling evidence for the effectiveness of implementing Peer Teaching pedagogies as a regular teacher practice to enhance students' learning outcomes. The study shows that students who participated in a year long Peer Teaching program demonstrated significantly higher performance in numeracy assessment compared to the non-participating students. The study data also indicated a positive correlation between the number of Peer Teaching classes attended and the students' endline scores, suggesting that increased hours of Peer Teaching is correlated with the improved performance of the students. Given these findings, in addition to the other solutions, integrating Peer Teaching pedagogy into the regular classrooms emerges as an effective approach to address the aforementioned challenges and support teachers in improving student learning outcomes. Leveraging the power of peer collaboration and personalized and adaptive learning nature of Peer Teaching pedagogy it offers a great solution for enhancing educational quality and bridging the learning gap in government schools.

B. Peer Teaching pedagogy facilitates personalized and adaptive learning for students

When students take the role of facilitator in Peer Teaching, they bring a unique perspective as Learners, which is absent in an adult-led classroom. This student lens allows them to understand the challenges their peers face and appropriately respond to that feeling. Approaching teaching from a student perspective, the Student Leaders provide relevant examples and analogies of the concepts from the shared experiences that connect to the Learners' interests. Another effective aspect of Peer Teaching is the use of student language. Student Leaders communicate complex concepts using familiar terminologies that make it easier for the Learners to understand. To Vygotsky, language through interacting with others was a powerful mechanism in a child's cognitive development [4]. Receiving explanations from a more capable peer enables the less capable peer to correct the misconceptions, fill in the gap of understanding, strengthen the connection between new and previous information, and develop new problem-solving skills and knowledge [18]. Furthermore, when this language of interaction is embedded within the culture and social context of the students, it encourages the active participation of the Learners in the discussion and learning process. Thus, Peer Teaching fosters an inclusive learning environment where Learners feel more involved. The collaborative learning environment in Peer Teaching encourages students to actively participate, share their knowledge, and support their Learners. It creates a sense of belonging and builds a peer-supportive community within the learning setting. In a peer-supportive community, students can freely express their ideas, knowing their peers are there to support them with guidance and assistance. It allows them to seek clarification and collectively solve the problem. This collaborative learning dynamic fosters a sense of trust and respect among students creating an environment where they feel comfortable taking risks and making mistakes.While personalization is possible in teacher-led classrooms, factors such as high student-teacher ratios, multigrade classrooms and diverse learning needs within a classroom hinders teachers' ability to provide individualized attention and feedback. Hence, supportive peer learning spaces within the schools offer invaluable benefits to students and serve as resources for teachers that benefit both students and teachers.

VII. Limitations

Though the results of the study make a case for the use of Peer Teaching as a pedagogy towards improving student outcomes and engagement in classrooms, it does have certain limitations. The study was conducted in 4 schools of Anekal block of Bengaluru which limits the generalizability of the findings as it may not fully represent the diversity of the educational settings. Furthermore, while the study was conducted using the mixed method approach of quantitative and qualitative research, the sample size is relatively small. The study also faced limitations stemming from school holidays and student irregularity resulting in differences in sampling numbers. These differences were further pronounced as a result of the overall small sample size of the study. The qualitative nature of the study leaves room for potential biases that could influence the interpretation of the data. Based on the above limitations, we believe that conducting this study with a larger sample size, more rigorous controls and robust tools for qualitative data analysis will help us gain better insights into the potential of Peer Teaching and other collaborative learning programs in helping solve for challenges in achieving student outcomes.

VIII. Conclusion

The paper provides insights into the effectiveness of Peer Teaching pedagogy in Indian government schools. It puts forth the fact that students are often motivated and interested in learning from their peers, as it creates a relatable learning environment for them. Using the findings and evidence as a base, educators can design programs and interventions that create more opportunities for students to interact with their peers. As the role of technology in education and the opportunity that it provides increases, it will also be valuable to explore how to design student-centered technology platforms. Incorporating technology in learning spaces where students can interact with their peers, share ideas and collaborate on projects can increase

ownership, engagement, and participation. Expanding learning beyond the school premises by creating peer-led (online or offline) spaces shall enable students to share ideas, engage in conversations with like-minded peers, and collaborate on projects and questions of mutual interest. Students can utilize these spaces to raise awareness about issues such as bullying, menstrual health, girls' education, and other relevant topics. These spaces or technology platforms should be designed in a way that puts students in the driver's seat with minimal adult intervention, allowing them to brainstorm and find solutions. Peer-led technology platforms can also enhance collaboration and social learning among students. It can bring together students from different backgrounds, cultures, and geographical locations. This diversity can enrich the students' learning experiences, exposing them to wider perspectives and ideas. By leveraging the potential of technology, educators can create interactive and inclusive learning environments that enhance student educational experiences and prepare them for the digital age. However, it is crucial to prioritize cyber safety for children and consider cost-effectiveness when developing such programs. Overall, the study and its findings open a world of possibilities for those in the education (and edtech) sectors to reimagine learning to become collaborative and student-centered.

IX. Acknowledgements

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Sustaining Learner Engagement: Integrating Project-Based Learning & Cross-Cohort Approach

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***Abstract*— Effectively teaching students presents unique challenges in sustaining their engagement and promoting meaningful learning experiences. This paper presents project-based learning (PBL) employed in an 'Instructional Systems Design' course offered at the Indian Institute of Technology Bombay. Individuals with different levels of prior learning experience were brought together as a cross-cohort group in the course. The study features instructor actions and learning activities in fostering cross-cohort collaboration and engagement. Quantitative and qualitative analysis was conducted on various data sources, including survey responses, classroom observations, participation in learning activities and the final project output, to evaluate learner engagement. The learners expressed a positive perception of the cross-cohort teaching-learning approach, with 77.8% of survey participants (n=18) agreeing that they benefited from peer learning during their interactions. Content analysis of participants' responses revealed three major motivating factors for learners: teaching methodology, multi-cohort interactions and PBL. The analysis of participant involvement revealed a high level of engagement throughout the course, as evidenced by the submission of 125 entries (N=26) in a non-graded activity. The cross-cohort team successfully developed an impactful website. A significant majority (88.9%) of learners expressed agreement that the class activities associated were particularly rewarding in terms of their overall learning experience. These findings contribute to our understanding of the effectiveness and benefits of cross-cohort interactions in a higher education classroom. Moreover, the study presents an effective approach that integrates PBL and cross-cohort approach, providing implicit recommendations for instructors seeking to enhance learner engagement and involvement across diverse cohorts.**

Keywords—Project-based learning, cross-cohort interactions, learner engagement, effective teaching, higher education

I. Introduction

Effectively teaching students, especially within the context of higher education, entails specific challenges in maintaining their engagement and fostering meaningful learning experiences. In this advancing digital era, traditional teaching methods may not effectively sustain learner engagement. Literature emphasizes the importance of innovative teaching in higher education, considering the rapid developments in ideas of knowledge, the role of educational technologies, and the evolving needs of students [1, 2].

Instructors must continually adapt and develop new strategies that not only capture learner engagement but also ensure effective learning in the classroom [3]. This paper aims to present a strategy used by an instructor from the Interdisciplinary Programme in Educational Technology (IDP-ET) at the Indian Institute of Technology Bombay. While teaching an Instructional Systems Design (ISD) course, the instructor aimed at creating a balance between meaningful learning experiences and enhanced engagement. Here, we exhibit the integration of project-based learning (PBL) and cross-cohort approach, where individuals with different levels of prior learning experience from various cohorts are brought together as a cross-cohort group. Since the offering of project-based courses is common, the paper sheds light on the exploration of integrating the two approaches to enhance the learning experience.

The study goes beyond demonstrating the result findings by featuring specific actions taken by the instructor as practical suggestions for researchers and practitioners seeking to enhance learner engagement across diverse cohorts. Overall, this paper contributes to the ongoing discourse on innovative teaching practices in higher education, providing a tangible example of an instructor's approach to fostering engagement and meaningful learning experiences in an ISD course.

II. Literature Review

A. Project-Based Learning

Educators are constantly seeking methods to improve the engagement and learning of their students. PBL emerges as a promising approach that is being explored in conjunction with few other methods to foster learner engagement and transform learning into a more active student-driven experience [4]. One of the studies examined the effectiveness of using wikis for PBL in higher education across three disciplines [5]. While students mostly held a positive attitude towards the use of wikis for PBL, the level of participation on wikis varied among students of the three disciplines which was influenced by their previous learning experiences, technical backgrounds, etc. New active learning tools are also being investigated to enhance the PBL approach. A study investigated the integration of design sprint (DS) and PBL in teaching software engineering, specifically emphasizing user experience [6]. The results highlighted the positive impact of DS on student learning, emphasizing the importance of innovative techniques and prioritizing user experience in project-based software development.

B. Cross-Cohort Projects

A cross-cohort group refers to teams where the experience levels and specialities of the members are diverse [7]. Although the number of studies on the cross-cohort teaching-learning approach is limited, it is recognised that subjecting students to a cross-cohort project is one way to introduce them to a dynamic team with different knowledge and experience levels. One of the recent studies showed implementation of a cross-cohort

project in mechanical engineering where 2nd and 3rd year students collaborated on designing and analyzing a pick and place mechanism. Over half of the students (51%) had a positive impression of the cross-cohort project structure, and 85% of students considered it an effective way to apply course concepts [7]. Another article reported collaboration of academicians from diverse disciplines and multiple student teams to research and develop a note-taking tool, resulting in satisfying and thought-provoking learning experiences [8]. A similar study presented an undergraduate software engineering project where student teams from different cohorts also developed a note-taking app for academic clients at their university [9]. The study explored the benefits of student-staff collaboration, and addressed the challenges of multicultural teams with some recommendations to make the most of such projects.

In light of the existing literature that explores PBL and cross-cohort projects to an extent, our study aims to examine learner engagement on integrating the benefits of both approaches, specifically in the context of a higher education classroom. Specifically, we will investigate how instructor actions facilitate engagement of different cohorts in a project, considering their diverse knowledge and experience levels. Our study intends to enhance the understanding of the benefits and effectiveness of cross-cohort teaching-learning approach through PBL.

III. PEDAGOGICAL DESIGN

A. Goals of the Course

The ISD course was offered using the PBL approach among the cross-cohort group, with the following learning goals.

- To understand and apply the foundational concepts, principles, models, and theories that underpin effective instructional design practices.
- To apply the instructional design practices in a real-life project of creating 'Persons with Disabilities (PwD)' website for sensitizing the Institute community, while benefiting from the diverse experiences of the cross-cohort group.
- To promote learner-centered design, focusing on the needs and preferences of the target audience by seeking regular feedback from varied stakeholders.
- To understand the ethical responsibilities of instructional designers, including issues related to accessibility, copyright and data privacy, drawing on the collective experiences of the group.

By conducting the course as a cross-cohort group, the learners were provided with an opportunity to collaborate, share insights, and leverage the diverse expertise within the team to enhance the learning outcomes and the quality of the instructional materials developed.

B. Instructor Actions

The intervention focused on nurturing learners' engagement, fostering opportunities for meaningful learning and supporting a collaborative learning environment that surpassed traditional grade levels. The instructor's actions involved in this approach were categorized into three primary components, namely cultivating initial enthusiasm for the course, creation of meaningful learning activities and supporting cross-cohort collaboration and engagement (Fig. 1).

1) Cultivating initial enthusiasm for the course: This began with a strategic approach where the instructor first identified the multiple cohorts who could contribute to and benefit from the course at different levels. These cohorts, layered into 3 categories (Cohort X, Y and Z ranging from 1st year students to postdoctoral fellows) were envisioned to bring in a richness of perspectives and experiences to the learning environment. The instructor clearly defined the benefits tailored to each cohort in a powerpoint presentation and effectively communicated the same through an email to all. Through articulation of advantages in a compelling manner, participants could understand the value they would gain through the course. Equally important was respecting participants' autonomy by refraining from excessive follow-ups. The instructor provided individuals with the freedom to make their own decision to either engage or abstain from enrolling in the course.

2) Creation of meaningful learning activities: The instructor took several proactive measures to design and facilitate meaningful learning activities. The evolving interests of different cohorts were realized by providing a dedicated online writing space, which was called Homework 0 and has been elaborated further in the next subsection. Here, the participants could express their learning preferences and ensure course content relevance.

Learning activities were designed, striking a balance between the learners' interests (as identified from Homework 0) and the intended goals of the course. By incorporating elements that appealed to the participants' individual motivations, the activities were designed to be more relevant and engaging. Tasks were broken down into manageable learning objectives aligned with pedagogically appropriate learning activities. These activities encouraged critical examination and were open to diverse and valid perspectives from multiple cohorts.

3) Supporting cross-cohort collaboration and engagement: A key strategy that the instructor employed to support cross-cohort collaboration and engagement was the inclusion of a high-significance class project, inspiring a sense of purpose and commitment. The project here encompassed creation of a PwD website to sensitize others to four specific disabilities in the context of the Institute, and providing guidelines for inclusivity.

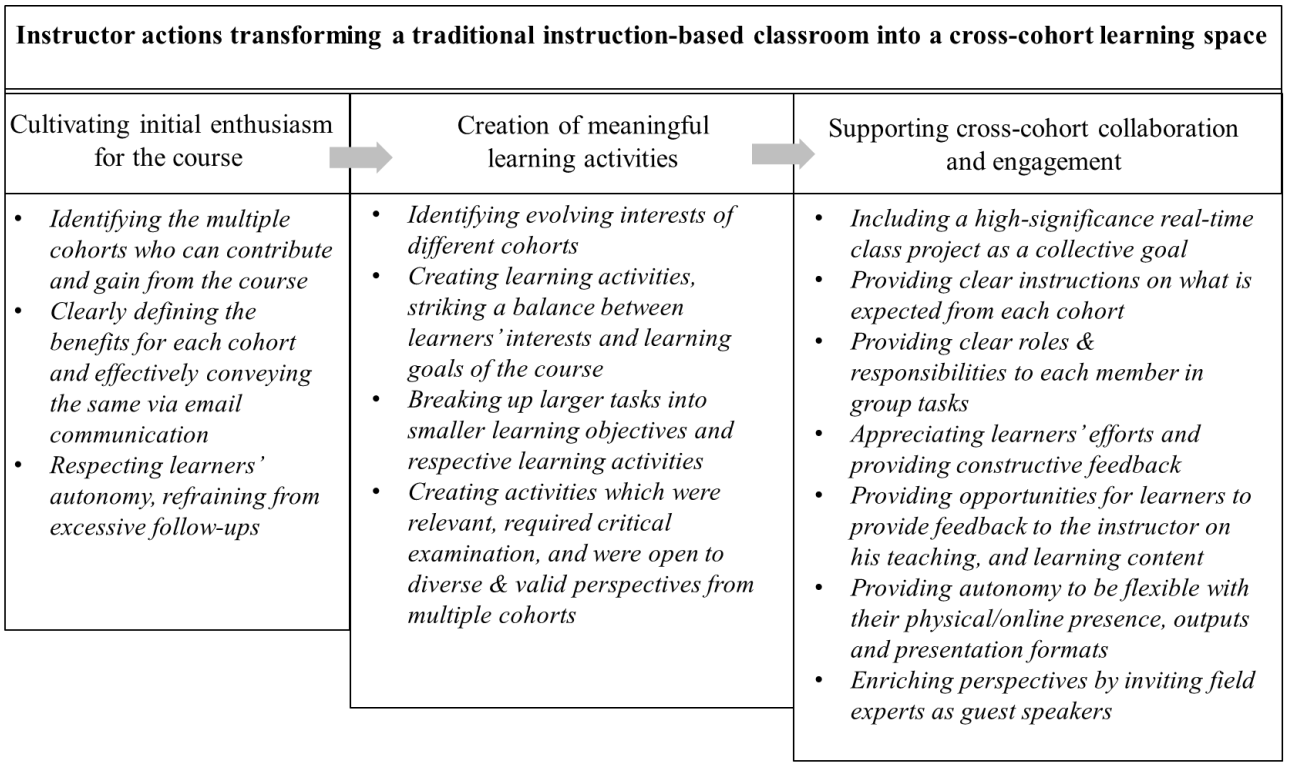

Fig. 1. The figure illustrates the instructor's actions, categorized into three primary components.

Clear instructions and expectations from each cohort kept learners focused and motivated. While assigning new learning activities, the instructor provided answers to questions, such as: How much time will it take? Why should I do this? How do I do this? What aspects should I write about? For group tasks, clear roles and responsibilities were assigned to each cohort, promoting collaboration and accountability. This structure empowered individuals to contribute meaningfully and fueled their motivation to persist. The instructor regularly appreciated learners' efforts and offered constructive feedback for improvement. Moreover, the instructor actively asked for feedback from the learners regarding his teaching methodology, and the relevance of course content through Homework 0 reflections as well as quick surveys conducted in the classroom. By valuing their input and actively incorporating their suggestions, the instructor engaged and supported learners.

The instructor also embraced flexible classroom presence, accommodating both physical and online attendance where active learning was prioritized in the hybrid mode as well. The learners had significant freedom in creating their project outputs, allowing them to explore and express ideas in unique ways. This autonomy fostered a strong sense of ownership and pride in their work, motivating them to excel. Lastly, the instructor enriched the course perspective by inviting field experts as guest speakers, who shared their knowledge and experiences, providing valuable insights and engaging learners by showcasing the real-world applications and significance of the course.

C. Learning Activities

Utilizing PBL and cross-cohort interactions in the classroom, the instructor integrated diverse learning activities to enhance the course experience.

- *Homework 0*: Throughout the duration of the course, the instructor offered participants a designated Google doc space called Homework 0. This ungraded writing activity served as an avenue for learners to express their expectations, desired learning outcomes, and provide feedback on what they liked or disliked about the course. Additionally, learners benefited from reading about others' perspectives and reflections, enhancing their overall learning experience.
- *Group activities:* To collectively achieve the goal of completing the website creation project in the course, the larger tasks were divided into smaller ones, and assigned to multiple cross-cohort groups. Group sessions were conducted during class time to brainstorm ideas, which were then implemented as assignments outside of the class hours. Each group, with 5-6 learners, was a mix of expertise, including Cohort X, Y and X which fostered a dynamic exchange of fresh ideas and experience, benefiting all participants involved. In these group activities, distinct roles were assigned to each cohort. Cohort Z (senior cohort) contributed their valuable experience and expertise, offering guidance and insights without aggressively imposing their ideas. Cohort X (junior cohort) brought a fresh perspective and innovative ideas to the table, offering creativity and novel approaches. Cohort Y (mid-level cohort) contributed a balanced mix by combining their experience with actively assisting Cohort X in exploring proposed techniques, fostering a collaborative and stimulating environment within the group.
- *Constructive discussions:* The instructor employed a range of active learning strategies, including

think-pair-share, each one say one, reflection exercises, debates, etc. to cultivate constructive discussions in the classroom. An example of such an activity was "Pin the Instructor" which was an optional learning exercise. Participants from Cohort X and Y were encouraged to trap the instructor in a contradiction by posing challenging questions related to the course content. Cohort Z, on the other hand, was tasked with helping the instructor navigate and address these traps during class discussions. The activity, which led to significant discussions and learning in the classroom, was conducted just before the mid-semester examination with an intention to serve as a revision opportunity for learners to revisit the course content. Such discussions also facilitated the incorporation of diverse perspectives, coming in from multiple cohorts, when making project decisions, resulting in rich and valuable learning experiences.

- *Presentations and feedback:* Groups presented their respective work in the class at every project milestone. Cohort X was assigned the responsibility of delivering the presentation on behalf of the cross-cohort group, aimed at enhancing their presentation skills and fostering their ability to seek feedback and respond to questions. These sessions were scheduled at regular intervals throughout the course to share their progress on different aspects, such as instructional materials, initial drafts of the web page structure, findings from usability studies, and other relevant milestones. This allowed for a valuable exchange of ideas, where the group received feedback and suggestions from both their peers and the instructor. The cross-cohort groups were able to provide feedback to teams beyond their own, fostering a collaborative learning environment. Hence, the sessions facilitated constructive criticism, offered suggestions for improvement, and encouraged the exchange of varied viewpoints.

IV. METHODS

A. Research Question

The aim of this study was to create an engaging learning experience through PBL among a cross-cohort learner group, transcending hierarchical boundaries. Thus, the following research question was investigated in this study: How does the instructor's pedagogical design support effective integration of PBL and cross-cohort teaching-learning approach to engage diverse cohorts?

B. Participants

The ISD course was offered as a credit course in the IDP-ET for all first year students in Spring (January-April) 2023. However, the course was also participated by other cohorts playing different primary roles in the course (Table 1). There were 8 first year MTech and PhD students (Cohort X), 12 PhD students from 2-4th year (Cohort Y), and 6 learners including 5th year PhD students and postdoctoral researchers (Cohort Z).

TABLE 1: COHORT PARTICIPATION IN ISD COURSE

Cohort	Participant Information	Primary Roles
X (n=8)	Ist year MTech & PhD students	Learning technical concepts and exploring new ideas through application of disciplinary practices
Y (n=12)	2-4th year PhD students	Supporting Cohort X in application of idea through their previous knowledge
Z (n=6)	5th year PhD students & postdoctoral researchers	Mentoring the group and providing directions to think about without thrusting their own ideas

C. Data Sources and Data Analysis

The data sources of this research came from a survey questionnaire administered in the classroom to evaluate engagement, classroom observations, and the analysis of Homework 0 and final project output created by learners (Table 2).

To design the survey questionnaire, we reflected on the purpose of our research, and focused questions towards understanding learners' engagement and experience in the course. There were a mix of questions (five multiple-choice and six open-ended questions) related to general interest in the class, class activities, project work and cross-cohort interactions. The multiple-choice questions (MCQs) were evaluated on a 5-point Likert scale followed by an open-ended question on each of them. To illustrate, some of the questions that were a part of the survey were:

- I look forward to attending the ISD class (MCQ). Please provide evidence or reasons to support your answer.
- I find the class activities rewarding in terms of experience (MCQ). Please provide evidence or reasons to support your answer.
- I am learning from others during cross-cohort interactions (MCQ). How is this interaction mechanism different (better/worse) than interacting with your own classmates?

The study used two types of data analysis: quantitative and qualitative. The quantitative data was examined by performing frequency analysis of data from the Likert scale to yield percentages. Qualitative data analysis was conducted on the responses collected from the participants to examine their engagement with the course. Inductive thematic analysis [10] was conducted to understand their perceptions, involving open coding and subsequent frequency analysis of categorized responses. The analysis involved identifying the emerging themes and patterns from the data without pre-established categories. The study also utilized classroom observations to monitor a few key aspects. Specifically, the classroom observation protocol was limited to identifying the specific cohort of the learner, tracking daily participant attendance, as well as monitoring their consistent entries and active engagement in Homework 0 space. Furthermore, Homework 0 analysis of reflections was performed to evaluate their level of engagement with the task.

A wide range of stakeholders, including students, faculty members and external organizations with expertise in the field of PwD, were invited to provide feedback on the project outcome. An in-depth analysis was conducted to evaluate the project output, considering user experience studies, audience relevance and stakeholder feedback to gain valuable insights on the quality and its alignment with the project goals.

TABLE 2: DATA SOURCES FOR EXAMINED FACTORS

Data Sources	Factors Examined
Classroom observation Survey questionnaire	Cross-Cohort Learning Benefits
Classroom observation Survey questionnaire Homework 0 analysis	Participant Perspective and Involvement
Final project analysis	Project Outcome

V. RESULTS

A. Cross-Cohort Learning Benefits

The course (N=26) had a mandate for only 8 first year students; however, the proposed cross-cohort approach enthused 18 (69%) learners from other cohorts to commit to the course. 77.8% of the survey participants (n=18) agreed that they learnt significantly from others during their cross-cohort interactions. Below are some examples of responses obtained from participants representing Cohorts X, Y, and Z, highlighting the benefits of cross-cohort learning in the course.

- *Cohort X: "Interactions in ISD class include senior students, postdocs and the instructor. Their contributions to the discussions are always enriching. Discussions with classmates are of course fruitful but such cross-cohort discussion leads to more learning."*
- *Cohort Y: "It brings specific dialogues or conversations from different places and time (courses that were attended in different years or projects where I did not participate)."*
- *Cohort Z: "For me interacting with juniors has always been useful, they ask questions that make me reflect on my prior knowledge more deeply."*

B. Participant Perspective and Involvement

Despite the absence of an attendance policy, the classroom witnessed a minimum of 80% (N=26) attendance in all classes. Content analysis of participants' responses identified four distinct categories of factors that motivated their participation and engagement in every class. Fig. 2 displays the frequency distribution for each category. To provide insights into the learners' perspectives, below are the definitions of the emerged themes along with examples of learner quotes for each category.

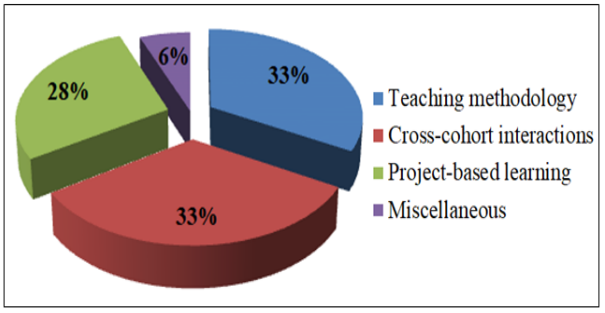

Fig. 2. Factors that helped sustain learner engagement in the course.

1) Teaching methodology: The responses (33%) regarding teaching methodology indicated explicit mention of the approach and strategies employed by the instructor to introduce new concepts, facilitate discussions, orchestrate class activities in order to shape the learning path.

"I am interested to know how the understanding of concepts in the class will shape the training module. How is the lecture designed for the day e.g. what activities, what sort of discussions among students, etc. Homework 0 is discussed in the class in some form either as a muddy point or some activity. This leads to deeper reflections."

2) Cross-cohort interactions: The responses (33%) regarding cross-cohort interactions referred to the dynamic and engaging discussions, non-formal structure that characterize the learning environment, and how it helped in meaningful exchange of diverse perspectives.

"Helps me notice shared assumptions and conceptions about loosely defined terms and have real-world contextual discussions. Also because of the diversity in opinions and perspectives, and the space allowing for free flowing expression/engagement."

3) Project-based learning: The responses (28%) regarding PBL referred to the interesting and challenging nature of the class project.

"It is lively. Project is interesting and challenging."

4) Miscellaneous: The miscellaneous responses referred to random comments, such as credit, that did not align with any specific theme.

The analysis of participant involvement in learning activities revealed that the non-graded Homework 0, designed to encourage post-class reflection, witnessed high engagement. This was evident through the active participation of 26 learners, who collectively submitted 125 reflection entries throughout the course period. Moreover, the considerable word count of 26,999 within these entries indicated the participants' motivation to express thoughtful reflections, emphasizing their engagement with the course. To exemplify the profound extent of introspective reflections from Cohort X, two learner quotes have been presented below.

"I liked how a lot of different instructional strategies like writing down our reflections alongside in the slides itself and discussing their significance, Think-Pair-Share, pointing out to the need for writing down our thoughts to reduce cognitive load, etc. were used in the ISD class itself. Besides, the use of an inductive approach, that is letting us

write an instructional plan first and only in the end introducing the corresponding ADDIE model was very useful to actually understand the model and not just remember its steps in a row. So I just felt that we were actually able to observe and feel the use/implementation of different ISD strategies during the class instructional process only."

"One can be mindful of the learning objectives during the class by being aware of the 'hat' they are wearing. Interactions with Prof. Swati Pal highlighted an important aspect regarding the project goals, which was the temporal aspect, i.e. short and long term goals (or goals that can be implemented in the near future vs. long term goals). While brainstorming on the solutions, the form of the solution is also an important factor, in the context of Instructional Design, it can be either a series of videos, posters, websites, etc. Receiving critique on ideas at a nascent stage is a new experience."

As evident above, learners actively engaged in post-class reflection, not merely as a task but as a transformative learning experience. Their thoughtful entries in non-graded Homework 0 revealed a journey of self-discovery and understanding. The terms 'observe' and 'feel,' used by learners, encapsulate this introspective process, allowing them to bridge theory and practice, gaining profound insight into the process of instructional design. This experience deepened their understanding and elevated their engagement with the course, highlighting the effectiveness of the instructor's pedagogical approach. Moreover, as evident through the second quote, this introspective approach encouraged students to be mindful of the learning objectives and the various roles they play in the learning process.

C. *Project Outcome*

One of the learning goals of the ISD course was to apply the instructional design principles to create a PwD website for sensitizing the Institute community. The cross-cohort interactions played a crucial role in utilizing their diverse perspectives and experiences when making important decisions during the creation of this highly significant project. The course team, consisting of Cohort X, Y, and Z, collaboratively developed a website addressing the needs of PwD in the context of the Institute (https://sites.google.com/view/iitb-pwdcell-training/). This website encompassed various components, including videos, scenario-based learning activities, reflection questions with feedback, guidelines, posters, etc. (Fig. 3).

While it was important to achieve the learning goal by completing the project, equal emphasis was placed on assuring the quality of the output within a practical context. Along with the feedback received from the instructor and cross-cohort groups, the website also underwent comprehensive user studies and received valuable insights from various stakeholders to ensure its alignment with the needs and standards of the field. Besides, the project's successful completion resulted in a highly positive learning experience for the course participants. 88.9% of the survey participants (n=18) expressed agreement that the class activities associated with the project were especially rewarding for their overall learning experience. As evidence, the team created an impactful website, subsequently handed over to the PwD Cell of the Institute for further enhancements and eventual hosting on their official platform.

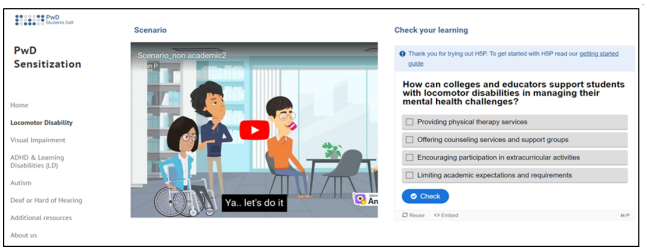

Fig. 3. A screenshot of a scenario-based learning example from the PwD website

VI. DISCUSSION

In the context of higher education, the need for innovative pedagogical approaches has become increasingly evident [1]. While the individual benefits of PBL and cross-cohort interactions are recognized, there is much less research that investigates effective integration of these strategies in the higher education classroom, and its impact on learner engagement. Literature suggests that the quality of teaching holds the greatest influence on the quality of student learning [11]; therefore, the pedagogy employed by the instructor in any new context assumes paramount importance. Based on the results, the effective integration of PBL with a cross-cohort approach was evident, resulting in high learner engagement, positive impact on their learning experiences, and the successful creation of a meaningful website for sensitizing the Institute community about PwD. In addition, the study offers practical insights for instructors aiming to enhance learner engagement and create a more inclusive and dynamic learning environment.

Learner engagement was evaluated through survey responses, classroom observations, participation in learning activities, and examination of learners' final project output. The course drew a diverse group of participants, with 69% falling in Cohort Y and Z, indicating the cross-cohort approach appeal. 77.8% of participants acknowledged learning from others through these cross-cohort interactions. Testimonials from different cohorts emphasized the role of these interactions in their learning experience. This is in agreement to a previous study which reported inter-cohort connections as an important experience for learners [8]. Participants' engagement in the course was evident through their consistent attendance in the class even without an attendance policy. Teaching methodology, cross-cohort interactions and PBL were identified as factors that helped sustain learner engagement in the course. The pedagogical design, presented here, exhibits how instructor actions can support the cross-cohort collaboration and engagement in this integrated learning approach. Active participation in non-graded Homework 0 reflected participants' motivation to express and actively engage with the course. The cross-cohort course teams successfully developed a Project website, which was subsequently handed over to the Institute for eventual hosting on their official platform.

Interestingly, pedagogical innovation is considered as a process rather than an outcome and innovative teachers as people who engage in that process [1]. Through this ISD course, the instructor engaged in one such process by combining the benefits of PBL and cross-cohort teaching-learning approach. The course enabled the learners

to apply course concepts to develop a real-life project and experience the advantages of collaborating with diverse cohorts. Our study on the widely offered ISD course contributes to the existing literature by providing empirical evidence and insights on the effectiveness of integrating these approaches, fostering collaboration, knowledge sharing, and enhancing learning outcomes among diverse learners.

At the same time, the study's limitations, such as a small sample size of 26 participants and the absence of a control group, restrict the generalization of the findings to a broader context or population. To address these limitations and advance our understanding on the topic, future research with expanded scope and a substantial sample size is warranted.

In conclusion, this study represents an important initial step in demonstrating the effectiveness of implementing PBL with a cross-cohort teaching-learning approach in the context of a higher education classroom. The findings offer valuable insights for designing future courses that prioritize engagement and impactful learning experiences for learners.

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GaMINLab – A Redesign of science inquiry simulation labs based on meaningful gamification

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***Abstract*—Practical labs in science are expected to foster disciplinary practices of "doing science" in learners. Simulation-based labs which provide the convenience of conducting practical lab experiments online offer affordances such as simulating phenomena beyond boundaries of physical labs and offering sophisticated experiences using AR/VR. Simulation-based labs, however, come with their own set of challenges such as steep learning curves, learner working in isolation, lack of personalization which may adversely affect learner engagement and motivation. OLabs is a set of simulation-based labs for schools widely used in India. The main goal of this work is to re-design simulation-based labs like OLabs to engage learners in science practices and to motivate learners to engage in science practices. Gamification is known to have positive impact on learner engagement and motivation.** *Meaningful gamification* **approach focuses on intrinsically motivating learners to find meaning in the given learning context. First, an exploratory mixed methods study was done in OLabs context to analyze the pattern of learner engagement learner perception and identify overall challenges in such labs. Second, a design for GaMINLab – Gamification (Meaningful) in Inquiry Labs is presented - which aims to a) engage learners in science disciplinary practices through simulation labs b) intrinsically motivate learners to engage these practices. GaMINLab, the proposed redesign of simulation-based labs like OLabs, was informed by the study findings and literature recommendations for fostering disciplinary practices, addressing challenges in simulation-based labs and meaningful gamification. The design features of GaMINLab are discussed and plan for validation of this design is proposed.**

Keywords—Simulation-based labs, meaningful gamification, science disciplinary practices, inquiry labs, scientific inquiry

I. Introduction

Practical labs, an integral part of the science curriculum, are expected to help learners learn science, learn about science and learn to do science [1] [2]. Learning to do science includes engaging in and developing expertise in scientific inquiry practices [1]. These lab goals have been considered important by science education researchers, scientists, accreditation bodies as well as the teaching community at large in various countries [3][4]. However, typical labs in schools are cookbook-based [2][5], designed for verification of known concepts and have procedural pedagogy[6]. Several efforts have been made in the science education research community to address these challenges and has led to the development of lab curricula and resources that emphasize science practices e.g. ISLE Labs [7].

In recent years, the use of simulation-based labs has extensively emerged and received renewed attention in pandemic when schools were closed and there was no access to physical labs. The relative advantage of such labs is facilitating learners do virtual experiments anytime, anywhere and any number of times. The pedagogical goals of simulation-based labs include modelling the behaviour of physical lab, providing variants not available in physical labs, and inculcating science practices through inquiry. These labs also offer possibilities to illustrate concepts beyond the boundaries of traditional labs, for example illustrating magnetic field intensity, lifecycle of mosquito, behaviour of pendulum on Jupiter, food digestion process, etc. Notable examples of simulation-based labs include PhET [8], WISE [9], Virtual Labs (ChemCollective) [10], GoLabz [11], Labster [12], etc.

In spite of the worldwide proliferation of simulation-based labs and their advantages, there are some limitations and criticisms. There are reported challenges such as isolation of learners from peers and teachers, steep learning curves, lack of suitable guidance, lack of personalization, focus on imitating physical phenomena than learning, having cookbook-based exercises, etc [13][14][15][16]. Effective usage of simulation-labs needs active participation from learners in intended lab tasks [17]. However, the challenges may lead to frustration among learners, resulting in early dropout or loss of motivation and engagement. Thus, it is critical to give adequate attention to engage and motivate learners to do the underlying lab related activities.

One established approach to nurture student engagement is gamification which is the use of game attributes to drive game-like player behavior in a non-game context [18]. Game-based mechanics can engage learners, motivate their actions, and help them solve problems [18]. It is reported that gamification of simulations may enhance learner engagement and their readiness to practice related activities [19]. Meaningful gamification, a type of gamification, uses game elements to intrinsically motivate participants, rather than extrinsically motivating them by giving just rewards [20]. This approach aims to have a long-term effect in engaging learners to do desired activities, as compared extrinsic motivation which are short-term and reward-driven [20].

The goal of this work is to re-design simulation-based labs to a) provide opportunities for engaging in science disciplinary practices b) engage and motivate learners as they engage in these practices. The context of this work is OLabs, which is a set of standard simulation-based labs for school level experiments in science and is widely used in India [21]. We first investigate learner challenges as they work with of OLabs. We report an exploratory study done towards these investigations, focusing on learner pattern of engagement with OLabs, learner perception and overall needs and challenges as they interact with OLabs (Section III). We then propose a re-design for simulation-based labs based on science inquiry practices and meaningful gamification. This re-design, called GaMINLab (Gamification (Meaningful) in INquiry Labs) (Section IV) is informed by a) the exploratory study findings, b) literature recommendations for fostering disciplinary practices, addressing challenges in simulation-based labs and c) meaningful gamification (Fig.1). This paper concludes with a proposal to validate the GaMINLab design (Section V).

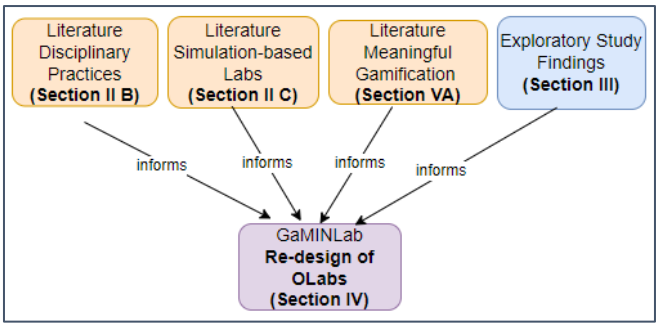

Fig. 1. Literature and Study informing design of GaMINLab (re-design of OLabs)

II. Background and Literature Review

A. OLabs in India

Researchers and practitioners have noted that lack of basic lab infrastructure, limited practice opportunities and lack of proper assessment have resulted in the unfortunate neglect of experimental work in Indian Schools [22]. OLabs [21] is a significant initiative by the government of India to address these concerns and supplement physical labs. It was initiated by Ministry of Electronics and Information Technology (MeitY), India and is supported by Ministry of Education (MoE). MoE which provides key inputs in aligning OLabs to India's National Education Policy (NEP 2020). So far OLabs has made available 273+ labs in 3 Indian languages in 5 subjects and is recommended to be used in multiple use cases such as pre or post physical labs, homework, revision, etc. Salient features are alignment to national curriculum, content authenticated by MoE, free, can be adapted by any local school board, availability in online/offline/app version. Each lab in OLabs comprises a core simulation and related sources like related theory, procedure and self-assessment. The simulation includes objects and conventions similar to those found in the corresponding physical lab. A procedure aligned with the physical lab manual is also provided. OLabs has been adopted by thousands of central government schools, private and state schools in India and lakhs of users access it on a daily basis.

In its current form there are no tasks/problems built-in to engage learners in science disciplinary practices. Learners are expected to perform a sequence of steps as prescribed in the lab manual/procedure, to complete the online lab. Considering our goal to re-design OLabs to engage learners in disciplinary practices, we will review the literature for a) recommendations for fostering science disciplinary practices b) design guidelines for simulation-based labs.

B. Disciplinary Practices

Science education is increasingly focusing on engaging learners in disciplinary practices as emphasized in global curriculum recommendations [4][3]. Disciplinary practices in science include *asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations, engaging in argument from evidence, and obtaining, evaluating, and communicating information* [6]. The practices need to be considered and adopted as practices for learning rather than single set of procedures that need to be executed [4][6].

For fostering disciplinary practices in a learning environment, literature recommended guidelines such as a) giving opportunity for direct experience with phenomena b) provide opportunity to make learners' thinking visible so that they can grapple these ideas together to construct meaning c) giving learners task with only essential procedures and relevant resources to complete the investigations [2][5][23][6]. Inquiry learning is recommended as an effective approach to learn science [24]. In scientific inquiry learners engage in the processes of sense making, discussing ideas, developing evidence-based explanations, and communicating ideas [24] and scientific inquiry ability can be developed through "doing science" via hands-on experience in a supportive environment [1].

C. Simulation-based Labs

Simulation-based labs facilitate learners to do experiments online and bridge the geographical and time constraints of doing lab activities. These also come with affordances to illustrate/provide experience for phenomena beyond boundaries of physical laboratories. The simulation-lab's exercises and supporting environment play a critical role in what kind of learning the lab may foster. However existing labs are criticized to have cook-book based exercises similar to traditional physical labs [5]. There are also other issues such as steep learning curves, learner isolation, lack of personalization in such labs [13][14][15][16]. To address these challenges literature recommends design guidelines for simulation-based labs such as a) provide opportunities for investigations in sites beyond classroom b) pose driving questions to give learners purpose to explore the lab and to draw their attention to various aspects of the lab c) incorporate implicit scaffolding d) provide opportunities to reflect on findings e) allow clarifying understanding/misunderstandings with peers and engage learners in cooperative/collaborative work [24][5][2].

III. Study

Section II-C reports the challenges and constraints in simulation-based labs as reported in literature. As an important input for re-design of OLabs, it is necessary to study the learners' challenges and needs in context of OLabs as learning is fundamentally influenced by the context in which it takes place [25]. Thus, an exploratory study was envisaged to understand simulation-based labs' challenges in context of OLabs in its current version. We used mixed methods research design in this study. In this study, answers to research questions listed below were sought:

- RQ-1 What is the pattern of engagement of learners with simulation-based labs?
- RQ-2 What is the learner perception of simulation-based labs?
- RQ-3 What are the challenges faced by learners in using simulation-based labs?

A. Method

The participants were from Class IX/X of different urban schools, following different boards of curriculum CBSE/State Board/ICSE. The study was done in an online mode due to Covid-19 restrictions. Technical requirements for this study were laptop/tablet at home with reliable internet connection. Total 8 students participated in this study. As participants of this study were minors, consent was sought from the guardian and participants. The consent forms were as per researcher's

institute ethics committee template for parental, teacher consent.

1) Lab Experiment & Materials

The laboratory experiment chosen was "simple pendulum", a Class IX physics lab from the OLabs physics subject lab set. This lab adheres to all instructional goals of OLabs. It contains a "simulation" where learners can get hands-on experience of the related experiment by manipulating the given controls and recording observations. The simulation includes variants which are not available in corresponding physical lab viz. select environment, select/change shape, material & diameter of bob, wire, pendulum length. Other components of the lab are "theory", "procedure", "animation" (usage demonstration video), viva voce (self-evaluated).

The activity sheet given to the learner contained some questions to generate curiosity among the learners. Thereafter it contained 2 guiding questions *a) Will the behaviour of a simple pendulum change if you take it to Jupiter or Mars? b) What are the factors (e.g material of the bob, length of the pendulum, mass, color, shape of the bob, atmosphere, acceleration due to gravity, etc) that affect oscillation behaviour of a simple pendulum?* The intention of providing these questions was to encourage learner to explore various aspects of lab and to direct their attention to variants available in the lab, for the lab as such does not provide any specific exercises.

2) Procedure

The study was conducted as a 1.5-hour session, divided into 4 parts: a) introduction to study (5 min), b) pre-test (15 min), c) activity using OLabs (30 min), and d) post-test + perception survey (20 min). This was followed by a one-to-one informal discussion (semi-structured interview) to gather feedback on usability and learning experience. All participants joined a Zoom meet for common session and thereafter moved to breakout room for their individual activity. The study instructor and team were available online for any assistance and each breakout room had an exclusive observer. All necessary documents were online and the relevant links were shared by instructor to individual student on completion of previous stage. During the entire study, the participants were allowed to access their science textbooks and reference books.

B. Data Sources, Instruments & Analysis

Data collected included screen and video recording of participant session, audio recording of interviews, perception survey responses and observer notes (Table-I). Perception-survey questionnaire contained questions such as *"which component(s) of OLabs did you find useful? "for which purpose(s) would you like to use OLabs?", "what was your first impression of OLabs?", "would you like to use OLabs for any other topics in science?". Interview questions were open ended questions such as "can you give an account of how you did the activity?","what difficulties did you face in this study,"* etc. Notes were maintained by the researchers that contained observations recorded during the live session.

To identify pattern of engagement, 7 participants screen recording during the activity was manually analysed to record - a) number and type of input variants used and b) number and type of other components like core lab tools and support tools were used. Time spent by each participant for the entire activity as well as time spent interacting with the "simulation" were recorded. Observer notes were analysed to find reference to any pattern observed while the learner engaged with simulation. For perception on OLabs, the perception survey responses were processed and triangulated with interview questions. For learner challenges, observer notes were analysed to identify pattern of accessing the lab, queries asked, interventions required by instructors, learner difficulty while using any component of OLabs. Interview transcripts were coded to identify challenges reported by participants in questions related to difficulties faced", "aspects learners did not like in the lab". Screen recordings were analysed and triangulated with observer notes & interview transcripts.

TABLE I. RQS, THEORETICAL CONSTRUCTS, OPERATIONAL CONSTRUCTS AND DATA SOURCES

RQs	*Theoretical Constructs*	*Operational Constructs*	*Data Sources*
RQ1	Pattern of Engagement	Usage of variants Proportion of time spent on simulation Usage of simulation	Screen Recordings Observer notes
RQ2	Learner Perception	Preferred usage Usefulness of components Interest	Perception survey responses Interview transcripts
RQ3	Learner Challenges	Difficulties in using lab	Observation notes Screen recordings Interview transcripts

C. Findings

1) Pattern of Engagement

While leaners can learn by watching and listening, research indicates that higher achievement is associated with getting involved in a more overt manner in the simulation [2]. We operationalised engagement to proportion of time spent on the interactive simulation as compared to other textual and video content. It was measured in terms of the time spent in the simulation (i.e. the interactive part of the lab) and percentage of variants manipulated in simulation (See Fig.2 and Fig. 3). Time spent on simulation was - average: 9.14 minutes, median: 8 minutes and ranged from minimum 3 minutes to maximum of 16 minutes. We can observe that the learners spent an average 40% of 30 minutes activity time on the simulation part and 60% on other parts of the lab such as text-based theory, procedure, help video etc. There were total 6 variables available for manipulation in the given lab. On an average out of 6 only 2 variables (<50% of total variants) were manipulated by the learners. Observer notes contained excerpts related to low/no variant usage *"didn't change variable values available in lab, took all readings in default value", "changed environment value once, other values not changed", "...checked options in each dropdown box, but didn't update any".*

2) Learner Perception

The learner perception of OLabs was gathered on parameters such as preferred usage of OLabs, first impression of OLabs, most useful component of Olabs (See Fig-4). Participants mentioned "simulation" as most useful, and procedure, "viva voce" as least useful. For 87.5% of the participants the first impression of OLabs was appealing, while 12.5% of the participants felt it was frustrating. The most preferred usage of OLabs mentioned by participants is "to revise the lab activity" and "to get a feel of the lab

virtually". The least usage method preferred was mentioned as "trying out variants of the lab", this was also indicated from data that most /participants used less than 50% of the variants.

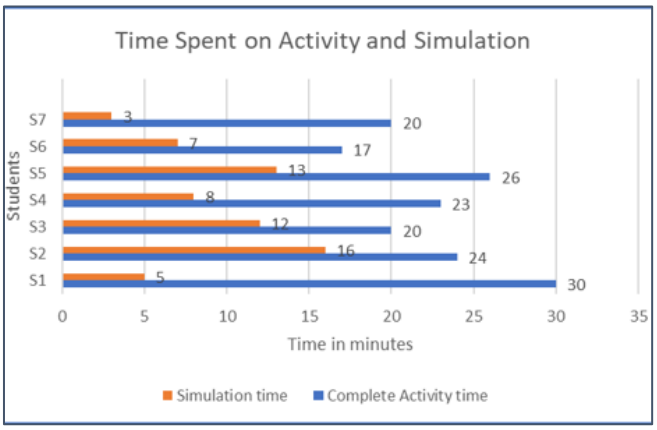

Fig. 2. Time spent on activity and simulation

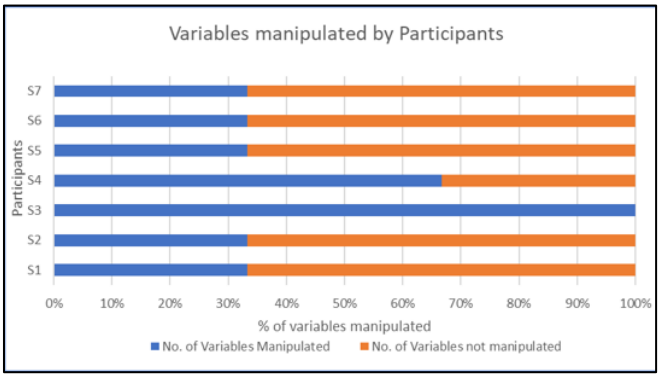

Fig. 3. % of variables manipulated

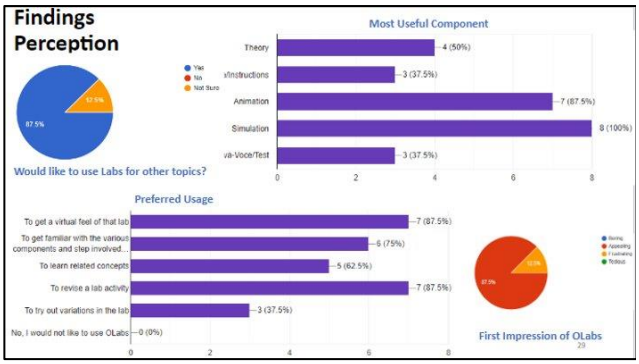

Fig. 4. Learner Perception of OLabs

3) Overall Challenges

Four main challenges have been identified:

- Difficulty in getting started. Interview excerpts - *"i didnt know at first what to do." "was confused with what is expected", observer notes – "student is not getting what to do in activity properly, … is trying but not clear about the steps"*.
- Instructor intervention needed when stuck, observer notes – *"after randomly trying out the lab, the learner sought my help on how to take readings" "intervened after the student spent lot of time struggling with placement of protractor*."
- Struggling to manipulate objects. Interview excerpts "*bob was not moving*", "*it was difficult to stop timer*"
- Difficulty in simultaneous manipulation of objects "*time synchronization was difficult*" observer notes – "*she seems to have some confusion with the timer she was trying to read the protractor readings and the number of oscillations at a few instances*"

D. Discussion

We found that there was low usage of variants despite guiding questions in activity sheet hinting them to use the variants. Trying out variants was also voted as the least preferred usage of OLabs. These two findings together indicate that learners had low motivation to use the variants. Also, the given instructions and questions were insufficient to get them to use available variants. Despite 85% of learners indicating simulation as the most useful component, the learners spent on an average only 40% of time with simulation, while 60% time was spent on reading text-based content and viewing videos related to lab. Whereas learners undoubtedly can learn by watching and listening, research indicates that higher achievement is associated with getting involved in a more overt manner in the simulation [2]. We however find in this study the low engagement of learners in the simulation workbench – low variant usage and lesser time spent with simulation than other components. Learners faced issues in getting started, despite given help in form of video, procedure and demo. Instructor help/intervention was needed when learner was stuck.

The findings confirmed challenges from literature such as lack of guidance and handholding [16] and steep learning curves [14]. A new challenge found in this context is difficulty in simultaneous manipulation of several visual objects on the screen. The important takeaways from the study for the redesign of OLabs are as follows: a) The need to motivate the learner to effectively utilize the available variants and supports in the lab while engaging them cognitively in simulation-related activities. b) The need to flatten the initial learning curve when getting started and using the simulation. c) The need to provide inline support for learners when they encounter difficulties or engage in activities, as instructors may not always be available.

IV. Design of GAMINLab

A. Theoretical Basis - Meaningful Gamification

One of the takeaways for re-design of Olabs from the study findings is the need to motivate the learners to do relevant usage of the variants/supports in the simulation. It is also critical to motivate and cognitively engage them in science inquiry activities. Apart from the literature on disciplinary practices and simulation-based labs which were discussed in Section-II, we drew from literature related to gamification, as it particularly is known to be effective to improve motivation and engagement of learners in the topic of interest [18] and hence relevant to our context. Gamification is the "application of game mechanics in a non-gaming context" [18] and involves use of elements traditionally found in games, such as narrative, rewards, conflict, etc, in non-game activities. Gamification of virtual simulations can enhance engagement and readiness for practice and hence relevant in our context [19]. Reward-based gamification, a commonly used technique involving badges, leaderboards, and points in real-world

scenarios, is often tempting due to its ease of implementation and immediate impact. [18].

Reward-based gamification which primarily leads to extrinsic motivation may not be effective for long term changes and not all learners may find it satisfactory [26] [18]. In a learning context, it's more valuable to assist users in discovering their intrinsic motivations for engaging in desired behaviour rather than solely relying on rewards.. Rather than providing rewards for desired behaviour, designers can create systems to intrinsically motivate them by fulfilling user needs, thus helping users to find their own reasons for engaging with the desired behaviour. Moving beyond reward-based gamification, the system can be designed to use gamification elements to engage learners in the exploration of narrative or storyline, to make interesting decisions, to explore different paths to solve a challenge on their own, play with other people, explore options for gaining mastery of the given topic, etc. This is the core idea behind meaningful gamification [18]. Meaningful gamification, a type of gamification, uses game design elements to help build intrinsic motivation and, therefore, meaning in non-game settings by creating a ludic learning space where participants can explore and find meaning [18][20]. Meaningful gamification derives basis from self-determination theory [26] which mentions intrinsic motivation as a construct combining competence, autonomy, and relatedness. When these three psychological needs of competence, autonomy and relatedness get fulfilled, people will find tasks meaningful and continue to participate in them.

Reference [20] proposes "RECIPE" for meaningful gamification which is operationalization of meaningful gamification concepts using six elements viz. *play, exposition, choice, engagement, information and reflection*, inspired by game design. When reordered these elements form mnemonic "RECIPE". RECIPE elements and related guidelines can be used for incorporating meaningful gamification by intrinsically motivating learners i.e. fulfilling the learner needs of autonomy, mastery and relatedness. "Play" element includes the freedom to explore and fail within boundaries. "Exposition" element recommends creating stories for participants integrated with the real-world setting in the form of meaningful narratives. "Choice" element recommends developing systems that give power to participants to choose activities or in what order they want to perform tasks or they want to work alone or in groups, etc. "Information" element recommends using game design elements to allow participants to learn more about the real-world context. This can be done via non-player characters, with embedded narrative, etc. "Engagement" element recommends creating opportunities for participants to engage with others in meaningful ways. Engaging with others can be in form of cooperation/collaboration. "Reflection" element recommends creating opportunities for participants to connect their game-related experience to their past experiences, to deepen engagement and learning. One or more of RECIPE elements can be used to meaningfully gamify a learning context. Another approach for meaningful gamification is choosing gamification elements catering to learner needs of autonomy, master and relatedness and operationalising these elements relevant to the learning context.

B. Design Features

We propose a design called GaMINLab (Gamification (Meaningful) in INquiry Labs), which represents a redesign of simulation-based labs such as OLabs. The core design features are listed below.

1) Challenges & Problem Scenarios

The learner will be given challenges in the form of problems to be solved, each categorized to different problem scenarios like a park, a museum or a beach, etc. This aligns with the literature's recommendations, which suggest providing learners with challenges to motivate them, fostering investigations that extend beyond the confines of a laboratory, and presenting real-world problems to solve instead of relying on cookbook procedures or exercises [5] [20][2]. Example of problem in park "You can perform an interesting activity when you visit a park to ride a swing, you will need a watch…compare the time period of swing in different cases…" (Fig. 5)

> You can perform an interesting activity when you visit a park to ride a swing. You will require a watch. Make the swing oscillate without anyone sitting on it. Find its time period in the same way as you did for the pendulum. Make sure that there are no jerks in the motion of the swing. Ask one of your friends to sit on the swing. Push it once and let it swing naturally. Again measure its time period. Repeat the activity with different persons sitting on the swing. Compare the time period of the swing measured in different cases. What conclusions do you draw from this activity?

Fig. 5. Sample Problem in "Problem Scenario - Park"

2) Problem Solving activities

As recommended in literature, the learners need to be given opportunities to recruit the science practices such as doing investigations, collecting observations and evidence, developing explanations based on evidence, as part of their pursuit to solving a problem [6] [24]. The GaMINLab system prompts learner for problem-solving activities which can be attempted as quest to solve the chosen problem. The problem-solving activities are adaptation of the problem-solving inquiry framework in technology enhanced classrooms [27] viz. *Identification, Exploration, Reconstruction, Presentation/Communication, Reflection & Negotiation. Exploration, Reconstruction, Presentation/Communication are broadly mapped to tasks Investigate using the Lab, Propose Answers and Predictions* and *Share and Discuss your Lab Investigation Report* (Fig. 6). *Reflection & Negotiation* related tasks are implicitly included in all the problem-solving activities.

In "Investigate using the Lab", the learner is provided access to the simulation of the lab and told to prepare an investigation plan towards solving the problem. The learner can manipulate the simulation-based lab as relevant to the investigation. and record observations. Fig.13 illustrates this activity and its components. In "Propose Answers and predictions", the learner is encouraged to propose answers to the given problem with appropriate reasoning, by referring to the initial investigation plan and the recorded observations. "Self-Assessment" is the final assessment task, the learner is expected to give the answer to the problem, articulate the reasoning for the chosen answers and also upload a final lab investigation report.

3) Simulation as a tool

The learner is provided access to specific OLabs simulation in context of solving the problem in "Investigate using the lab" (Fig. 12). Suitable permission sought from OLabs team to use simulation. The simulation is given as a tool to investigate, make predictions, etc in quest to solve the given problem. This is in line with the literature recommendation that using simulation as a tool to engage with underlying scientific principles, facilitates productive use of the simulation in given context [17]

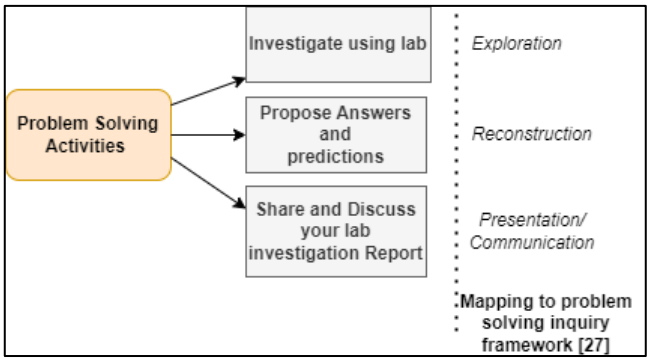

Fig. 6. Problem Solving Activities in GaMINLab

4) Artefacts

While solving the problem, learner is encouraged to prepare artefacts like investigation plan (Fig. 13), interim and final lab investigation report comprising investigation plan, observations, findings, proposed answers for the problem with reasoning, etc. This not only makes learners' thinking visible [23][6][24] but also serves as an authentic means for assessing what they did and learned while solving the problem. [2].

5) Peer Discussion & Peer Evaluation

The learner is given an option to chat with peers to discuss ideas, clarify misunderstanding regarding predictions, investigations. The learners can also share their lab investigation report with peers. Artefacts can be self, peer or teacher evaluated using given rubrics. Giving such opportunities for cooperation avoids isolation and makes learners connected to others and fulfils their needs of relatedness [20][5][2].

6) Choice of Alternate Paths

There is no predefined sequence of problem-solving activities. At every stage the system prompts the learner with options to proceed further and learner can choose any one from those options, thus making a 'choice' in strategy to solve the problem Potentially a learner can view the problem and directly jump to attempting the final assessment or go through one or more problem solving tasks or restart all over again. E.g. After reading the problem scenario the tool prompts to learner with options to proceed further *"I want to go ahead with solving the problem", "I want to get familiarized with the Lab environment"*, etc (Fig. 7 and Fig. 8). The learner can also choose the scenario of the problem and the problem itself. The system also allows to restart solving a problem and learner has freedom to choose from given paths. Alternate paths help towards fulfilling their need of autonomy in the system [20].

7) Meaningful Badges

Motivating learners to use variants and try other aspects of lab is an important need indicated by study findings. Each disciplinary task completion is acknowledged by tool in form of corresponding badge. The badge is awarded by our tool automatically on completion of tasks. The badge the learner would earn is flashed on top of the page to indicate what learner will earn on complete a stage to make learner aware of the badge that would be earned on completion of the given task. Badges Investigator-Rookie and Data analyser-Rookie will be on completion of "Investigate using Lab", Reasoner–Rookie awarded on completion of "Propose Answers & Predict", Communicator-Rookie awarded on completion of "Share and discuss your Lab Investigation Report", Collaborator-Rookie awarded on completion of "chat with peers". After "Rookie", higher levels for each type of badges will be awarded depending on number of labs for which these tasks are successfully completed. Fig. 9 illustrates some badges awarded in the system. The badges can also be given when one or more other badges are earned. These acknowledgments given in recognition to them as they are progressing towards their final goal fulfils their needs of mastery [20] and also motivates them to try further problems, and activities including variants.

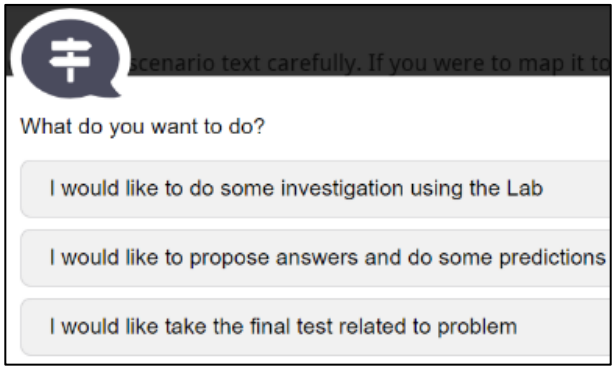

Fig. 7. Alternate Paths (solving the problem)

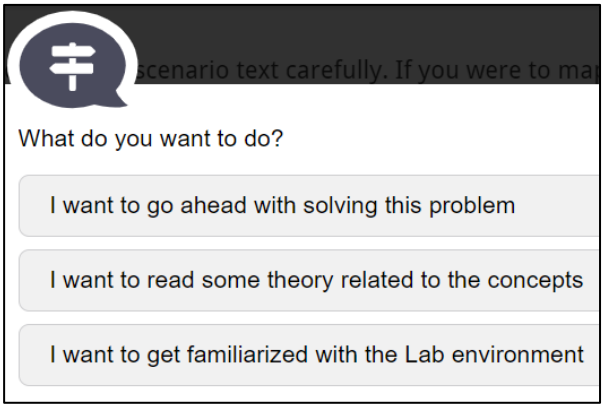

Fig. 8. Alternate paths (problem solving tasks)

Fig. 9. Badges - Investigator "Rookie" and "Pro" ; Reasoner "Rookie"

8) Lab Onboarding

Lab onboarding activities make a learner familiar with the user interface objects in the lab, lab variants, actions needed for taking observations, Activities include interactive content using hotspots, quiz and badge awards on completion (Fig.10). Onboarding tasks makes the initial use of the system less daunting (need as per the current study findings) and fulfils the learners' need towards mastery [20].

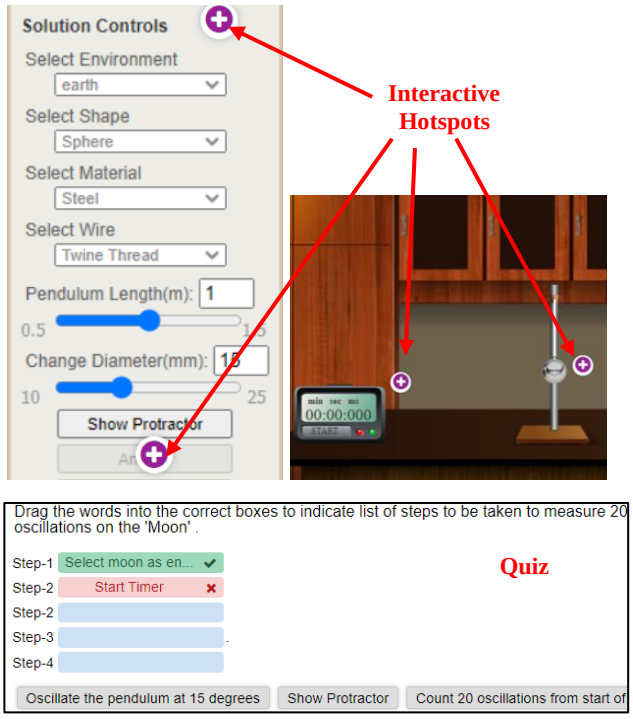

Fig. 10. Lab Onboarding tasks – Interactive hotspots and quiz

9) *Scaffolding*

The current OLabs study findings indicated the need for inline help & guidance in absence of instructor. It is recommended to scaffold the related tasks with relevant information & assistance [28][24]. In the system scaffolds are provided where the learners are preparing the investigation plan (Fig. 13) and lab investigation report. When learners choose the options from alternate paths, the system provides a brief information to indicate what can be expected in the chosen stage which will help learner decide to move ahead or retrack the action.(Fig. 11)

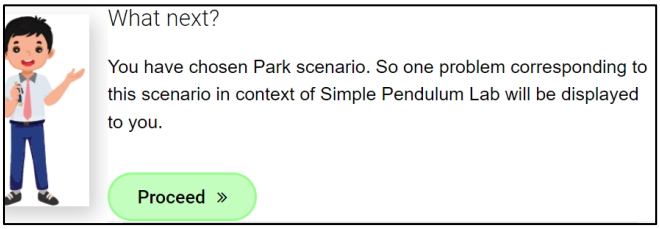

Fig. 11. Guidance about what can be expected next

V. Discussions and Future Work

The proposed system, GaMINLab, re-design of simulation-based labs like OLabs, provides opportunities for learners to engage in disciplinary practices such as planning and carrying out investigations using the simulation lab, analyzing and interpreting recorded observations, constructing explanations based on evidences (observations) in form of investigation reports, and communicating information by discussing and sharing investigation reports with peers. The OLabs simulation is included as a tool to do engage in these science inquiry practices and related tasks. Collaborating and discussing ideas addresses the need of relatedness of the learners and avoids them feeling isolated in the tasks.

The gamification elements included in GaMINLab, which aim to operationalise meaningful gamification are the real-life problem scenarios, choice of problem, scenario and problem, alternate paths to solve the problem, meaningful badges learners earn as they develop skills in the system, retry and restart, lab onboarding, etc. Making autonomous choices regarding which path to follow and which problem to solve fulfils their psychological desire to make self-determined choices, autonomy. Freedom to retry/restart lowers stake of failure, and motivates learners to resolve or continue solving problem even after failing initially. Acknowledgment in form of badges motivates them to repeatedly engage in various problem-solving activities. Lab onboarding tasks, scaffolding

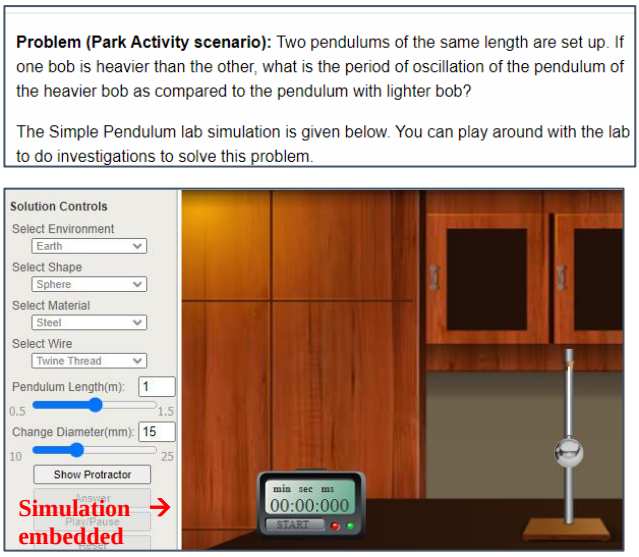

Fig. 12. Investigating using the lab - problem and embeded simulation

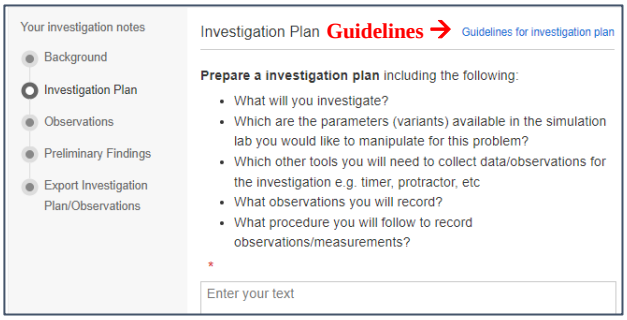

Fig. 13. Investigating using the lab – prepare investigation report

may avoid early frustration during initial encounter with lab and the system. Badges and lab onboarding fulfils the need of mastery of the learner. Thus, GaMINLab design attempts to intrinsically motivate learners (by fulfilling their needs of autonomy, mastery and relatedness) to engage in relevant science practices.

Currently GaMINLab is designed with one lab (OLabs simulation lab simple pendulum) and two problem scenarios. We plan to add one more lab and corresponding two problem scenarios. Prior to a study with learner, review will be done by teachers, edtech researchers including gamification experts in area of Education to ensure content, face and construct validity and to gather feedback on design and operationalization of game elements in our context. After incorporating feedback from teachers, researchers, a pilot study with 10-15 class IX/X participants will be planned. In this study we seek answers to questions "What is the pattern of engagement of learners while using GaMINLab?, "How motivated are the learners while engaging in GaMINLab"?,

”What is the degree of disciplinary practices reflected in artifacts produced by learners?, What is the learner perception of GaMINLab? i.e. a) How usable is the system? b) User Perception of the system. Data sources to be collected are sscreen recordings, aactivity logs, user attempt reports, interview transcripts, Observer Notes, intrinsic motivation survey responses, pre-test post-test responses, learner produced artifacts - (all revisions), badges earned, chat & forum logs, SUS responses, perception survey responses, observer notes,. Study-2 will be conducted for larger set of

learners (50-60), after incorporating suitable changes in system based on the findings of pilot study.

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Making active teachers: Effects of a teacher training program for making-based active strategies

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***Abstract*—Educational theorists have long argued for learning experiences that are personally meaningful, involve working and inquiring with physical and virtual materials, and center learners agency and their cultural resources. Therefore there is a need to shift to such making-based strategies for STEM education. In our work, we have developed toy and model making-based activities for middle school (grades 6-8) students. However, as with any technology, teachers' perceptions and self-efficacy in being able to implement these activities in their classrooms is crucial to translate the theorized learning benefits in practice. This paper reports on a research study evaluating the efficacy of a 3-day teacher professional development workshop for making-based active learning strategies. We worked with middle school science and math teachers who learned toy and model making as students would, and how to implement these activities in a classroom. Our research goal was to study shifts in teachers beliefs, intentions to adopt and perceptions regarding making-based active learning strategies. We found that there was a statistically significant change in teachers' beliefs of the purpose of science education and an increased intention to adopt making-based active learning pedagogies. We also found, through qualitative analyses, that teachers perception about making-based active learning from before to after the workshop became grounded in their experiences. Together our findings suggest that having teachers experience making-based active learning pedagogies as students first supports their intention in adopting such strategies, which could lead to a shift in STEM education in the long-term.**

***Index Terms*—teacher professional development, making-based learning, teacher adoption, teacher perception**

I. Introduction

The goals of science, technology, engineering and mathematics (STEM) education have shifted from conceptual understanding to developing skills such as critical thinking, design and scientific inquiry [1], [2]. Research suggests that learners develop skills when they work on open-ended, real-world and interdisciplinary problems. However, STEM education, including technology-enhanced learning, has maintained emphasis on conceptual understanding and closed-ended problems. Given the centering of skills in education policies such as NEP 2020, there is a need to rethink the way we teach STEM subjects, and specifically how we use technology in STEM education. Educational theorists have long argued that learning experiences should be personally meaningful and authentic to learners [3], [4], [6]. They suggest that learning experiences that involve working and inquiring with physical and virtual materials, and that center learners agency and their cultural resources accomplish this. Such experiences keep learners interested and in their zone of competence so they remain committed to the learning process [7]. Finally, making with materials helps learners develop skills such as design and inquiry [8]. Therefore there is a need to shift to making-based pedagogies for K-12 STEM education.

Towards these goals, we have developed making-based active learning strategies for middle school (grades 6-8) STEM education wherein students learn by making and experimenting with toys and models, to connect the textbook concepts to the world around them. These toys and models make use of "low tech" i.e., easily available and cheap materials coupled with activities based on learning sciences literature. However, as with any technology, teachers' perceptions and self-efficacy in being able to transact such strategies in their classrooms is crucial to translate the theorized learning benefits in practice [9], [10]. Making-based active learning strategies are especially hard to implement in classrooms, because they often contradict the goals of formal education where curriculum is primary; maker activities, on the other hand, are open ended and often lead to student failure which a teacher needs to deliberately orchestrate, they take time and require careful classroom management [11]. Teachers need extensive training to implement such strategies in their classrooms and while literature acknowledges this need, there is still a dearth of empirical research with respect to teacher training for maker-

based pedagogies in school [12].

In this work, we contribute to this space by reporting on a research study evaluating the effects of a three-day teacher training workshop for making-based active learning strategies, customized specifically for active learning with "low tech" toys and models. The training, which was based on the principles of immersing participants in making-based activities that are engaging and fun, that allow participants to experiment themselves, learn from their peers and reflect on their experiences, had the goals of shifting teachers' perceptions of the goals of science and math education towards an application-centric view, and shifting teachers' intention to adopt more making-based active learning strategies. Broadly our research questions were:

1) What is the effect of a three-day teacher professional development programs on teachers perceptions of the goals of science education, and their intention to adopt making-based active learning strategies?
2) How do the teachers perceptions of making-based active learning strategies shift after a three-day professional development programs?

Using mixed methods (surveys analysed using quantitative and qualitative methods) we found that there was a change in some aspects of teachers' perceptions of the goals of science education and an increased intention to adopt making-based active learning strategies. The open-ended responses highlight the productive nature of the shifts in teachers perceptions and we discuss implications of these findings. We begin in the next section by describing related work and literature in the space of maker teacher professional development programs.

II. Literature Review

A. Principles of Effective Teacher Professional Development Programs

Research has shown that despite the excellent quality of technology and content, its adoption can be disrupted by lack for support for teacher adoption and their beliefs regarding the technology [9]. Specifically research suggests that the relationship between beliefs and technology adoption is bidirectional, with beliefs and actions reinforcing each other. This suggests the crucial role of teacher professional development programs (PDPs) in changing teacher beliefs, and introducing technology gradually in ways that align with teachers beliefs [10]. Towards these goals literature recommends that PDPs should include features such as modeling preferred instructional strategies, engaging teachers in active learning, and building a professional learning community [13]. When teachers experience the strategies as students would and reflect on their experiences, they are able to understand the effectiveness of these strategies for students. For science PDPs research also explicitly recommends an emphasis on science content knowledge, in addition to science practices [14], [15]. Further, researchers also recommend that in order to create deep change in teachers pedagogical practices, it is important to design pedagogical materials that are adaptive, responsive, and engaging and intellectually satisfying [16]. By adaptive and responsive we mean materials that allow teachers to productively adapt the materials, be innovative in their teaching and set up practices that are responsive to students knowledge, culture and ideas. Together literature recommends the following core features of effective PDPs [17]:

- Focused on **content** and how students learn the content
- **Active learning** wherein teachers have an opportunity to get involved and experience the content as students would.
- **Coherence** with other professional development, their knowledge, beliefs and policies.
- Should include at least **20 hours** or more of contact time
- Have groups of teachers from the same grade and subject **participating together** to build an interactive professional community

B. Related Work in Teacher PDPs for Making-based Pedagogies

There is an increasing adoption of making-based pedagogies in K-12 education [18] and corresponding research on designing effective teacher PDPs specifically-focused on making-based pedagogies. In terms of best practices, researchers have found that interest-driven learning of the tools, inquiry-based and constructionist learning of the pedagogies, positioning teachers in roles of leadership and combining lab-based with classroom-based PD were effective in PD [19]. These findings are echoed in other research which suggests the benefit of combining formal, informal and independent learning activities for maker PD [20] with each type of activity serving different learning needs and occuring as and when a need arose. Another model of makerspaces PD which has been suggested in literature is the adaptation of the "focus, fiddle, friends" model to the innovation diffusion [11] wherein the authors recommend a focus on teaching and learning strategies, modeling how to teach, exposure to the technology without distraction, emphasis on play and sharing learning among participants. Finally, as described in previous literature relating to the bidirectional relationship between beliefs and actions, researchers in maker teacher PD have recommended focusing on providing teachers hands-on experience in domain and context-specific making in order to improve their associated pedagogy skills, and attitudes and beliefs towards making-based learning [12].

C. Research Gaps and this work

Towards making-based pedagogies, previous research has heavily focused on the use of makerspaces in schools wherein the emphasis remains on the use of specialized tools to make projects. While makerspaces provide the perfect environment for fostering meaningful and authentic learning, the creation and maintenance of makerspaces at resource constrained schools is difficult, and often makerspaces are left to languish. In such contexts it is important to bring making-based active learning into the classroom by providing simple making activities such as toys and models customized for

various topics and concepts in science and math, which use everyday materials already available in resource constrained schools. The goal is to bring in making in a manner than can be integrated easily by a teacher into the classroom and provide certain benefits of making including authentic real-life contexts, keeping learners interested and helping them develop skills. Such a resource-constrained context is under studied in educational technology research; our work contributes to this gap by studying "low tech" making-based active learning pedagogy at low SES schools in a low income country. We study how to train teachers to adopt this pedagogy, so that we can derive principles of good TPD adapted to this context.

Our TPD approach is based on the characteristics of high quality TPD programs that are known to be effective for engendering change in teachers practice and beliefs, including modeling preferred instructional strategies ie, making-based active learning strategies. We begin by immersing teachers in the pedagogy as a student might be, triggering their interest through real-life problems and storytelling, developing their skills in making the toys and models through hands-on practice and demonstrating the steps of the active learning pedagogy that accompanies the making. A thread that runs throughout the program is that of motivating the need for a hands-on pedagogy and daily reflection on their actions. Together we hypothesize that this will lead to an improvement in their skills and a change in their beliefs regarding the goals of science education and classroom practice. In the next section, we elaborate on the implementation of the workshop.

III. Implementation

The aim of the workshop was to motivate and inspire the teachers to approach teaching using a making-based active learning strategies. A secondary goal was also to improve the science content knowledge of the teachers themselves as suggested by literature. We worked with middle school science and math teachers who learned how to use the toys and models as students would, and how to implement these activities in order to trigger students' interest in STEM and help them connect textbook concepts to the real world. During the sessions we started with an object - a toy or a model- and led them through the curricular concepts. To achieve this, each of the sessions had different approaches such as collaboration, inquiry and problem-based learning. The workshops were conducted by various members of our outreach team all of whom are proficient in all of the workshop content. Each workshop was led by two facilitators, one of whom led a session and the other supported. The roles were switched across sessions.

We started with simple familiar things in the world around us and use them to understand the principles of science and math and recognize their relevance in the real world. To achieve this the workshop was designed based on the following principles adapted from the teacher professional development literature described above. We conjecture that when a teacher participates in a workshop designed based on these principles, they will be motivated to use the same in their classrooms.

1) Motivate the teachers about a need for making-based active learning through storytelling.
2) Allow teachers to experience the hands-on activities as students would.
3) Engage them in a fun and enjoyable experience.
4) Allow them to experiment themselves and make observations.
5) Discuss their observations and learning with their peers around them.
6) Reflect on their learning at the end of each day.

The three day workshop consisted of the following sessions, each of which involved some hands-on activity.

A. *Importance of understanding the definitions and its application in real life - Introduction and Ice Breaking:*

The workshop started with a simple question, " Two shops are selling iron. One at 100 Rs per kg and the other at 100 Rs per Liter. The question is from which shop would you buy iron from?" and using a series of questions motivated teachers to understand that volume is not just a property of liquids but all states of matter. The goal of the discussion was to recognize that understanding a definition is different from knowing it.

B. *Incremental approach to learning - Sound:*

Instead of starting with defining sound and its various elements like frequency, wavelength, and pitch, the session started with making a whistle from a straw and then feeling the vibrations that produce sound. Altering the length of the straws gave an understanding of the relation between length and frequency. Making different sound - producing toys and questions related to how the sound is produced helped teachers understand the concept of sound.

C. *Using simple materials around us as effective teaching learning material - A4 paper:*

Something as simple as an A4 paper can help us visualize different concepts in math and science. Making a hole in an A4 paper big enough for a person to pass through seems impossible but the solution makes us aware of space filling curves around us. Fitting long lengths into smaller places is what alveoli in our lungs, and queues in airports and vilis in our intestines do. Finding the ratios of A series paper helps in visualizing the definition of square root of 2. Folding up papers to reach the moon seems like a vague idea but also shows us the power of exponents. Many such activities using an A4 paper made the teachers appreciate the need to look for teaching learning material in things around them

D. *Importance of approximations - Air around us:*

To measure our lungs' capacity, this activity started with a 3 feet long bag and two participants blowing into it. One participant blows directly into the bag and one from some distance. The one blowing from some distance, pushes the air around to go into the bag and so it is not the lung capacity. For the person who blew into the bag the volume of the air could be approximated with known quantities like a 1L bottle. Using

a series of activities and questions we measure the weight of this air.

E. Experiential Learning based STEM - DC Motor:

In this session concepts like energy and its conversion, electromagnetism, current and the working of a motor was experienced by making a DC motor. This motor was made using easily available things around us such as safety pins and a battery.

F. Understanding the why and how of arithmetic-Fractions:

Arithmetic in schools usually involves following procedures to get answers. With so many procedures, we forget to find the reason a certain procedure works. This session started with the following question - "In a city, x of male population is married to y of the female population. How much of the city is unmarried?" The moment we mentioned two fractions, participants added them by making the denominators equal. But doing this meant that we were assuming the male and female population to be equal. This leads to a series of questions which makes the participant question the algorithm and find the reasons for why it works.

G. 3D Geometry - Visualization using vegetables:

Often in textbooks we read about 3D solids, yet all the visualizations are 2D representations in books. In this session, using vegetables like a cucumber and potato we played around with 3D shapes. The task of making a 3D shape with three different projections (circle, square and triangle) takes some tinkering and imagining with a cylindrical cucumber piece. Understanding the importance of using 3D shapes for better visualization was conveyed during this session.

H. Role of Embodiment and Perspective - Astronomy:

This session started with asking the teachers to explain the reason for seasons on earth. It turns out that many people share the same inaccurate ideas, because our casual observations of the sky and the 2D pictures of 3D motion gives us these wrong ideas. In this session we explored the real reasons for seasons and day and night, by making participants replicate earths movement with their own bodies.

I. Integration of art and STEM - String Art:

In this session we use strings to create different curves. These curves are formed by joining points on the circumference of a circle. If we join the points to its double we get a cardioid, and a point to its triple gives a nephroid. These shapes are what we see in a coffee mug due to reflection of light. Moreover, concepts like prime and composites can be understood using string art too.

J. Experimentation in Science- Candle Chemistry:

The books say that when you light up a candle and cover it up with a glass, the reason the candle goes out is because the oxygen available is consumed. If this was true then when we repeat the same experiment with two candles of different lengths they should not go out together. A series of experiments let's us arrive at some understanding behind the reason for a candle going out. It also gives a real life connection to fire safety rules in case of emergencies.

K. A Box of Interesting Toys and Models:

In this session we briefly discussed many other toys that could not be discussed in detail during the session and teachers were asked to explore and play with the toys to become more familiar with their working and how they could be used in a classroom.

L. Books and feedback:

Towards the end of the workshop we shared the importance of reading books to get inspiration and ideas in their subject. We shared a set of books by educators such as Arvind Gupta, Martin Gardner, Gijubhai Badheka, Father Magnus J. Wenninger and many more people.

IV. Methods

Broadly the goal of our work was to investigate the impact of the three day workshop on teachers beliefs about the goals of science education and their intention to adopt making-based learning. Our specific research questions were:

1) What is the effect of a three-day teacher PDP on teachers perceptions of the goals of science education, and their intention to adopt making-based active learning strategies?
2) How do the teachers perceptions of making-based active learning strategies shift after a three-day PDP?

A. Sample and Procedure

We conducted our study as part of the three-day teacher PD workshops for middle school (grades 6-8) science and math teachers mandated by the government for all teachers in a specific type of low SES school in one state of the country. We had 840 participants in our workshops which were spread across nine back-to-back workshops. All of these teachers were invited to participate in the research study which consisted of filled up pre and post questionnaires. Of these not all the teachers filled up both the pre and post questionnaires, and matching the responses on the pre and post questionnaires we obtained 299 valid responses, which is our sample size for this study.

On day one of the workshop, before the first session we invited participants to join a *WhatsApp* group where we posted the link of a *Google* form which consisted of the pre-questionnaire and teachers were allowed some time to fill up the form. After that all the teachers regardless of whether they filled the form, participated in all the activities across three days. At the end of each day, we also posted the link to a daily reflection form in the same group which was participants filled out in the evening, so we could examine the responses and debrief/elaborate specific issues participants had in the previous day. In the last session of day three, we again posted a link to a post-questionnaire and participants had some time to fill up the form before the end of the workshop.

B. Instruments used

In order to measure teachers perceptions of the goals of science education, we adapted the questionnaire from [21] which requires teachers to rank 12 goals of science education. This questionnaire is based on the goals of scientific literacy delineated in [22]. Acknowledging the context of our teachers who are typically not exposed to the goals of science education and may have difficulty understanding all the goals described in literature [21], we had iterative discussions between the members of the research team all of whom have extensive experience working with teachers, to decide which goals would be relevant to our participants and how they should be phrased. The above list was then pruned to four statements and rephrased using simple language which would be most clear to these teachers, ie, *Preparation to join the workforce*, *Prepare students for the college entrance examinations.*, *To be Informed Citizens* and *To apply the knowledge in daily life to solve problems*. Also accounting for the fact that, given the broad sociocultural context of their place of work, our teachers might simultaneously value multiple goals to the same extent, we had questions on a 3-point Likert scale of "Importance" rather than a ranking.

To measure teachers' intention to adopt making-based and active learning strategies, we chose seven typical strategies of making-based active learning [23] including relating the lesson to students' daily lives, asking students to talk and explain the subject to you or their peers, going beyond the textbook and asking students to do projects, encouraging students to ask questions, demonstrating an experiment, making students do a hands-on activity or play with toys and trying to form an emotional connection with your students, on a four-point frequency of usage scale. We chose strategies that are commonly used in making-based learning, are supported by empirical evidence of learning and aligned with the learning approach described in our teacher PDP. The questionnaire also included two open-ended questions; one to explore teachers perceptions regarding effective strategies for learning science and mathematics, and second to explore teachers perceptions regarding the role of hands-on (making and active) work for learning science and mathematics.

C. Analysis approach

To answer RQ1, we employed statistical methods to examine the differences between participants ratings of the goals of science education and intention to use making-based active learning strategies before and after the PDP. In particular, we did tests to examine whether the data was normal, and then applied the appropriate paired sample parametric or non-parametric test to test for statistically significant differences.

To answer RQ2, we employed Thematic Analysis [5] and inductive coding, so the themes emerged from the data. One researcher first read through all the responses to familiarize themselves with the data, which were typically one or two sentences long and often written in the participants native language, Hindi. The responses in Hindi were translated into English before analyses. They began by summarizing the responses to generate initial codes, which were then grouped into larger themes that describe teachers perceptions about effective processes for learning and the role of hands-on work for learning. Some of these responses were so short that they involved no interpretation for instance, "Learning by doing" which was coded as such and ultimately grouped within the theme "Activity-based learning and hands-on approach". However there were other short responses such as "Smart Classes" which were initially referred to as "Novel technology" but ultimately grouped under the theme of "Making use of EdTech". Some responses were ambiguous; for instance, "Environmental activities" which could be interpreted both as "Learning by doing" or "Connecting to the real-world". Ultimately such responses were grouped under both the themes of "Activity-based learning and hands-on approach" and "Connecting book knowledge with real-life, practical examples". Next two researchers together reviewed these themes to ensure that the data extracts within the themes were coherent and that the themes were distinct from each other. We also examined that all the themes together gave an accurate description of the entire dataset, and any discrepancies were resolved through recoding and reorganizing the themes. Finally we named the themes and wrote out descriptions of each of them.

V. Results

A. RQ1: Goals of science education and intention to adopt making-based active learning strategies

The descriptive and inferential statistics of the teachers ratings regarding the goals of science education and intention to adopt making-based active learning at pre and post survey are shown in tables I and II respectively. Skewness and kurtosis tests of the data showed that the data did not satisfy the criteria for normality and so we applied the non-parametric Wilcoxon signed rank test to infer the statistical significance of the differences between the pre and post responses.

TABLE I
Descriptive and inferential statistics of teachers beliefs regarding goals of science education

Item	Mean (SD)- pre	Mean (SD) - post	p-value
Preparation for jobs	2.555 (.607)	2.502 (.615)	0.159
To apply science & maths in daily life to solve problems	2.957 (.204)	2.987 (.115)	0.02
To be informed citizens	2.849 (.411)	2.843 (.374)	0.59
Prepare students for the college entrance examinations	2.656 (.56)	2.579 (.57)	0.008

The findings show that we see a statistically significant increase in teachers beliefs of the importance of the the goal of science education of applying science and maths in daily life after attending the workshop, while there is a statistically significant decrease in teachers beliefs of the importance of the goal of preparing students for college entrance examinations. The change in the importance ratings for the items of preparing students for jobs and to be informed citizens was

TABLE II
DESCRIPTIVE AND INFERENTIAL STATISTICS OF TEACHERS INTENTION TO ADOPT MAKING-BASED ACTIVE LEARNING STRATEGIES

Item	Mean (SD) - pre	Mean (SD) - post	p-value
Relate the lesson to students' daily lives	3.753 (.524)	3.906 (.324)	0
Ask students to talk and explain the subject to you or their peers	3.662 (.647)	3.789(.497)	0.005
Go beyond textbook and ask students to do projects	3.137 (.907)	3.405 (.786)	0
Encourage students to ask questions	3.963 (.221)	3.933 (.299)	0.12
Demonstrate an experiment	3.398 (.75)	3.592 (.64)	0
Make students do a hands-on activity or play with toys	3.344 (.802)	3.585 (.636)	0
Try to form an emotional connection with your students	3.843 (.523)	3.876 (.443)	0.92

not statistically significant, indicating that there was no change in the teachers ratings after attending the workshop.

With respect to the intention to adopt making-based active learning strategies, we observed a statistically significant increase in the intention to adopt five out of the seven effective strategies we asked about, including relating lessons to students daily lives, asking students to talk and explain, going beyond the textbook and asking students to do projects, demonstrating an experiment and making students do hands-on activities or play with toys after the workshop. The only two strategies which did not show increases were encouraging students to ask questions and trying to form emotional connection with students, both of which already had high ratings indicating that there could be a ceiling effect.

B. RQ2: Perceptions regarding effective making-based active learning strategies

For the question of effective strategies to help students learn science and math, the themes observed in the data at pre-survey included

1) Activity-based learning and hands-on approach: This theme included a wide variety of responses such as letting students do activities first and then learn about the related concept, allowing them to question and interact, and making models using waste materials. Thus teachers had a broad perception of what is meant by activity-based learning, including both physical and mental activities.
2) Connecting book knowledge with real-life, practical examples: This theme included responses such as using examples that relate to things in the surrounding environment and live experiences like taking students for a tour, camping, outdoor activities.
3) Creating engagement and enjoyment: This theme referred to the idea of teaching while having fun, through stories and games and by generating curiosity in the minds of kids.
4) Understanding individual students needs: Teachers also observed the need to understand an individual child's mind to teach him/her in the best possible way and do remedial teaching if necessary.
5) Making use of Ed-tech: Teachers mentioned that the use of audio-visual aids and smart boards without elaborating on the type of usage.

We notice that teachers responses were mostly general, indicating at a more abstract level what can be effective for learning rather than referring to specific approaches. At the post survey, teachers reported the following themes related to effective approaches for learning science and maths.

1) Varied teaching approaches and strategies: Similar to the pre-survey, teachers reported a wide range of approaches and strategies that can be effective for learning. The difference was that teachers reported more concrete examples of activities that can be effective for learning such as using storytelling, connecting math with art, doing experiments, giving examples from the natural world, learning through games, inductive and deductive approaches to learning, asking students to make observations and then discussing it in the class and the use of toys. Thus we observe that while at pre survey teachers reported fairly general approaches to learning, at post survey they reported concrete approaches, may of which they experienced during the workshop, as being effective for learning.
2) Enhancing student engagement and participation: This includes giving students a chance to connect with the teacher while having fun during activities, encouraging students to think more about the topic and getting them to speak up, better student engagement through activities, models, and storytelling and motivating weaker students to speak up. Again we observed that participants responses were more concrete and grounded in their experiences during the workshop, than at pre-survey.
3) Application of learning in real-life contexts: Teachers reported that they learned various ways to connect math and science concepts with daily lives that can be effective for learning.
4) Practical and hands-on learning: Teachers reported that they learned new skills, learning by doing and practice, new ways of doing experiments and developed a problem-solving attitude towards finding new and innovative ways to make concepts easy for students to grasp.
5) Innovative tools and resources: Teachers reported certain tools and resources that can be effective for learning such as string art for explaining geometry and mathematical tables, using YouTube videos and puzzles, and vegetables for learning about various shapes, all of which again were related to experiences during the workshop

We note that teachers often reported their perceptions of effective learning strategies based on what they had experi-

enced during the workshop. In summary, the shift in teachers perceptions from pre to post survey was that teachers perceived that several of the activities they engaged with during the workshop could be effective for learning. Vis-a-vis the role of hands-on activities, which was the focus of the workshop, teachers reported at pre-survey that hands-on activities

1) Provide active Learning: They are means of making learning active and meaningful, and adding a context of daily life experiences to learning math and science.
2) Improve conceptual understanding: Teachers reported that hands-on activities improved students conceptual understanding and retention by increasing their concentration and receptive capacity, helping them visualize concepts, making concepts interesting, making the curriculum seem easy and helping students learn at a faster pace.
3) Motivating and enjoyable: Teachers perceived that these activities increased the motivation, interest, enjoyment and participation of learners. Related to this is an interesting perception that hands-on activities help develop trust between teachers and students regarding what is being taught in the class.
4) Improved thinking: The final theme was a broad perception that hands-on activities made teaching and learning effective because it provided learners real experience and helped improved their critical thinking, scientific reasoning and creative thinking.

We notice that teachers responses regarding the benefits of hands-on learning were broad, referring to the general benefits of providing active learning and improved thinking. At post-survey however, teachers perceptions related to the role of hands-on activities changed as follows:

1) Enhanced conceptual understanding and thinking: Similar to at pre-survey, teachers reported that such activities help learners develop deeper conceptual understanding and make hard concepts easier to understand. Further they reported that this deeper conceptual understanding, makes problem solving easier. Finally they reported that such activities develop learners critical thinking and scientific reasoning.
2) Engagement and Active Learning: Teachers reported that such activities help attract even those students who would otherwise find science and math difficult to understand, generate curiosity and interest towards math and science, and students learn while having fun.
3) Practical Application and Real-Life Relevance: In this theme, teachers reported that hands-on activities help learners recognize that science and math play an immense role in our daily lives, so understanding the concepts becomes really important. They are good for generating innovative ideas through which students can make use of waste materials to do some practical and would help students become aware citizens. They also help break many superstitions as students are getting to know scientific reasoning around every phenomenon. Finally teachers reported that these activities help learners develop a different viewpoint towards the way of life, making life easy for students. Thus we see that teachers recognized certain deep and interesting roles for hands-on activities in learning.
4) Improved Student Interaction and Teacher-Student Relationship: Similar to at pre-survey teachers reported that hands-on activities help bridge the gap between students and teachers as students engage and interact more with their teachers during the performance of activities.

Thus we observe that between pre and post survey, participants reported a more nuanced understanding of the role of hands-on activities, in terms of how hands-on activities improve conceptual understanding and the learning process, and went beyond the benefits to learning such as attracting students to science and math, which is an important goal of education.

VI. Discussion and Conclusions

In this work, we studied the effect of a three-day teacher professional development program on teachers beliefs regarding the goals of science education and their intention to adopt making-based active learning strategies (RQ1). We also studied the shift in the nature of their perceptions regarding effective teaching and learning strategies, and the role of hands-on activities on learning (RQ2). To answer RQ1 we found that teachers assigned an increased importance to applying science and maths in daily life as a goal of science education and a decrease in the importance given to preparing students for college entrance exams. This suggests a shift from a knowledge goal of science education to an attitude goal of science education [21]. The reason for this shift could be the explicit emphasis in the workshop on the use of making-based active learning with toys, models and activities that are contextualized to the daily lives of the teachers and students. With respect to the intention to adopt, we found that teachers reported an increased intention to apply several effective making-based active learning strategies, except for encouraging students to ask questions and forming an emotional connection to students, which could be because of a ceiling effect.

To answer RQ2, the themes in the data showed that teachers perceptions regarding effective teaching and learning strategies for science and math became grounded in their experiences of the workshop. Similarly, regarding the role of hands-on activities, the thematic analysis shows that the themes in the post survey reflected a deeper and more concrete understanding of how hands-on activities can improve learning by improving conceptual understanding and thinking, helping students stay engaged and active, understand and apply the concepts to real-life to solve problems, and improve the teacher-student relationship. We argue that teachers experiences with these learning strategies that they experienced throughout the workshop, such as doing hands-on activities, making toys and models, connecting real-life to science concepts, explaining their reasoning, and storytelling, could have resulted in them recognizing the benefits of these strategies for learning, and

their increased intention to adopt these strategies in their own teaching.

Together our findings suggest that having activities to motivate teachers and having them experience making-based active learning strategies as students first, helps shift their beliefs of the goals of science education, and an associated increase in their intention to adopt such strategies which they perceive could lead to attaining these goals of science education. In the long term, such a shift in their beliefs and intentions could lead to a shift in their classroom behaviours [10]. These findings agree with the broader literature in terms of the features of effective teacher PD programs [14], and specifically maker teacher PD, which suggest an emphasis on providing teachers practice in the skills of making to improve associated pedagogical skills and beliefs [12]. The novelty of this work lies in the fact that we provide an approach to contextualize maker teacher PD to a "low tech" resource constrained scenario where an integrated and extended immersion in both making and pedagogy supports teachers in shifting their beliefs and intentions. These findings have implications for improving the practice of making-based pedagogies in "low tech" resource constrained scenarios. Firstly, we present a set of design principles for teacher PD which can be used by schools and/or governments to design teacher PD workshops for making-based pedagogies for science and math, for grade 6-8 teachers. We also present a set of activities and sessions for the training workshops that can be adapted to the specific local context or used as is.

The specifics of our context imply that our findings must be generalized with caution. Our work was done in a context of a large scale government mandated teacher PDP. It is difficult to unpack the effect of the mandate of the findings in this work. However, while we do not report them here, focus group interviews corroborated several of the findings in this paper which suggests that the findings are representative of the specific type of teacher we worked with - a middle school science and math teacher working in a resource constrained school. Our work focused on the beliefs of teachers as they are known to be crucial for adopting any novel technology and pedagogy in the classroom. However our work is limited because it does not study the effects of the change in teachers beliefs on actual classroom practice, and further on the students learning outcomes. In future work, we aim to build on the findings in this study to include more toys/models and making-based learning activities to support teachers in integrating making-based active learning across the entire middle school science and math curriculum. We also aim to study these teachers longitudinally and evaluate whether the beliefs translate to practice and ultimately to improved learning outcomes.

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Laying the Foundation: Student Perceptions on Extended Orientation Programme for Creating Holistic Engineers

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***Abstract*— The contemporary landscape of engineering no longer confines engineers to the mere demonstration of technical skills. This paper reports on a study of Foundation Programme - a 6-week long orientation programme for first year students conducted in an engineering institute in India. The programme, which includes creative mental and physical activities, has the goal of introducing students to the importance of being active, ethically sound and socio-culturally aware engineers. The aim of this study was to gauge the contribution of the Foundation Programme in shaping holistic engineers and to understand students' perceptions of such programs. This research also delves into the difference between the perceptions of first year and fourth year students regarding different attributes of holistic engineers, such as creativity, volunteerism, physical activity, and so on, after having gone through such an orientation programme. Semi structured, in-depth interviews were conducted with the students from the batches of first year and fourth year. Students noted the orientation program's role in fostering academic and personal development. Notably, first-year students emphasized ethical, cultural, and societal awareness, while fourth-year students prioritized technical and fundamental skills, suggesting that they could not retain the values taught during the FP. Based on the findings, it is recommended that the program content be integrated into a digital learning platform accessible to students throughout their academic journey. This platform could also include features for students to periodically track their progress.**

Keywords*— *Engineering education; Design of orientation programme; Student perceptions; Holistic Engineer.

I. INTRODUCTION

Throughout history, society has relied on engineers to solve problems by employing mathematics and scientific knowledge. This traditional definition of engineering is effective for addressing linear, mechanistic, and discrete challenges but there is a growing realization that the challenges of the 21st century are multidimensional, interdisciplinary and increasingly complex. The close interaction between engineering and society necessitates the recognition of social and political dimensions when addressing various engineering issues. Examples of such issues include clean energy generation, storage, and conversion; water conservation and ensuring access to clean water; mitigating air, land, and water pollution; providing healthcare to disadvantaged populations; addressing global warming; and leveraging biotechnology for agriculture, food production, and medicine. These challenges are complex and require interdisciplinary teams comprising individuals with diverse expertise who understand and appreciate each other's concepts and approaches. With the increasing globalization of business and society, engineering has become a global profession, demanding a deep understanding of different cultures and contexts. However, the current technical and narrow focus of engineering education limits its appeal to a broader population. Urgent and significant changes are needed in engineering education to keep pace with evolving requirements. Therefore, there is a pressing need for the scope of engineering education to expand and adapt to these changing demands.

Despite this, undergraduate engineering programs in many universities still largely resemble those from the mid-20th century. To truly design for the betterment of humanity and to enhance the general quality of life, engineers should embrace a holistic approach that extends beyond math and science. This necessitates a unity of knowledge that encourages engineers to explore fields such as literature, history, philosophy, psychology, religion, and economics [1]. By understanding the complexity of the human condition, engineers can better serve society. The Accreditation Board for Engineering and Technology (ABET) acknowledged this need for change by updating its accreditation criteria to include 'Diversity, Equity and Inclusion Awareness' [2]. These changes reflect the recognition that engineers must expand their perspectives and skill sets to effectively address the evolving challenges of our information-based world.

Most of the educational institutes organize student orientation programs for acquainting incoming students to the institutional policies. Such programs are held for a duration ranging from a couple of days to a few weeks. This study is based on an extended orientation program named 'Foundation Programme' held at an engineering institute in India. The Foundation programme is a 6-week long orientation programme for engineering students wherein varieties of activities and competitions are held including sports, art, public speaking, dancing, musical instruments, and so on. Orientation programs and attributes in engineering education have independently received considerable attention in educational research. However, the specific focus on the Foundation Program's impact on students' perception of engineering education, as well as the weightage given to different attributes, remains an understudied area. While existing studies [3-6] have shed light on the significance of the FP and engineering attributes, none of these studies are located within the Indian context, where engineering education holds unique characteristics and challenges. In this

work, we aim to bridge this gap by studying the immediate and long-term impact of foundation programs on students' perceptions of engineering attributes.

The research questions addressed in this paper are as follows:

RQ1: How do the students perceive extended orientation programs, such as the Foundation Programme?

RQ2: What is the difference between the perceptions of 1st year and 4th year students regarding different attributes of engineering education after having gone through such an orientation program?

II. Related Work

A. Theoretical Framework - Unity of Knowledge

To truly serve humanity, engineers must strive to develop a comprehensive understanding of the complexities of the human condition. This requires engaging with diverse fields of study such as anthropology, literature, historical studies, philosophy, psychology, religious studies, economics, and more. By embracing the concept of the "unity of knowledge," originally introduced by James Marsh in the early 1800s and revitalized by Harvard sociobiologist E.O. Wilson in his book "Consilience: The Unity of Knowledge" [7], engineers can integrate knowledge from various disciplines to address intricate problems and make meaningful contributions to society. This approach emphasizes the importance of interdisciplinary collaboration in tackling complex challenges and advancing the well-being of humanity.

Unity of knowledge [7] in engineering refers to the interconnectedness and integration of various disciplines and fields of knowledge within the engineering domain. It emphasizes the idea that engineering is not a siloed field but rather a collaborative and multidimensional endeavor that draws upon diverse areas of expertise. By integrating knowledge from different fields, engineers can develop comprehensive solutions that address complex challenges. For example, in designing a renewable energy system, engineers need to combine their understanding of physics and materials science with environmental knowledge and economic factors to create a solution that maximizes energy production while minimizing environmental impact. Another example can be how AI deepfakes can create various privacy concerns and that can be addressed by experts from humanities discipline to create policies for protection.

For this, engineers are required to possess a broad understanding of mathematics, physics, chemistry, and other scientific disciplines. Additionally, they must be familiar with social sciences, economics, and environmental factors to design solutions that are not only technically feasible but also socially responsible and sustainable. The unity of knowledge in engineering encourages engineers to take a holistic approach to problem-solving, considering the broader implications of their designs and innovations. Engineers often work alongside professionals from various disciplines, such as architects, scientists, economists, and social scientists, to develop innovative and integrated solutions [8]. This collaboration leverages the expertise of each discipline, leading to more effective and sustainable outcomes. The unity of knowledge in engineering thus also promotes interdisciplinary collaboration. Finally, the unity of knowledge in engineering contributes to continuous learning and professional development. Engineers are encouraged to stay abreast of advancements in multiple fields, fostering a culture of lifelong learning and adaptability.

Overall, the unity of knowledge in engineering recognizes the interconnected nature of knowledge and encourages engineers to embrace a multidisciplinary approach. By combining diverse fields of knowledge, engineers can create innovative solutions that address complex challenges and contribute to the advancement of society.

B. Orientation Programs in Engineering and Engineering Attributes

Boyd [9] aimed to evaluate the effectiveness of an orientation program for freshman engineering students in terms of its impact on academic performance and retention rates. The program included various components such as academic advising, workshops, and social activities. They found that students who participated in the program had significantly higher first-year GPAs compared to the control group. The program participants also had higher course completion rates, indicating greater academic success. Dorimé-Williams [10] focused on a summer bridge program designed to enhance student engagement and retention in engineering education where he found that these programs were helpful for developing academic skills and networking, as well as easing the school to college transition of the students. Talking about integration with technology, according to Miller and Viajar [11], orientation coordinators agreed most strongly with the notion of emphasizing the importance of technology to new students coupled with providing new students email accounts immediately upon arrival to campus. Additionally, he suggests that including representatives of the campus information systems group in the conversation about technology inclusion could assist in determining what actually can be done on campus, and that support or training systems should be in place to help both new students and orientation team leaders.

In this paper, we are also addressing "attributes of engineering education" which refers to the various skills, qualities, and characteristics that are typically emphasized or cultivated in engineering programs and curricula. In a student exit survey conducted by Cicek, Labossiere and Mann [12], graduating engineering students were asked to rate 12 attributes based on their mastery of the skill, on a 3-point scale. The results revealed that both 'Impact on Society and Environment' and 'Ethics and Equity' received low rankings in the survey, with the former being among the lowest-rated attributes. Lee and Chin [13] asked students to rank 8 attributes where self-ethical responsibility was ranked lower than other skills such as communication, teamwork, and problem-solving. Interestingly, Canney and Bielefeldt [14] reported that women students are more socially responsible than men. In terms of mode of education, Sankaran and Mohanty [15] reported that undergraduate engineering students learned soft skills the best via the internet and cocurricular activities.

By examining the impact of the FP on students' perception of engineering education, our study seeks to establish the link between the program and the attributes valued by students. The ratings provided by the participants regarding the importance of different skills and attributes serve as indicators of their preferences and priorities in engineering education. We aim to uncover any changes or trends in attribute weightage between first-year and fourth-year

students, providing insights into the lasting effects of the FP on students' educational values and priorities. By examining the perceptions of first-year and fourth-year students, our study aims to explore the lasting effects of the FP on students' perspectives, aspirations, and priorities. Understanding the long-term impact of the FP on students' perception of engineering education and its attributes is essential for designing effective curriculum structures and educational interventions.

Moreover, by conducting our research in the Indian context, we contribute to filling the gap in the literature regarding the FP's effects on engineering education within this specific cultural and educational setting. The Indian engineering education system is known for its rigorous curriculum, competitive environment, and diverse student population [16,17]. Exploring the Indian context allows us to identify the unique challenges, opportunities, and outcomes associated with the FP, ultimately enriching the broader understanding of engineering education.

In summary, our study addresses the underexplored area of the FP's impact on students' perception of engineering education, with a specific focus on attribute weightage. By examining the experiences of first-year and fourth-year students within the Indian context, we contribute to the understanding of long-term effects, unique challenges, and educational priorities within the engineering education landscape. This research has the potential to inform curriculum design, pedagogical approaches, and educational policies, ultimately enhancing the quality of engineering education and preparing students for successful careers in the field.

III. METHODOLOGY

A. Sampling and Procedure

A purposive sampling technique was employed to select participants for the study. Participants were chosen based on their enrolment in engineering programs and their participation in the extended orientation program at the institute. All first- and fourth-year students who had completed the orientation program were emailed, requesting their participation in the interviews. A consent form was emailed to the students, upon completion of which, they were sent a calendar invite for an in-person interview of approximately 25 minutes. A total of 17 students volunteered to participate in the interviews, comprising 8 students from first year and 9 students from fourth year. The interviews were recorded on an audio recorder.

B. Instruments Used

The semi-structured interview schedule was employed as the primary instrument for data collection in this study. Semi-structured interviews were conducted with an aim to explore participants' perceptions in great depth, allowing them to provide more detailed explanations and examples of their experiences with extended orientation programs and their views on the different attributes of engineering education. This schedule was designed to ensure comprehensive exploration of the research questions while allowing flexibility for participants to provide additional insights. It consisted of a series of open-ended questions and prompts derived from a thorough review of the existing literature, ensuring their relevance to the study's focus. The schedule was designed to cover various aspects related to orientation programs and attributes in engineering education.

The attributes chosen for the study were taken from Engineering Professional Responsibility Assessment Tool (EPRA) [18] - Business Skills (i.e. Business Knowledge, Management Skills & Professionalism), Fundamental Skills (i.e. Math & Science), Technical Skills (i.e. Conducting Experiments, Data Analysis, Design, Engineering Tools, & Problem Solving), Professional Skills (i.e. Communication, Contemporary Issues, Creativity, Leadership, Life-Long Learning, & Teamwork), Cultural Awareness/Understanding (i.e. of your culture, and those of others), Ethics (i.e. ensuring all of your work follows professional codes of conduct) and Societal Context (i.e. how your work connects to society and vice versa), Volunteerism (for professional and personal reasons). Other attributes like Creativity and Physical Activity were taken from the five pillars of the 'Foundation Programme' which were - Values and Ethics, Teamwork, Social Awareness, Creativity and Physical Activities and Sports.

To ensure the suitability of the interview schedule, it underwent a rigorous development and validation process. Initially, the schedule was drafted by one member of the research team based on the research objectives and theoretical framework This schedule was then discussed among the team and revised until there was agreement that the schedule covered all aspects of engineering attributes.

C. Data Analysis

The interviews conducted were transcribed and thematically analyzed [20] using QDA Miner Lite, a qualitative data analysis software tool, to look for patterns. One researcher (the first author of this paper) coded the data based on our research objectives to identify initial themes and categories related to student perceptions of the FP programs and the significance of engineering attributes. Consensus meetings were held among the research team to resolve any discrepancies and ensure agreement on the themes.

IV. RESULTS

A. RQ1: Perception of FP

We found that while students offered some suggestions for change, such as greater junior-senior interactions, and immersion in the local culture via expeditions, the feedback from students regarding the Foundation Programme was positive overall. The themes that emerged from the analysis show that students perceived the impact of the program on various aspects of their lives, ranging from communication skills and confidence, art and creativity and gender sensitization to social and interpersonal skills as seen in Table 1. This suggests that the intended purpose of the FP, to help engineering students acquire a breadth of knowledge and skills, apart from technical skills was attained. The highlighted keywords came up the most number of times in the interviews.

Following are some excerpts from the interviews:

"It was all about experience and memories over skills."

"A lot of peers who I met here, they have been engaged in JEE preparation for four years, and they have compromised their social life, family functions and a lot of things. Many of them used to play sports they gave up, so I guess the foundation program kind of gets you back and gives you that

lost time which you have during JEE preparation. The second reason would be that these sessions kind of really help us to come to a general thinking of society as a whole, because we are all from different cultures, and even if we are from progress today, our thinking somewhere or the other differs at different places in different states. So, I guess some states are very conservative with certain ideas. So, when we come in here and we are exposed to this program, it kind of helps us to build that thinking that, okay, this is the world that we are."

"Gender sensitivity sessions opened my eyes and made me feel empathetic towards all sexual orientations. This was extremely new to me."

B. Perception of Engineering Attributes

Fig. 1 shows the ratings provided by the first- and fourth-year participants to their perceived importance of the various engineering skills and attributes. As seen from the figure, the first years gave the most importance to the physical activities (mean = 6.3125), followed by societal context (mean = 6.125) and the lowest importance to volunteerism and cultural understanding (mean =4.75). On the other hand, the final year students rated technical skills as the most important (mean = 6.333) and creativity as the second most important (mean = 6.222), while they rated volunteerism as the lowest (mean = 3.222), followed by ethics (mean = 4.333). While we did not do statistical inferential analysis as the goal of this work is not to establish quantitative differences, these numerical differences are presented as a context to the themes identified and described next. Broadly, these findings tell us that 1st and 4th year students perceive different skills and attributes as important, except for volunteerism which was consistently viewed as the least important. Further, in general we see a trend from 1st to 4th year of increasing importance on technical skills and lowering importance to ethics and societal context. Finally, we see from the figure that first year students' ratings of the skills and attributes are more uniform, compared to 4th year students whose ratings showed more variability, indicating that first year students perceive engineering attributes more equally while fourth year students have stronger conceptions about certain attributes as opposed to others.

The causal themes that emerged from the interviews are illustrated in Table 2. The findings suggest that the first-year students seem to be more idealistic and focused on the macro level whereas the fourth-year students had a more nuanced and micro perspective. For example, the latter prioritized the collaborative aspect of business skills and talked about the importance of managing a team, thus placing emphasis on the production process, whereas the first-year students were thinking about "optimizing their output" or marketing their product itself and making as much profit as possible. Similarly, the fourth-year students perceived theoretical knowledge of science as a foundation for advanced research and a prerequisite for learning plethora of complex courses, while on the other hand, the first-year students were of the opinion that fundamental skills do not hold much weightage for an engineer until it is applied, and they would rather focus on other skills which could be more closely related to profit making. Their perception of the importance of technical skills centered around the core aspects of experimentation, problem-solving, and the application of conceptual knowledge. They understand that engineering is a discipline that requires a strong foundation in these fundamental areas to devise innovative solutions. However, the perception of fourth year students of technical skills expands to encompass larger-scale testing, the utilization of high-end tools in laboratories, and the integration of simulation software. They recognize the significance of engaging with advanced equipment and technologies to conduct comprehensive testing and analysis. They have come to appreciate the mantra of "practice makes perfect," especially in areas such as coding, where continuous refinement and practice lead to greater proficiency.

Both the cohorts felt that cultural understanding is an arena for which external agencies can be hired. For many first-year students, cultural awareness is not on the radar while working. They do acknowledge the significance of understanding the basic needs of people and mentioned a course taught in their institute which talks about considering cultural acceptance of the products manufactured by their intended users in the locale. Final year students talked about the marketing and sales aspect of this. For example, the success of downloadables such as gaming applications rely on numbers, which can be improved by interacting with the target audience and tweaking the application according to the feedback.

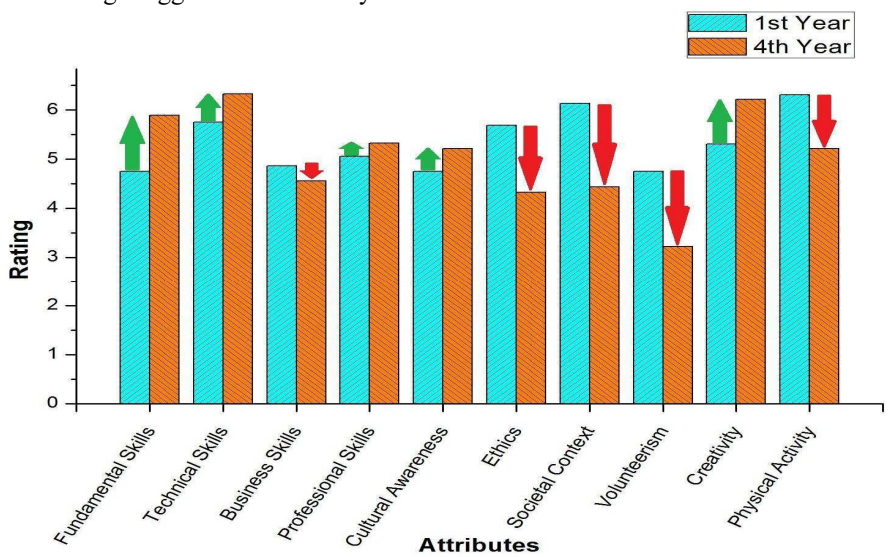

Fig. 1. Student ratings of engineering attributes.

TABLE I. EMERGING CATEGORIES AND KEYWORDS REGARDING PERCEPTIONS OF FOUNDATION PROGRAMME

Learning and Academics	Art and Creativity	Social and interpersonal skills	Personal development
• Learning cultures of different parts of India • Time Management • Boring lecture sessions • Learning through trial and error • Engaging lectures • Gender sensitivity • Reduce the daily duration • Include English classes • Making up for lost time during JEE preparation • Rubik's cube • Management skills	• Calligraphy • Drawing • Dance sessions • Furniture building • Musical instruments • Singing • Juggling • Creativity	• Nostalgic • Fun • Mind games • Dance sessions • Campus exploration • Bonding • Help each other • Get to know the whole class • Out of comfort zone • Sports competition • Ice breaking • Speaking activity • Team spirit • Cleaning drives • Social work • Don't judge someone • Explore what you like • Volunteering	• Communication skills • Open-mindedness • Changed perspectives • Personality development • Confidence • Exercise • Transition from school to college • Transition from COVID to normalcy • Stimulating • Inspiring • Progressive • Unlearn • Express • Leadership skills

TABLE II. EMERGING CATEGORIES AND KEYWORDS REGARDING PERCEPTIONS OF FOUNDATION PROGRAMME

Attributes	Student Perception	
	1st Year	*4th Year Subhead*
Fundamental Skills	• More importance to application of fundamental knowledge • Priority to other skills which are more closely related to monetary profit	• Foundational knowledge for advanced research and courses
Technical Skills	• Experimentation • Problem solving • Application of conceptual knowledge	• Large scale testing • Using high end tools in labs • Simulation softwares • "Practice makes perfect", eg - coding
Business Skills	• Market oriented	• Managerial / Team roles oriented
Professional Skills	• Communication skills • Team skills	
Cultural Awareness	• External agencies can be hired for this	
	• Not on radar for a couple of 1st years • Basic understanding of the people • Courses which talk about cultural acceptance of products	• Good for sales and marketing
Ethics	• Various hypothetical scenarios where they might have to choose between ethics and professionalism / productivity / innovation	• Confused • Core values to abide by
Societal Context	• Understanding societal impact	
Volunteerism	• Learning opportunity • Importance of networking • Time management skills	• Taken for granted • Skillset is too valuable to offer it for free
Creativity	• Creativity is not the norm	• Novelty in research • Hard to be disruptive in the industry
Physical Activity	• Productivity	
	• Lifestyle diseases	• Placement pressure • Inter college competitions

Questions around 'Ethical skills' evoked mixed responses with keywords like "subjective", "complicated", "impossible", and so on. Students, mostly first years, thought of various hypothetical scenarios where they might have to choose between being ethical or creating something innovative, or even being professional and following the protocols that come from 'above'. They believed that an ethical threshold should manage privacy and safety concerns, but strictly adhering to extreme morality might come at a cost. The range of responses can be seen across the following quotes from participants:

"What we do as engineers does not affect the people like that. Think of any terrorist group, they directly do something which is not ethical. There are manufacturing plants which cause pollution, but in general we do not think of ethics very highly. The management or the PR guy should look at it before and determine how they are going to handle it. We will just provide the solutions. It is important but compared to the other skills like technical skills, this falls behind." "I recently came to know that people steal research. They will sit for hours, copy your work and reproduce it. This is wrong. So, for me ethics are super important, and that is the reason that

most of the PhD scholars are alone, they don't talk to people, they don't share their research."

"If you have to launch a rocket and there is some problem at the end of it then there are many factors to consider. Because of ethics you may say that we should not risk the lives of the astronauts but again you have invested billions of dollars into it. So even if there is some risk you will send the astronauts for the greater good."

"I will think about ethics if the public demands it."

Overall, there seems to be an understanding that ethical dilemmas can arise in complex situations where multiple factors need to be weighed.

The first-year students viewed engineering essentially as a response to societal needs. To them, it is important to understand the problem at hand, work towards it and monitor how it is doing in the society. On the other hand, final year students were not really sure of the significance of societal context in engineering education but found its applied nature appealing.

Freshers and final year students held contrasting perspectives on volunteerism, with positive and negative connotations associated with each. Freshers perceived professional volunteering as a valuable chance for learning and networking. In contrast, final year students expressed skepticism, feeling that unpaid work might not fully utilize their skillset, potentially leading to exploitation or being taken for granted.

"We only focus on things which will show up on our resumes."

"I am a woman in STEM. I need not volunteer. I am already doing good by representing women. here."

First-year students emphasize the importance of standing out from the crowd and being unique while maintaining that creativity should not overpower practicality or sustainability. They also acknowledge that creativity is often impacted by technical and financial constraints. It is not a norm in the industry and not essentially required to be a good engineer. Final year students talked about the need for novelty in research and being creative in presenting one's findings. They also shared about how hard it is to be disruptive in an industry which already has a set template for one to follow. The last attribute that was inquired about was physical activity. Students talked about how their professors have emphasized the need for physical and mental wellness for increased productivity. Following the Foundation Programme, a significant number of students took up sports, as active involvement in various athletic disciplines was mandatory. First years also expressed concerns about an anticipated sedentary lifestyle which might bring illness to the body.

V. DISCUSSION AND CONCLUSIONS

Our research was driven by two fundamental inquiries: a) How do students perceive extended orientation programs, exemplified by the Foundation Programme? b) What distinctions arise in the perceptions of first-year and fourth-year students regarding various facets of engineering education following their participation in such an orientation program? Our findings for *RQ1* reveal a prevailing and unanimous endorsement from students regarding the Foundation Programme. They uniformly regard it as a valuable experience that has significantly enriched both their academic and professional journeys. While initially regarded as a welcomed interlude, this program has subsequently emerged as a catalyst for profound personal development, bolstering their social adeptness, expanding networking opportunities, and enhancing self-assuredness.

Engineering students in the west are already moving towards global engineering. Many universities and organizations in the United States have been advocating for the cultivation of a new generation of "global engineers" who are prepared to practice effectively in an increasingly diverse, interconnected, and rapidly changing world. ABET's EC2000 accreditation criteria, established in 1997, requires that graduates "understand the impact of engineering solutions in a global and societal context." Schools like Purdue University have embraced this global agenda and have specific objectives in their strategic plans to expand pathways to global education, develop successful global citizens and leaders, and prepare graduates for a dynamic global workplace [20].

Within the Indian context, the emphasis on a holistic engineering education has been recent. Traditionally, students value an engineering degree for the fact that it leads to obtaining a job, and not for the fact that they can solve global challenges through engineering. Thus while in the west orientation programs have been focussed on sparking interest to retain students in engineering and have been successful in doing so, the goal of the FP has been to develop engineers who recognize the social, cultural, creative and ethical aspects of engineering. Our findings suggest that the FP has been successful to some extent in achieving this goal. Similar to our findings, Boyd's [9] study on orientation programs demonstrated their positive impact on academic performance and student retention, suggesting that such programs have a beneficial influence on students' immediate priorities. Similarly, Dorimé-Williams [10] emphasized the role of orientation programs in easing the transition into engineering education and enhancing academic skills, which could explain why first-year students place higher importance on a broad range of attributes.

Our findings for *RQ2* highlight a noteworthy contrast between first-year and fourth-year in terms of their shifting emphasis. Initially, immediately after participating in the orientation program, first-year students placed higher importance on attributes such as ethics, cultural awareness, and societal context. Conversely, fourth-year students increasingly prioritize technical skills and fundamental engineering knowledge as they progress through their academic endeavors. This transformation echoes findings in the existing literature. Cicek, Labossiere and Mann's survey [12] on engineering attributes among graduating students revealed that 'Impact on Society and Environment' and 'Ethics and Equity' received relatively low rankings, aligning with the declining importance of societal and ethical attributes among fourth-year students seen in our study. Additionally, Lee and Chin [13] found that ethical responsibility ranked lower than other skills, which corresponds to the nuanced perceptions of ethics in the present study. This shift from idealism to pragmatism over the course of an engineering education journey underscores the need for continued reinforcement of ethical and societal values, especially as students prepare to embark on their professional careers.

Overall, the Foundation Programme was perceived positively by the students. The findings suggest that students' understanding and interpretation of engineering attributes change over time, influenced by their experiences and education. Immediately after going through the programme, students reported high ethical values and cultural awareness. However, as time went on and they reached fourth year, there was a steep decline in their valuing of social skills and conceptual skills. The responses became more pragmatic and less idealistic. This suggests a need for reiteration of the value-based content for sustained understanding of the importance of all the engineering attributes.

It is imperative to reinforce the ethical and societal values in Indian students when they are about to start their professional journey. The students seem to lose consciousness of the learnings imbibed during the Foundation Programme and it is recommended to introduce an intervention through technological means to help them keep in touch with the learnings of the FP. This can be achieved by creating a module in institutional LMS for students to regularly review the contents of the FP. Interactive quizzes and games can be utilized to enable students to apply the skills and values learnt during FP by simulating various real-life scenarios that they may face in their professional career. Additional sessions can be delivered to the students through the online platform to help them realize the importance of these skills and values. Periodic refresher sessions will help the students in long-term retention of the knowledge.

The study offers valuable insights but it is constrained by the relatively small sample size of participants (8 first-year and 9 fourth-year students), which may hinder the generalization of findings to a larger population, although detailed student responses help describe perceptions richly. Another limitation is the possible presence of various factors that come into play after a student completes the orientation program and indulges in the institute curriculum and culture across three years, which might affect the way they view engineering education and its various aspects by the time they reach the fourth year when we interview them. However, we have not specifically focused on what these factors might be, which is a limitation of this study.

There are several promising avenues for further research that can expand and deepen our understanding of this area. Firstly, conducting the research with a larger sample size would provide more robust insights. Secondly, a multi-institutional study can be conducted so that more generalized inferences can be made regarding the perceptions of the students and any biases can be removed. Additionally, delving into gender differences in learning behavior may offer valuable insights into how engineering curriculum is perceived and approached by different genders.

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Does learner mindset matter while learning programming in a computer-based learning environment?

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***Abstract*—Computer programming has gained significant attention in recent decades. However, concerns persist regarding students' learning outcomes and success rates in programming courses. It is established that learner interaction influences learning outcomes in a computer-based learning environment (CBLE). Many factors influencing learning interaction with a CBLE have been analysed in this context, except the learner mindset. The term "learner mindset" refers to an individual's beliefs regarding the potential for their abilities to change and improve. Those with a fixed mindset believe their abilities are set in stone, whereas individuals with a growth mindset believe learning can enhance capabilities. This study examines how different learner mindsets (fixed versus growth) affect interaction patterns in a computer-based learning environment (CBLE) designed explicitly for teaching Python programming. We collected the log data along with learners' self-report to mindset questionnaire. We aim to identify learners' interaction patterns and behaviour by analysing log data and utilising process-mining techniques. Based on their reported mindsets, we have reported the differences in the behaviour of learners' interaction patterns within the CBLE observed.**

***Index Terms*—Learner mindset, learner behaviour, learning path, process mining for learning behaviour**

I. Introduction

Over the past few decades, computer programming has garnered significant attention due to its potential to foster vital skills such as logical thinking, problem-solving, creativity, and technological advancements [1], [2]. Despite the surging demand for computer programming skills, concerns persist regarding learning outcomes and student success rates. Aho and Lanski argue that traditional computer science education does not prepare students for workforce success [3]. This causes significant concern for computer science educators worldwide. Moreover, understanding why students fail in computer science education research remains a crucial issue in computer science education [4]. Developing an inclusive and effective learning environment to teach introductory programming courses so that dropout rates and learner performance improves remains a problem in CS education [5], [6].

Factors such as student self-efficacy [7] levels of readiness and computer literacy [8], age and ethnicity [9], learning styles [10], cultural diversity [11], social interactions with peers [12] etc. have been reported to influence students' interaction with the learning environment. Increased learner interaction with the learning environment has been reported to result in positive learning outcomes [13]. Through classroom-based studies, it has been shown that learners with different mindsets behave differently while learning [14]–[18]. But learners' mindset has not yet been investigated in this context for computer-based learning environments.

It is established from the literature that learners' interaction with the learning environment and other students plays a crucial role in improving learning outcomes [13], [19]–[22]. Therefore, investigating the factors influencing learners' interaction is considered highly important. However, there is a paucity of research investigating the difference in the interaction behaviour of learners of a different mindset in a computer-based learning environment. To fill this lacuna, we propose to look into the following research goal- 'To assess the effect of learners' mindset on their behaviour in a computer-based learning environment.'

There are two mindsets based on beliefs in abilities - one with fixed abilities that must be demonstrated and another with abilities that can be developed through learning [23]. A person's mindset decides motivation and actions while learning, influencing learner behaviour. This, in turn, can influence learning programming skills. A growth mindset, which is the belief that skills and abilities can develop through

hard work, trying challenging things, learning from failure, and adjusting strategies to accomplish goals, can help students succeed in programming. Students with a growth mindset tend to see mistakes as a chance to grow and seek out challenges to improve themselves. This mindset can help students develop problem-solving skills essential for programming.

For this research, we used the PyGuru- a computer-based learning environment [24] to collect the data from 38 first-year undergraduate students. Students responded to the mindset questionnaire [25], [26] and the demographic survey. We applied descriptive and diagnostics analytics to highlight the differences in the interaction behaviour of fixed and growth mindsets learners. The results show that individuals with a Growth mindset pay attention to the information that can help them expand their knowledge. In contrast, individuals with a fixed mindset aspire to effortless perfection and get discouraged by failure. Similarly, individuals with Growth Mindset are not afraid of failures but look forward to learning. Contrary to this, individuals with a Fixed Mindset give their best in assessments and aim to achieve higher grades.

The paper is organized as follows: In Section II, we discuss related work, and in Section III, we provide context for the data. Section IV describes our methodology, including the prepossessing of click stream data, and we present our results in Section V. Finally, we conclude in Section VI.

II. Related Work

In order to understand the basis of our work, in this section, we first describe the term "Mindset" and then provide the details about the various studies done around this construct. We also discuss various techniques for analyzing learner behaviour in CBLEs reported in the literature.

A growth mindset is a belief that personal characteristics, such as intellectual abilities, can be developed, and a fixed mindset is the belief that these characteristics are fixed and unchangeable [26]–[29]. Research on these mindsets has found that people who hold more of a growth mindset are more likely to thrive in the face of difficulty and continue to improve, while those who hold more of a fixed mindset may shy away from challenges or fail to meet their potential [26]. In other words, based on the beliefs in abilities, two kinds of mindsets exist - one with fixed abilities that need to be proven and the other with changeable abilities that can be developed through learning [23].

The difference in Table I indicates that people with growth and fixed mindsets have different behavioural dynamics. Students with a Growth mindset have reported better performance [30]. While the influence of domain is stronger for undergraduate students, the mindset differs for different subjects. For complex topics, primarily STEM subjects, the mindset tends to shift from growth to a fixed mindset [18]. In programming where problem-solving and tackling errors (Both logical and syntactical errors) are important while achieving a certain level of mastery [31], [32]. Kench et al. 2016 reported no significant correlation between learners' performance and their mindset, but learner mindset played a role when learners developed their problem-solving strategies [33]. Learning strategies learners employ can better understand if we analyze learners' behaviour or actions in a learning environment.

TABLE I
Difference between Fixed and Growth Mindset (based on Dweck, 2017)

	Fixed Mindset	**Growth Mindset**
1.	The belief that your abilities cannot be changed	The belief that your abilities can be developed through learning new things
2.	Individuals with a fixed mindset are generally only interested in the feedback concerning their abilities	Individuals with a growth mindset pay attention to the information that could expand their knowledge base
3.	Individuals with a fixed mindset believe that if someone needs to work hard for something, they must not be good at it	Individuals with a growth mindset believe that even geniuses have to work hard for their achievements
4.	Passing the chances for learning, shying away from something which requires effort, and easily getting discouraged by failure	Learning from failure happens; continuous efforts are taken whenever challenges are encountered
5.	They aim to give their best in the assessment and achieve higher grades	They find success in doing their best, constantly learning and improving themselves

To comprehend how learners engage with the CBLE, various analytical and mining techniques can be utilized [34]. By analyzing the temporal connections between actions taken by high and low-performing learners, discrepancies can be highlighted, identifying areas where learners may require additional support or scaffolding [35]. Two methods commonly employed for such analyses are Sequential Pattern mining (SPM), Differential Sequence Mining (DSM) and Process Modelling (PM). SPM gives us emerging patterns from the ordered actions performed by the learners. SPM gives us the sequence of meaningful actions out of all the actions of learners from log data [36]. While DSM focuses on revealing less common and distinct behaviour patterns exhibited by different learner groups [37], PM involves organizing all the learner actions in a temporal sequence, which can be interpreted as the learners' problem-solving model over time [35]. Visualizing learners' action sequences through PM can help illustrate the actions performed by learners while learning introductory programming and try to solve the programming assignment problems. As PM considers the individual learners' log data in its entirety, it can give a comprehensive view of learners' actions in contrast with the SPM and DSM techniques which focus on the subset of the actions performed by the learners. Many studies have reported using process mining to understand learning processes in CBLEs better [35], [38], [39].

Literature has been scarce on the role of the learner mindset in affecting learner behaviour in the CBLE. This makes a compelling case to consider the study for understanding the influence of learner mindset on learner's actions in CBLE.

To gain insights into the learning path opted by the learners with different mindset use of Process Modelling as an analysis technique will be useful.

III. Learning Environment

PyGuru is an interactive computer-based learning environment that aims to facilitate the learning and teaching of Python programming skills. PyGuru comprises four key components: a book reader, video player, code editor, and discussion forum. Learners interact with these elements in various ways. We have captured these learner actions in the log data. Description of these actions in detail and corresponding entries in the log are discussed below.

The book reader component of PyGuru, as depicted in Fig. 1, allows learners to read (Read) and annotate digital text. Highlighting text involves selecting a section of the text and adding colour to it (Highlight). The annotation feature allows learners to comment on the text and attach tags for better organization (Annotate). The video player component of PyGuru, as shown in Figure 1(b), provides an interactive video-watching platform for learners. Learners can use basic video player features such as play, pause, seek, and speed enhancement (Play, Pause, Seek video). In addition, instructors can embed questions into the videos, which pause the video and wait for learners to respond (Video Question attempted). The code editor component of PyGuru is crucial for learners to practice coding. PyGuru offers two kinds of code editors to facilitate learning. The first code editor is embedded into the book reader to allow learners to practice coding immediately after learning about the concept. This code editor includes a coding window and an execute button. As depicted in Figure 1(c), the second code editor is more advanced and used to assign programming questions to learners. It evaluates the learners' code against test cases and allows learners to verify their program for errors and test cases before submitting (Verify). This code editor comprises four panels, including the instruction panel, input panel, coding panel, and output panel. Learners can verify their code against the test cases, view errors, and check the messages (See errors, View messages).

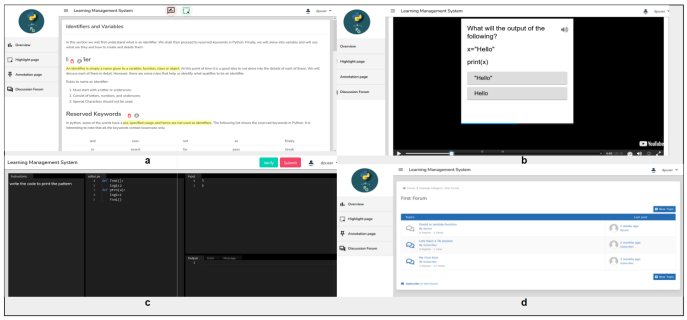

Fig. 1. PyGuru Environment (a) Book Reader (b) Video Player (c) IDE (d) Discussion Forum.

IV. Research Questions

For this paper, we had the following broad research goal: *"To investigate the effect learner mindset has on learner interaction while they interact with CBLE to learn computer programming."* This led us to the following research question:

- RQ1. What are the differences in the number of actions performed by learners with different mindsets in a CBLE for computer programming?
- RQ2. What are the different interaction strategies or learning paths in a CBLE for computer programming for cohorts of learners with different mindsets?

V. Study Design

The study was conducted with first-year undergraduate students enrolled for the Bachelor's in Information Technology course between 18-19 years. All the students interacted with the CBLE for 2 hours daily during the two days in the workshop-like mode. We followed a volunteer sampling process and conducted the study with students who responded to our call for participation in the workshop for learning Python through Introduction to Python workshop. All participants were enrolled in a Bachelor's program in Information Technology and provided informed consent to participate in the study, which was approved by the Institute Ethics Committee (IEC). The learners' participation did not impact their assessment and/or grades of their course, and no monetary compensation was provided. Participants were asked to respond to mindset questionnaire, demographic survey. In addition, the study collected log-interaction data from PyGuru for two sessions and administered a pre-and post-test to assess the programming knowledge of the participants.

We used the questionnaire developed by Dr Dweck [25], [26], [40] to get information on their mindset. This questionnaire is validated and accepted as a valid instrument to measure the mindset in adults [40], [41]. Therefore this short questionnaire was chosen as an instrument for this study. The questionnaire has statements about one's intelligence. Everyone differs in their ability to understand complex ideas, learn from experience, adapt effectively to the environment, and engage in reasoning to overcome obstacles and solve problems. This ability is often referred to as "Intelligence". Intelligence encompasses attention, memory, perception, planning, etc. [42]. Mindset is measured concerning this definition coined by the American Psychological Association through the report on 'Intelligence.' The questionnaire asks whether the person agrees or disagrees with those statements. It uses a 6 - point scale from 'Strongly agree' (6) to 'Strongly disagree'(1) to measure how much the respondents agree or disagree with those statements. The score was calculated by adding the numbers corresponding to the option selected by the respondent and dividing it by the number of questions. The respondents scoring less than 2.75 were classified as learners with a Fixed Mindset, and learners with a score greater than 3.25 were classified as learners with a Growth mindset.Total 42 students responded to our call for participation. Out of which,

15 have a Fixed Mindset (39.5%), and 23 have a Growth Mindset (60.5%). There were 4 students had mindset scores between 2.75 and 3.25, so their data was not considered for the analysis and hence not reported and our sample size for analysis was 38 students. Cronbach's Alpha was calculated for the mindset score of the learners, and it was to be 0.731, which is greater than 0.5 and hence acceptable. This was decided based on their responses to the questionnaire.

The study included a demographic survey that obtained information on the participants' age, gender, and proficiency with various programming languages and a survey on student mindset. The sample included a balanced representation of gender, with 18 females and 20 males. All the students reported to have no prior programming experience with Python and identified as 'beginners'. Although peer interaction was not restricted, it was observed to be related to queries regarding difficulties in log-in to the CBLE. Hence was not noted. Instructor interaction was also limited to the directions to log in and logistics of pre and post-tests.

Based on the student's responses to the self-report questionnaire, we divided the students according to their mindset based on their mindset score. This metric was used to divide the log data as well. We analysed the log data for the frequencies of various actions taken by learners. The log data of learners with a fixed mindset and those with a growth mindset were processed separately to create the process model.

VI. Results and Discussion

In this section, we present the differences in the actions performed by learners with Growth Mindset and Fixed Mindset while using the CBLE to learn Python programming. The discussion based on the average action counts for learners with Growth and Fixed mindset is followed by the discussion on process models generated using learners' log data.

A. Quantifying Learners' Actions

In this sub-section, we present the differences in the actions performed by learners with Growth Mindset and Fixed Mindset while using the CBLE to learn Python programming. We analysed the data by counting the frequencies of various actions performed by the students and attempted to answer RQ1. The frequency of different actions for both groups (fixed and growth) is presented in Table II. The data analysis showed that the learners with the Fixed mindset have a higher average for the count of navigational actions like - Reading, Videos compared to those with the Growth mindset (Refer to Table II). However, even with the greater count of clicks for videos, learners with a Fixed mindset have fewer click counts for Paused, Play, and Continue_video (while attempting the in-video questions). Such actions of "Paused", "play", and "continue_ video" indicates active video-watching behaviour and are linked to deeper engagement [43]. This is supported by the general characteristic of people with the Growth mindset that individuals with a growth mindset pay attention to the information that could expand their knowledge base [23]. Interestingly, learners with a Growth mindset frequently checked errors they encountered while executing their Python codes in the assessment component. Even though the average error frequency was higher for learners with a Growth mindset, the average success frequency was also higher. This suggests that learners with a Growth mindset tried to rectify the errors they encountered while testing their codes, which indicates their focus on developing themselves. Individuals with a Growth mindset pay attention to the information that could expand their knowledge base. People with fixed mindsets aim to give their best in the assessment and achieve higher grades [23]. This is supported by the frequency of attempting the quiz and answering the in-video questions. For learners with a Fixed mindset, the average number of times the quiz (1.6) was attempted is higher than that of the learners with a Growth mindset(0.52). The average number of in-video questions attempted is 1.67, and the average number of correct answers is 1.2 for learners with a fixed mindset. While the average number of in-video questions attempted is 0.91, and the average number of correct answers is 0.57 for learners with a Growth mindset. The average learning gain observed for the students with the Fixed mindset (0.933) was higher than that of students with the Growth mindset (0.652).

TABLE II
Average count of actions performed by the learners with Growth Mindset and learners with Fixed Mindset.

Actions	Average Count (Fixed Mindset learners)	Average Count (Growth Mindset learners)
Count of learners	15	23
Average of total actions	83.13	81.96
Average of Total time	0.05	0.08
Average of Execute (In-page IDE)	25.64	25.52
Average of avg act per session	28.63	31.34
Average of execute for programming assignment	1.2	2.13
Average of Assessment	2.47	2.48
Average of Verified	1.47	2.48
Average of See Errors	0.2	1.13
Average of success frequency	8.6	10.17
Average of error frequency	16.4	17.39
Average of Reading	13.2	12.04
Average of Video watching actions	6.8	6.13
Average of Pause Video	1.07	2
Average of Play Video	1.6	2.43
Average of Continue - Video watching	0.27	0.61
Average of invideo question attempted	1.67	0.91
Average of Quiz	1.6	0.52

Our findings suggest that learners with different mindsets have performed different actions (Table II). Even though learners with a Fixed mindset spend more time clicking on content pages, they spend less time in the CBLE. The average error frequency and the number of incorrect answers are not very different for both cohorts. Still, looking at errors is observed mainly in learners with a Growth mindset. Not so

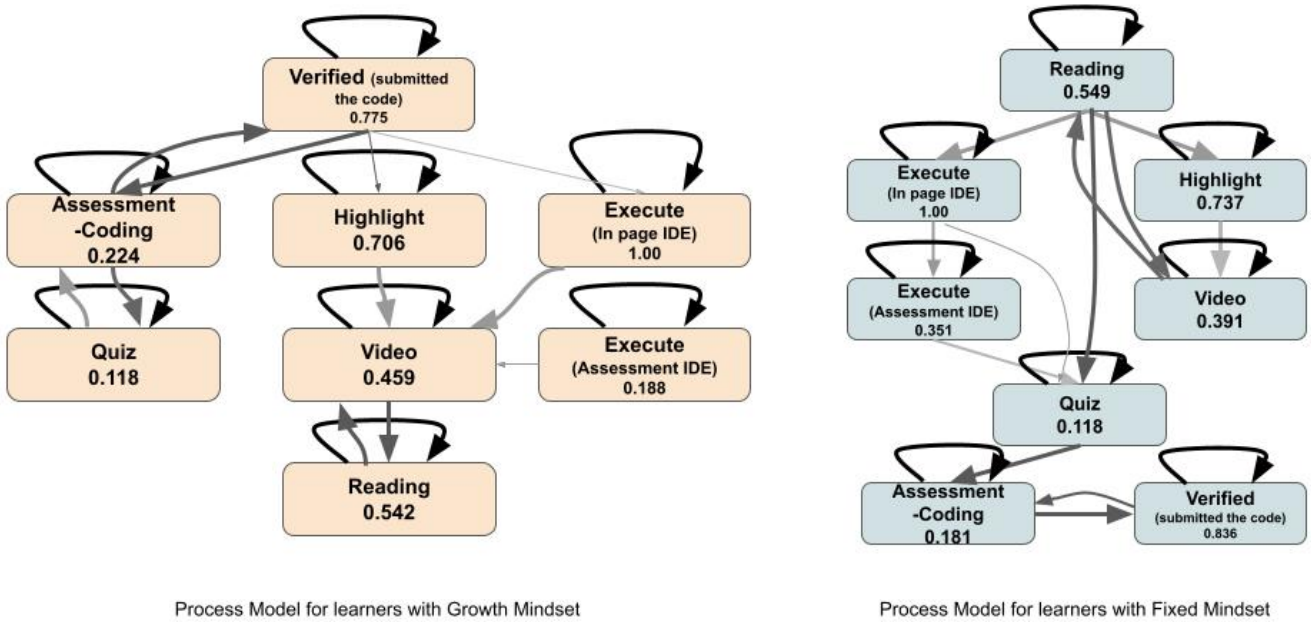

Fig. 2. The Process Models for Learners with Growth Mindset and Fixed Mindset.

surprising that the frequency of running the program without errors is higher for learners with a Growth mindset. Since no statistically significant difference was observed for the average action=4 counts for both cohorts, we analysed the log data to investigate the difference further. The same is discussed in the following subsection.

B. Learners' Process Models

We used the log data to create the temporal pictorial depiction of the action sequences performed by the learners in PyGuru. We tried to find answers to RQ 2 using process models for learners with a Growth Mindset and a Fixed Mindset. Process Models (PM) will give us a comprehensive view of actions performed by the learners. PMs will help us understand the learning path or strategies taken by learners with fixed and Growth mindsets. The details of the same are discussed in this section. The log data was used for ProM Tool- an open-source process mining tool (https://www.promtools.org/) to make the process models using the Fuzzy mining algorithm. The parameters for all the process models were - node cut-off = 0 (to keep all the nodes/actions) and utility ratio = 0.5 (to give equal weightage to significance and correlation). In all the PMs, the node represents the actions performed by learners, and the edge represents the transition from one activity to another. Each node has a significance value (between 0 and 1), and each edge has thickness indicating significance, while darkness depicts the correlation [44].

Figure 2 shows the process models for learners with the Growth Mindset and learners with Fixed Mindset. The node of "Execute," which corresponds to the execution of the code via the in-page IDE window, has a significance of 1 for both the cohorts - learners with the Growth mindset and learners with the Fixed mindset. The common action sequence for both groups is Quiz → Assessment → Verified.

But learners with a Growth mindset have both ways to transition for all three nodes, while learners with a Fixed mindset have only a one-way transition between Quiz and Assessment. In the CBLE, the component of Quiz and Assessment is placed after the content/ topics. Verifying the code is part of the Assessment component, where learners can verify their code against the test cases. For learners with a Growth mindset, the transitions from the most significant node - Execute, is - Execute → Videos → Reading. All these actions are related to checking the content. Another similar action sequence is observed for learners with a Growth mindset- execute → Videos. This transition also corresponds to checking the content. The Reading → Videos link is observed for both the learner groups viz—learners with a Growth Mindset and learners with a Fixed mindset. However, the link has stronger significance for learners with a Growth mindset than learners with a Fixed mindset. The action of Highlighting is not observed to be linked with the content navigational actions for the learners with the Growth mindset. However, it was observed to be linked with the content navigation actions for the learners with the Fixed mindset with the sequence

TABLE III
AVERAGE COUNT OF ACTIONS PERFORMED BY THE LEARNERS WITH GROWTH MINDSET AND LEARNERS WITH FIXED MINDSET.

Action sequences for learners with Growth Mindset	Action sequences for learners with Fixed Mindset
execute → Videos → Reading	Reading → Highlighted → Videos
Verified → Assessment → Quiz	Reading → Execute → execute → Quiz → Assessment → Verified
Verified → Highlighted → Videos → Reading	Reading → Quiz → Assessment → Verified
Verified → Execute → Videos → Reading	

as Reading → Highlighted → Videos. For learners with the Growth mindset, it was Verified → Highlighted → Videos → Reading. The differences in the process models for learners with a Growth Mindset and learners with a Fixed mindset can be observed in the unique action sequences observed for each cohort. These differences are shown in Table III.

The prominent difference between action sequences for both cohorts is that learners with a Growth mindset are going back to the content after verifying their codes in the assessment task. At the same time, learners with a Fixed mindset are going to assessment tasks after going through the contents. The cyclic action sequences observed for the learners with a Growth mindset are mainly concerned with the navigation between the assessment components - Coding Assessment and Quiz, which is - Quiz ⟷ Verified ⟷ Assessment. For the learners with a Fixed mindset, cyclic actions were found for the navigation, like - Reading ⟷ Highlight ⟷ Videos. Another cyclic action sequence observed was - Quiz ⟷ Execute ⟷ execute, but this sequence does not correspond to any meaningful click - result and mostly implies random clicks. The different learning paths taken by learners with Growth and Fixed mindset differed from what we had expected. The action sequences in the process models confirmed the observations made for average action counts. The action nodes observed for learners with Fixed Mindsets are aligned with the linear navigation sequence in PyGuru. Whereas the process model of learners with a Growth mindset clearly showed that they verified/ crosschecked the content. Process models clearly showed the different strategies used by learners with different mindsets. The learning strategies observed for learners with a Growth Mindset and learners with a Fixed Mindset are congruent with their characteristics mentioned in the literature [17], [23], [25].

VII. CONCLUSION

We aimed to assess the effect of learners' mindsets on their behaviour in a computer-based learning environment. The results revealed the differences in the interaction pattern of the learners with fixed and growth mindsets using their action counts and process models. Learners with a fixed mindset showed a greater average count of navigational actions, such as reading and watching videos. Still, they had fewer active video-watching behaviours like pausing, playing, and continuing. On the other hand, learners with a growth mindset actively checked errors encountered while executing Python codes, demonstrating their focus on self-improvement. They also had higher success frequencies and engaged in actions like executing, verifying, and reviewing errors. Furthermore, learners with a fixed mindset tended to attempt quizzes and answer in-video questions, indicating their aim to achieve higher grades. In contrast, learners with a growth mindset had lower participation in quizzes and in-video questions but exhibited a focus on content review and checking. Comparing average values per learner gave us insights into their learning behaviour and encouraged us to explore their learning strategies further. The study also identified distinct action sequences and transitions in the learning process for each mindset group using process models. The visual depiction of action sequences clearly showed that learners with a Growth mindset cross-checked the content after attempting the programming assignment and assessment questions. Another distinct learning strategy observed for learners with a Growth mindset was checking the errors and messages while completing the programming assessment tasks. This learning strategy was not observed for learners with a Fixed mindset. We could see the differences in the action counts of the learners with Fixed and Growth mindsets, which meant that they had followed different learning strategies. This was proven with the help of Process Models for learners with Fixed mindsets and learners with Growth mindsets. Process Models based on learners' entire log data gave us a comprehensive view of all the actions performed by the learners. They helped us identify the different learning strategies for learners with Fixed and Growth mindsets.

Acknowledging the limitations of this work because of the small sample size, there is a need for future studies with larger sample sizes. Overall, the findings underscore the importance of understanding learners' mindsets and their impact on learning behaviours. These insights can inform the design of interventions and instructional strategies to support learners in achieving their learning goals in CBLEs. Further research in this area can enhance computer science education by addressing the different needs and preferences of learners with different mindsets. This can potentially result in sustained engagement and better performance in programming courses. Since performance and engagement in the courses are highly correlated with the dropout rate [45], such an improved design of CBLE may even result in high retention rates for CS courses or any course taught using CBLE.

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Beyond technical knowledge: Identifying training program elements for educational robotics competitions

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***Abstract*—This research paper focuses on Educational Robotics (ER) competitions and highlights the importance of training programs for such competitions to foster 21st century skills. This paper offers components for designing impactful training programs. The methodology is unique as it not only includes a systematic literature review (SLR) to gather relevant information of training resources provided by various educational robotics competitions but also the data collected from participants of educational robotics competition in the form of 11 semi-structured interviews and 2012 survey form responses. The findings, derived from semi-structured interviews and surveys, underscore the need for training programs in ER competitions. In conclusion, this paper provides insights into educational robotics competitions, emphasizing their role in promoting essential skills. The research contributes to existing knowledge by emphasizing the need and elements of training programs in enhancing participant performance.**

Keywords—Robotics Competition, Project Based Learning, Educational Robotics, Training program.

I. Introduction

Educational Robotics (ER) is a research field that positively impacts the student's learning experience through the implementation of hands-on activities where robots play an important and active role [1]. Through such robotic activities, various learning outcomes are fostered, including problem-solving, collaboration, motivation, computational thinking, self-efficacy, and creativity. Numerous robotics kits have been specifically created for educational use, offering students opportunities to explore, implement, and receive valuable feedback. In the context of robotics competitions, several crucial aspects contribute to benefiting students [2]. These aspects encompass the competition's design, student training, mentor support, and teaching pedagogies. Together, they play a pivotal role in maximizing the educational impact of robotics competitions on students' growth and development.

The aim of Educational Robotics competition is: To encourage STEM concepts to help solve real-world problems, to help pursue career in field of technologies, to promote value of engineering disciplines, to develop 21st-century skills, to assist in teaching multidisciplinary engineering topics at universities. As shown in Fig. 1, the idea of robotics competitions was born, when IEEE Spectrum magazine decided to create the Micromouse Challenge in 1977. Two years later in the year 1979, the first competition was held in New York. The task was for a mobile robot to navigate a maze as quickly as possible. Subsequently, micromouse rose to prominence in the USA, Europe, and Japan.

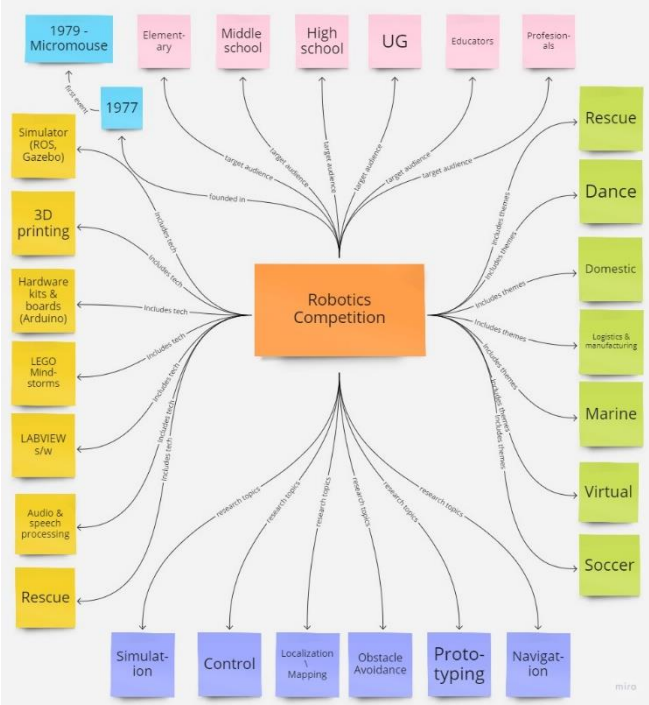

Fig.1: Concept Map of an overview of robotics competition

Recognition of Science and Technology (FIRST) Association by Dean Kamen in 1989. The first season took place for high school students in 1992 and the task was to build a robot and program it to complete the task.

The evolution of the digital realm has given rise to a plethora of diverse robotic competitions, encompassing various types of robots, themes, and tasks. These competitions span a wide spectrum, ranging from simple to highly complex challenges and cater to themes as diverse as domestic and industrial tasks, education, entertainment, manufacturing and logistics, survey and rescue operations, virtual bots, and cutting-edge technology demonstrations.

Within these competitions, an array of mobile robots is prominently featured, including automated guided vehicles (AGVs), humanoid robots, underwater robots, and unmanned aerial vehicles (UAVs). The technologies employed in these competitions are equally diverse, with participants utilizing tools such as Arduino kits and other hardware components, 3D Printing, advanced simulators like Gazebo and Robot Operating System (ROS), SLAM (Simultaneous Localization and Mapping), LabView, LEGO Mindstorms, Image processing, Machine learning, and Audio processing, among

others. These technologies play a crucial role in enabling innovation and creativity, driving the development and performance of the robots in the competitions.

The primary objectives of these competitions involve the building and programming of robots to accomplish specific tasks, such as navigation, obstacle avoidance, object manipulation, and ramp climbing. Additionally, some competitions employ autonomous robots for various tasks, while others focus on friendly robotic competitions. These engaging events are organized globally, spanning different regions and attracting participants from diverse age groups, including elementary, middle school, high school, undergraduate students, educators, researchers, and professionals [3].

II. METHODOLOGY

To find potential research papers in the educational robotics domain, we first determined relevant keywords. Subsequently, we conducted searches in prominent databases, namely Google Scholar, IEEE Xplore Digital Library, ACM Digital Library, and Scopus. An advanced search option was utilized, employing quotation marks to match exact phrases and boolean operators like OR and AND to refine or expand the search results. The literature review encompassed the period from 2010 to 2023, except for the Scopus database, where the review focused on the years 2013 to 2023.

The search string for Google Scholar was:
((“robotics competitions”) OR (“robotic competition”)) AND (“robotics training” OR “robotic training”)

The search string for IEEE Xplore Digital Library was:
((“robotics competitions”) OR (“robotic competition”)) AND (“robotics training” OR “robotic training”)

The search string for ACM Digital Library was:
[[[All: “robotics competitions”] OR [All: “robotic competition”]] AND [[All: “robotics training”] OR [All: “robotic training”]]]

The search string for Scopus was:
((“robotics competitions”) OR (“robotic competition”)) AND (“robotics training” OR “robotic training”)

Using above strings, we initially found 398 papers, of which 20 duplicates were removed. To identify the most relevant papers, we applied specific inclusion and exclusion criteria. The inclusion criteria focused on competencies in educational robotics competitions, available training, or resources. On the other hand, the exclusion criteria targeted papers centered on developing robotics systems using advanced technologies like machine learning, deep learning, artificial intelligence, reinforcement learning, deep reinforcement learning, papers based on industrial robotics applications, emphasizing medical applications and specific age groups like school-age students.

Based on the exclusion criteria, 275 of them were excluded and 103 papers remained for abstract screening. Among these, 91 were excluded due to their focus on topics such as students' attitudes towards STEM, student engagement, and the implementation of technical robotics courses and workshops. Ultimately, 12 full-text papers underwent a thorough assessment for inclusion in the study.

Additionally, to gain deeper insights into the training and resources provided by various competitions, we also gathered data from competition websites. In conjunction with the Systematic Literature Review (SLR) and website information, we conducted semi-structured interviews and administered a survey questionnaire to further understand the requirements for a comprehensive training program. A total of 11 semi-structured interviews were conducted, and we received 2012 responses to our survey. Considering the aim of the paper, the research questions are:

- RQ1: What are the existing educational robotics competitions, and what is the training and resources provided in such ER competitions?
- RQ2: What are the competencies required in educational robotics competition?
- RQ3: What are the factors necessitating the implementation of a Training Program for Educational Robotics Competitions?
- RQ4: What are the recommendations for the training program's content?

III. RESULTS

RQ1: What are the existing educational robotics competitions, and what is the training and resources provided in such ER competitions?

To address the RQ1, we searched for current robotics competitions that are conducted across the world. We came across 55+ unique competitions and thorough analysis of 11 well-known tournaments was conducted based on the popularity of the competition. The investigation included determining the competition's purpose and categories, target audience, mode of conduct, training, resources provided (before, during, and after the competition), mentor participation, and role.

Information regarding the factors mentioned above was discovered on the official competition website. However, specific details about the training and resources offered to students during the competition, as well as the role of mentors and other available scaffolds, were not readily available. Nevertheless, the competitions do offer certain resources, such as notes, guides, rulebooks, and certification courses for educators. The Table I below shows resources provided competition-wise:

TABLE I: COMPETITIONS AND RESOURCE AVAILABILITY

Name of Competitions	Resources availability
Micromouse	They have a dedicated resources page consisting of the following: • Hardware suppliers: Links are made available to purchase required components. • Arduino notes: Webpage has links that redirects to Arduino official website. • Software installation notes: It has installation steps and few links for additional readings.

	• Beginner's guide of multi-purpose robot: Introduction to concepts of robot
RoboGames	• Guide to Winning: Dave (judge for 25 years and co-founder of Combots) has described 10 rules to win. • Parts of a Combat Robot: 1-page document
ABU Robocon	• Rulebook: ABU Asia-Pacific Robot Contest 2022: It details out terms used, procedure of game, robot tasks, and rules
RoboCup (Robot Soccer World Cup)	• LEARN: a dedicated page • Introduction to Service Robotics: Open to all (specified date and time), Detailed syllabus, Course information (length, effort, subject, level, prerequisites), Class materials (zoom screen recorded YouTube video [duration: 30 - 65 mins], slides and pdf) • Information about the 2 types of robot platforms in the Education Challenge • Introduction to Service Robot Development: Class Materials (Slides, Open-source code, Video) • Hands-on workshop (robot building) for beginners: No details available • Matlab: 6 modules, Videos (duration 5 min - 12 mins) and web links • TurtleBot2 & ROS: 9 modules, Only Slides, • MARRtino & ROS: 4 parts, Only Slides
VEX Robotics Competition	• VEX Certified Educators: Consists of two parts (VEX Robotics Certification Programs, REC Foundation Certification Programs) • VEX Robotics Certification Programs has 8 courses. Each course has different units (each unit has: an introduction, LOs, explanatory video, additional links, questions, and unit exam - mostly MCQs) • REC Foundation Certification Programs has 3 courses based on role (Head referee, Event partner, judge). Each course has different units (each unit has: an introduction, LOs, additional links like Team Interview Rubric, and unit exam - mostly MCQs) • VEX research articles • VEX Library: Contains all the information about VEX, Coding, Building, Documentation, Resources, and Troubleshooting are made available category wise, Categories are Grade K+, 3+ (two subcategories), 6+, 9+ (three subcategories). • VEX Conference (upcoming 27th -29th April 2023) • Other activities: Hour of Code activities (Coding Activities Across the VEX Continuum), STEM Labs curriculum, STEM Library documentation, Professional Development Plus, Forum
Zero Robotics tournament	• Tutorials page: It consists of following information: Website basics, own ZR IDE, content level wise (beginner, intermediate, advanced), Content includes basic sphere controls, programming concepts, required math and physics, other activities are related to making sphere, physics, programming. • "Zero Robotics Middle School Summer Program 2022: 5-week STEM curriculum, it included domains such as programming, robotics, and space engineering with hands-on experience programming Astrobee Satellites. • Educator Guide: Detailed document, content is divided in 5-weeks, week wise schedule is made available, it consists of concepts and activities around computer science, maths and science and programming.
Robofest India	• Description of category of games: games based on the age-group, and each one has a pdf document explaining the game (like a rulebook)
B.E.S.T Robotics	• Resources: dedicated resources page, consists of web links of mathworks, Intelitek, CAD/CAM and so on, links redirect to respective official website (mostly)
Botball	• No dedicated resources • Only brief description about hardware/software, robotics education
FIRST	• Robotics Curriculum: yearlong (paid), includes learning modules, team activities, simulations, rubrics for assessment. • Grade-wise purchase kits • Grade-wise skill development summary chart: grades are PreK-1, 2-4, 4-8, 7-12, 9-12 • Book: Guide to excel in FIRST Tech Challenge: It has detailed description of robot architecture, design principles, programming ideas and game strategies, authors are two coaches who have guided teams to progress in all levels, this book is a reference for team members, coaches, and mentors • Other books
World Robot Olympiad (WRO) - India	• Team formation needs: 2-3 students, Dedicated Coach, A Smart Team Manager, A Sponsor/ Investor • General rules pdf

RQ2: What are the competencies required in educational robotics competition?

The author [6] suggests that participation in robotics competitions helps to increase students' interest in STEM discipline, robotics, programming subjects and develop skills such as teamwork, collaboration, and communication. He suggests that if such a robotics competition is to have a positive impact on the educational learning process, teamwork, and collaboration are the prerequisites for a competition.

In the literature study [2], authors proposed six learning outcomes for K-12 formal and informal learning environments. Authors have also identified problem-solving as one of the important learning outcomes for educational robotics competitions. Those six learning outcomes are:

- Problem-solving: According to research, robotics competitions can be an effective instructional tool for the development of problem-solving skills. These

skills are important cognitive activities that enable learners to seek solutions for a given problem, and they play an essential role in monitoring their understanding and applying their knowledge. Author found that providing strong guidance in problem-solving activities related to educational robotics can result in greater problem-solving skills for students, as compared to those in the control group.

- Collaboration: Collaboration is a crucial skill for students in the 21st century, which involves working and communicating effectively with others. In almost every STEM discipline, collaboration is emphasized as an essential component. It refers to the process of enabling people to complete a task or achieve a predetermined goal given that working environment is the same. In educational settings, collaboration is vital for fostering students' social interaction skills.
- Motivation: Motivation, defined as the individual's decision to allocate effort, engage in, and persist in a specific activity, has been identified as an important factor in educational settings. Researchers conducted a study to investigate how educational robotics can enhance students' motivation.
- Computational thinking: Research has shown that educational robotics is a valuable tool for developing this skill but takes time to develop. This result was revealed by a study conducted using the Lego Mindstorms NXT 2.0 educational robotics kit in training robotics seminars for schools.
- Creativity: According to research, creativity is closely linked to the mental process that enables individuals to generate useful and original ideas and solutions to problems. A quasi-experimental study based on robotics training involving one control group and one treatment group, with pre and post-tests, was administered. The study involved 120 11th-grade students, and data was collected through a questionnaire after an eight-session treatment period. The results showed improved positive impact on students' creativity and learning in physics.
- Self-efficacy: Self-efficacy is regarded as one of the key drivers of human behavior as it enables individuals to gauge their ability to achieve a specific task with their existing skills. A study revealed skills of middle school students increased in the robotics and gaming environment compared to only the gaming context.

Authors in [7] have characterized 21st Century skills into two domains: ICT skills and higher-order skills. These are further categorized into problem-solving, collaboration, communication, self-regulated learning, critical thinking, and creativity as shown in Fig. 2. According to the research, skills such as problem-solving, collaboration, communication, and critical thinking should be a part of the curriculum and should be taught and assessed too. These skills have gained more importance in the digital age of the 21st century. It states that it is crucial to start with the intended learning outcomes and create activities that align with methodologies such as "constructive alignment" or "backward design" when designing the curriculum. Organizations such as the United

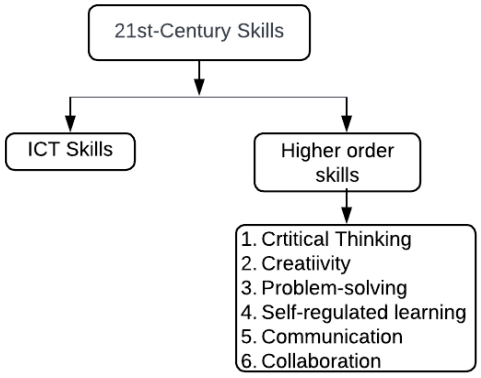

Fig. 2: Classification of 21st-century skills

Nations Educational, Scientific and Cultural Organization (UNESCO), the Organization for Economic Co-operation and Development (OECD), Partnership for 21st Century Skills (P21), Assessment and Teaching of the 21st Century Skills (ATC21S) have also emphasized the importance of integrating these skills into the curriculum.

According to ABET-mapped competencies (problem-solving, communication, teamwork, ethics, life-long learning, math, science, engineering knowledge; engineering tools; experiments and data, design, contemporary issues, understanding impacts), problem-solving is an essential competence for undergraduates in the engineering domain [8].

RQ3: What are the factors necessitating the implementation of a Training Program for Educational Robotics Competitions?

This RQ is addressed using following:

- Insights from literature
- Insights from data collection

Insights from literature:

Robotics courses currently lack a widely accepted methodology, in contrast to other disciplines where the curriculum is clearly established. Because there isn't a well-established curriculum, many participants turn to competitive robotics to master the subject. Students could approach robotics more scientifically and logically, however, if the curriculum was firmly based on concepts linking the applications of science and math. Teachers also lack a formal curriculum on which to base their course syllabus on. As they struggle due to a lack of experience and training, students are left with no guidance.

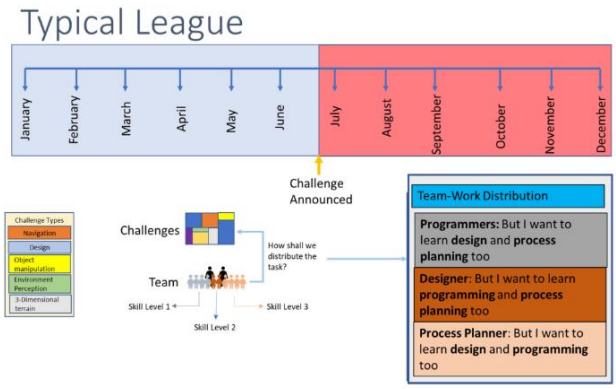

Fig. 3: Timeline of existing competitions [11]

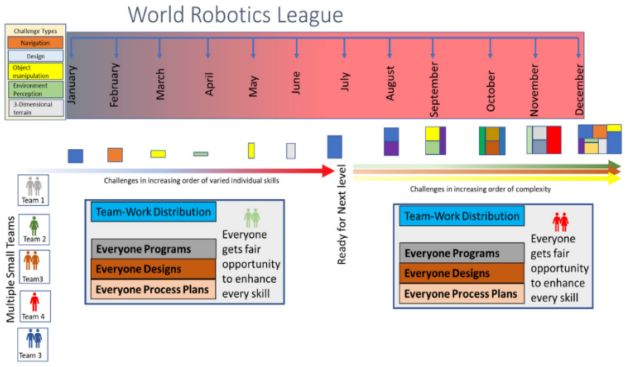

Fig. 4: Timeline of WRL competition [11]

Many competitions announce a challenge/theme after which students start their preparation. Fig. 3 shows an example structure of such competitions. Given the duration of the competition, students feel challenged to learn skills that are needed to build, experiment, and revise the tasks at hand. To teach robotics to students, the World Robotics League (WRL) developed an approach that gave more importance to curriculum-led challenges than the challenges at hand as shown in Fig. 4.

With this approach, students gain points as they make progress. Certification is mandatory for instructors who are involved with students. Such a curriculum with trained mentors is a successful way to train students [11].

Insights from data collection:

To further analyze the need for a training program, the researchers conducted data collection using semi-structured interviews and a survey form was sent to larger groups of students. These students were participants in one of the international educational robotics competitions titled e-Yantra Robotics Competition. This competition is designed for students in polytechnic, science, and engineering colleges and uses the Project Based Learning (PBL) approach to solve real-world problems abstracted as "themes". Distinct skills are taught to participants through various themes each year in an online mode with the gamified approach. The 6-7 months long competition is divided into two stages (stage 1 and stage 2), and these are further divided into multiple tasks [4][5][12].

Semi-structured interviews:

A total of 11 semi-structured interviews were conducted, consisting of both on individual (count 4) and collaborative / team level (count 7), with each interview lasting approximately 40 minutes from seven different themes of the current year. Participants were undergraduate students from 10 different colleges across 7 different states. Students were mainly from departments such as electronics and telecommunication, computer science and engineering, mechanical engineering, electrical engineering, mechatronics etc. Each team consisted of 2-4 members. Participants were selected from different performance levels based on their task submission scores, including low scorers, medium scorers, and top scorers among students and teams.

Questions used were classified in these categories: students background (to know their background and to help them feel comfortable and get started), motivation (to know what was their intention of participating in the competition), prior knowledge (to know if they had participated in other competitions and if they were aware of tech stack of current competition), challenges faced (to know what were the difficulties faced and how did they overcome), need of training program (to know whether training is required by the students, when and how would it useful). Each category had around 2-6 questions followed by follow-up questions. Based on students' responses, a few questions were skipped as they seemed to already be answered.

Few questions are listed below:

- *Which year are you in studying in and department?*
- *Have you participated in any other competition earlier?*
- *Did you know the concepts earlier needed for stage 1 implementation? OR were you exposed to very first time?*
- *What are the difficulties/challenges you faced while working on tasks?*
- *In the current competition, resources provided are in the form of documentation, videos, discussion forum, live session etc.? Do you think any additional support should be provided?*

Fig. 5 and Fig. 6 show a few excerpts from interview transcripts. Following are insights from the interviews:

- Some teams suggested a training program would be useful to interpret information and cover programming basics, considering beginners might find documentation challenging.
- Some teams referred to additional resources during the competition and expressed the need for examples in a training program to enhance understanding.

S1: We had to learn all the basics. "Provided resources were enough but not sufficient"… We were exposed to the concepts for the very first time… Resources were good to get started.. As competition has deadlines knowing beforehand about the software will help teams "Basic information can be provided" through a training program
S2: If I did not have previous knowledge, it would have taken time to complete.. Training would be "good idea for newcomers"
S3: "Referred to a lot of YouTube links and stackoverflow" that consumed time..No additional support is required
S4: It's a competition, no training is required. Competitors will increase. Self-learning should happen.."For learning, a training program is useful"

Fig. 5: Screenshot of interview transcript done for individual interviews. S1 - Student 1, S2 - Student 2, S3 - Student 3, S4 - Student 4.

T1: Do not know how to code.. Difficulty in understanding octave.. "Participants will get a better idea". It will reduce the number of problems that are faced later.
T2: Referred additional resources and videos.. Training program "will be helpful to complete tasks easily, to improve skills, no need to refer additional resources, helpful if you give examples, how it works"
T3: "Advantage of knowing concepts before hand". Resources were helpful.. Beginners might find it difficult.."Training program would help to interpret info"
T4: Searched a lot..Not able to find.." Basic tutorials will be helpful".. Don't know the correct path to reach solution. Additional support in form of video tutorials.. Training program can "help to learn new things, basics can be helpful"

Fig. 6. Screenshot of interview transcript done for team interviews. T1 - Team 1, T2 - Team 2, T3 - Team 3, T4 - Team 4.

- A team had difficulty understanding coding and faced time constraints. They suggested additional support through simulation video tutorials, covering robotics fundamentals would help but should not conflict with academics.
- Another team emphasized the importance of familiarizing participants with the required software beforehand, especially considering competition deadlines. Theme-specific topics like image processing and arm manipulation were suggested, along with basic simulator usage.
- Additional support was sought for learning new concepts and boosting implementation speed. Suggested topics included algorithm development, mechanism building, and robot development. Existing resources were deemed insufficient.
- Teams acknowledged the training program's role in facilitating a smooth start and reducing future issues.
- Certain teams were familiar with the competition's domain, finding tasks manageable. However, they highlighted the potential challenges for beginner teams and suggested topics like drone technology, AI, ML, IoT, and FPGAs for the training program.
- While most teams believed the training program would be useful, one team argued for self-learning as the competition grows. Nevertheless, they recognized the program's learning benefits.
- Certain teams also highlighted the benefits of having the training program before the competition, as it aligns with their summer break, ensuring that their academic commitments remain undisturbed.

Survey form:

In addition to conducting interviews, a survey form aimed to gather feedback from bigger group of students regarding their perceptions of the training program. Fig. 7 illustrates that out of 2012 students, 1645 (81.75%) expressed the need for such a program. This finding aligns with the responses obtained during the semi-structured interviews. Particularly, students from low and medium-scoring teams highlighted that they were relatively unfamiliar with the topics introduced in the competition.

As a result, they spent a significant amount of time familiarizing themselves with the basics, leaving them with less time to focus on the tasks at hand, ultimately leading to missed deadlines.

Students were asked about their views on the potential benefits of a training program at the beginning of the competition. Fig. 8 presents the findings, indicating that 1687 students out of 2012 (83.84%) responded positively, stating that such a program would indeed be helpful. Regarding the specific ways in which the training program would be beneficial, the researchers analyzed the text responses provided by the participants. Amongst the 2012 responses, 512 were thoroughly examined. The major themes that emerged from these responses were as follows:

- Improved Understanding: Many students believed that the training program would help them grasp the basics better, thereby enhancing their overall understanding.

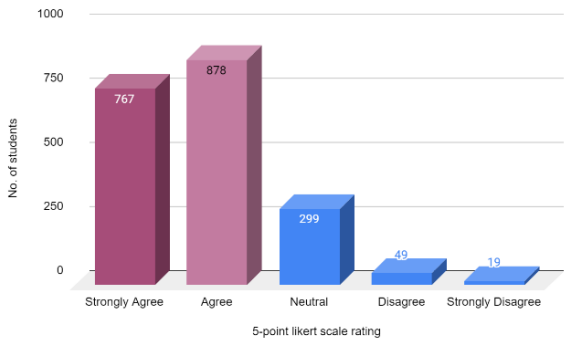

Fig. 7: Need of training program

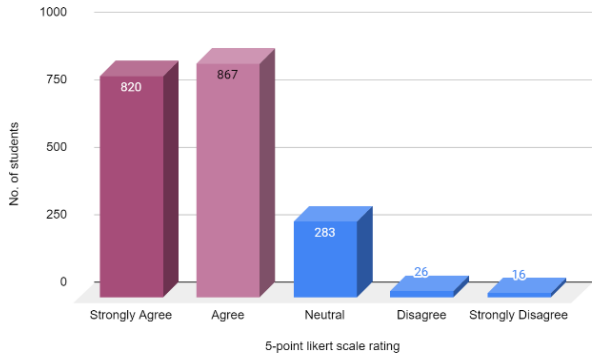

Fig. 8. Help of training program

- Increased Knowledge: Participants expressed that the program would facilitate the acquisition of new knowledge, boosting their competency in the competition.
- Enhanced Competition Performance: Students anticipated that the training would enable them to tackle competition tasks more effectively, thus enhancing their performance.
- Support for Newcomers: The program was seen as particularly beneficial for newcomers, helping them adjust and compete more confidently.
- Time Saving: Preparation through the training program would save valuable time during the competition, allowing participants to meet deadlines without dropping out.
- Improved Thinking and Problem-Solving Skills: Some responses highlighted the potential impact of the program on honing critical thinking and problem-solving abilities.

Based on the data collection and analysis, it became evident that students indeed expressed a genuine need for a training program, as the identified reasons convincingly demonstrated its potential benefits.

The findings presented in Fig. 9 indicate that students expressed a preference for a training program that lasts 4 weeks or no more than 4 weeks. This choice might be influenced by the fact that the competition itself already spans 7-8 months. Therefore, a shorter program is deemed more manageable, allowing students to balance their other activities effectively.

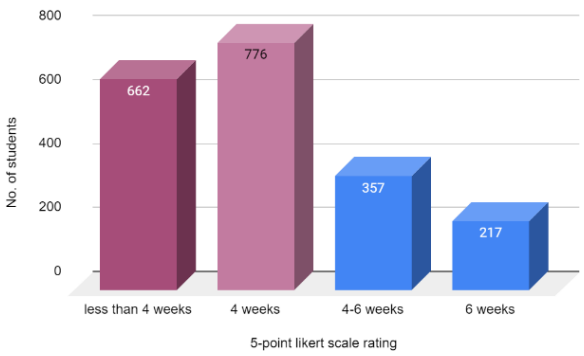

Fig. 9. Duration of the training program

RQ4: What are the recommendations for the training program's content?

The training program must cultivate the essential competencies needed for educational robotics competitions. While the e-Yantra Robotics Competition focuses on technical skills during the competition, it is evident that participating students lack the 21st-century competencies such as problem solving, collaboration skills, time management which are essential for educational robotics competitions. Competition requires students to design a robot which is an ill-structured problem to be solved. Such tasks also require students to possess design thinking skill. Based on the literature review, students' feedback, training program should be offered to address the following competencies:

- Problem-Solving
- Collaboration
- Time Management
- Design Thinking

Other than deciding the competencies, topic to be targeted was one more aspect for training program. In the same survey, students were also asked to suggest topics for program. The domain that appeared most was Embedded systems, followed by Image processing, and Python. All the remaining topics were also theme specific. We looked at the domains covered in themes of e-Yantra Robotics competition for past 10 years. It appeared that results inclined with students' feedback with similar domains Embedded systems, and Image processing. So, the appropriate domain for training program to base learning activities on would Embedded systems.

Merely developing a training program may not be adequate; ensuring learner engagement is of paramount importance. For this purpose, the program should be rooted in a learner-centric pedagogy. In line with this concept, [9][10] introduced the Learner-Centric MOOC (LCM) model, which provides a framework of guidelines, activity types, and actions aimed at fostering learner engagement through interactive activities and forum discussions, ultimately proving to be effective.

IV. CONCLUSION

In conclusion, this research paper sheds light on the significance of Educational Robotics (ER) competitions as platforms for fostering critical skills in participants. Through a comprehensive analysis of training resources offered in different competitions, the study reveals the undeniable importance of training programs.

The systematic literature review (SLR) served as a robust foundation for gathering relevant information, enabling the researchers to identify resources provided across various ER competitions. Moreover, the incorporation of semi-structured interviews and surveys enriched the research findings by providing valuable insights from participants, confirming the need for training programs in this field.

The paper's key takeaway lies in the provision of evidence-backed recommendations for designing impactful training programs to cater to the specific needs and goals of participants. The findings presented in this research paper serve as a guide for educators, competition organizers, and policymakers to recognize the importance of integrating effective training programs into ER competitions.

By emphasizing the role of ER competitions in promoting essential skills, this research makes a significant contribution to the existing knowledge in the field. It underscores the potential of such competitions as dynamic learning environments that go beyond mere technical knowledge, cultivating problem-solving, collaboration, time management and design thinking in participants. In summary, this research paper demonstrates that educational robotics competitions have a multifaceted impact on participants.

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Hybrid Simulation for Health Care Education using Wearable and Web-Based Technologies: A Theoretical Framework

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***Abstract*--Health care education has improved over the years using both technology and human actors. This combination has been shown to enhance certain elements of realism in health care training scenarios. The use of hybrid simulation in health care education has continued to expand to the present day. Most of the current hybrid simulation approaches reported in the literature have focused on specific simulation scenarios and are therefore limited in their application. To provide faculty with greater simulation flexibility, a configurable hybrid simulation approach is needed that can be utilized for multiple scenarios in multiple health care disciplines. This paper presents a theoretical framework for developing a configurable hybrid simulation for health care education that capitalizes on recent advances in wearable and web-based technology while at the same time leveraging the proven advantages of a standardized patient – a human actor who emulates a real patient during the simulation process by displaying normal human behaviours.**

Keywords--Standardized patient, human actor, wearable technology, hybrid simulation, health care education

I. INTRODUCTION

Hybrid simulation continues to play a significant role in health care education. There are many examples in the literature of the use of hybrid simulation for specific health care training scenarios [1],[2],[3]. However, there appears to be no evidence in the literature of a hybrid simulation setup that would provide health care educators with a configurable hybrid simulation that can be used across multiple health care disciplines.

Human actors, which are more often referred to as standardized patients, have been used in health care education since they were introduced in 1960 by Howard Barrows [4]. Although there seems to be no agreement in the literature regarding the responsibilities of a standardized patient or indeed the definition of the term standardized patient, there is general agreement on the overall goal - to emulate a real patient and therefore display normal human behaviours. The differences in responsibilities found in the literature are centered on what patient the human actor is emulating – themselves or someone else! Reference [5] argues that a standardized patient is a "person who agrees to be themselves to assist in staff education", and these patients "stay true to who they are and accurately answer any questions regarding their medical or social history." Alternatively, as a historical reference, [6] once defined standardized patients as professional actors or readily available volunteers trained to simulate a variety of medical problems in a "consistent, reliable, realistic and reproducible manner". Human actors have been shown to be a superior training 'tool' as it relates to patient interaction and thus connectedness between the patient and the student-caregiver [1],[7],[2]. Indeed, human actors have demonstrated that they are able to react realistically to health care procedures and caregiver dialogue [1].

The purpose of this paper is to present a theoretical framework for creating a configurable hybrid simulation approach for health care education that capitalizes on recent advances in wearable and web-based technology while at the same time leveraging the proven advantages of a standardized patient. The proposed theoretical framework may be an easy to use, configurable approach to simulation-based training in health care education that can be used across multiple disciplines to simulate a variety of clinical scenarios.

The paper first explores the advantages of using human actors in health care education simulations and how high-fidelity simulators, although superior in certain contexts, lack the ability to foster genuine communication between the health care provider and the patient.. The paper continues with a discussion on the use of technology to emulate health

symptoms and to provide feedback to the caregiver. The role of hybrid simulations in health care education is then explored with a focus on past simulation approaches. The paper concludes with a presentation of a theoretical framework for creating a hybrid simulation for health care education using wearable and web-based technologies.

II. HUMAN ACTORS IN HEALTH CARE EDUCATION

Human actors have been shown to enhance health care education by providing a more realistic training context which encourages interaction between the health care provider and the patient [5]. Researchers at the University of Delaware demonstrated this through the tracheostomy overlay system (TOS) that can be worn by a human actor (standardized patient), enabling students to perform invasive procedures [1]. Researchers found that nursing students interacted with the standardized patient significantly more than when participating in the same procedure with a high-fidelity mannequin, which lacks the ability to interact with the student in a natural way and provide feedback to the student on procedures being carried out [8]. The students were found to correct their own mistakes, ask questions, offer reassurance, and give explanations of what was happening to their patient more often when working with a standardized patient [1].

Similarly, researchers at the Mayo Clinic, in Jacksonville, FL, found that the use of standardized patients in internal medicine training was more effective, and better emulated realistic patient care than the use of a mannequin in acutely decompensating patient scenarios [7].The researchers found the results matched their expectations, as they had anticipated that most people would respond more effectively to live patients rather than to a mannequin because of the interactive nature of human beings. These results should not be surprising since such interactions mirror more closely the real-life caregiver–patient experience. Similar results were found by researchers at the University of the Free State, Bloemfontein, South Africa where drama students were used as standardized patients in mental health nursing education [9].

Standardized patients used in hybrid simulations for renal education at the Nurse Education and Research Unit, Queensland, Australia demonstrated that these patients were able to easily act in alignment with actual patient reactions to interventions involving the administration of drugs such as benzo diazepam or saline [5]. Further, researchers felt that standardized patients were able to emulate real patients better than high-fidelity simulators due to their ability to naturally engage with the student; indeed, realism was enhanced through simple gestures, wriggling in bed, or clasping the nurse's hands [5]. Additionally, standardized patients were able to shiver at the right time thanks to an earpiece that was connected to the control room from where the 'patient' was cued based upon the actions of the students [5]. The research team felt that the use of human actors added enough realism that the staff themselves became immersed in the learning scenario, blurring the lines between reality and simulation.

A final example of the use of human actors to improve communication was demonstrated using Avstick, a wearable device developed by the University of Delaware [2]. Avstick is an intravenous catheter insertion simulator for use with standardized patients. Avstick allows students to perform invasive procedures on the patient. While participating in simulations using Avstick, students were observed correcting their own mistakes more than during similar simulations using high-fidelity simulators, where students remained quiet or asked the minimal required procedural questions to satisfy the simulation rubric [2]. The researchers felt that the abundance of communication observed was a direct result of using standardized patients which created a positive experience for the patient, as it was theorized that the patient's experience was directly influenced by the way in which the clinician communicated his or her thoughts and intentions during a procedure [2]. The interactions between the student and the patient confirmed that trainees were much more willing to engage in conversation with a standardized patient wearing the Avstick than with a mannequin [2].

III. CHALLENGES PRESENTED BY HIGH-FIDELITY SIMULATORS IN HEALTH CARE EDUCATION

High-fidelity simulators provide the student with the opportunity to conduct invasive procedures on a computerized mannequin without the risk of harming the 'patient'- as the patient is a machine. High-fidelity simulators use a combination of computers and electronics to present various health symptoms to the student. These simulators can also support complex training scenarios that require multiple invasive lines and tubes. As such, there are certain training scenarios in which a high-fidelity simulator is indeed the best training tool to enable students to meet certain learning outcomes. However, regardless of the quantity and quality of electronics or level of computerization, the student is acutely aware that they are interacting with a machine – not a live person, and as a result, mannequins seem to be deficient when it comes to improving one's interpersonal communication skills [2]. As such, much

research has shown that the insentient characteristics of a high-fidelity simulator significantly influences how students interact with the 'patient', as they lack the necessary human characteristics that standardized patients offer to a simulation scenario [8].

Indeed, internal medicine students at the Mayo Clinic, University of Miami reported during a focus group, that interactions with a high-fidelity simulator were unrealistic when trying to focus on clinical reasoning and critical thinking skills during a training scenario [7].On the other hand, residents who participated in similar simulation training based upon standardized patients, exhibited better knowledge acquisition and felt they received a more realistic experience than residents who underwent the same simulation based upon a high-fidelity simulator [7]. Comparable results were seen at the University of Delaware where nursing students interacted with standardized patients much more readily than a high-fidelity simulator when conducting tracheotomy care [1]. Similarly, nursing students at the National University of Singapore, as evidenced during focus groups, reported that the use of standardized patients better represented real-life interactions with deteriorating patient's vs the use of a high-fidelity simulator and that the use of standardized patients added more realistic stress to the training scenario which in turn better prepared the students emotionally, to manage stress in similar real life clinical events [10].

IV. USING TECHNOLOGY TO PROVIDE CUES TO PATIENTS AND CARE GIVERS

Health care education through simulation has advanced because of the use of technology which can effectively simulate a large variety of health conditions and provide feedback on the quality of the care being delivered by the student [3],[7]. For example, a wearable device that sits over the actor's torso, aesthetically representing a chest and throat with an integrated tracheostomy tube, allows students to perform tracheostomy care and suctioning. Sensors built into the device provide cues to the actor, indicating if the suctioning technique is appropriate or if too much face plate pressure is being put on the patient. These sensors prompt the actor to respond appropriately (violent coughing, dyspnea, pain, eyes watering) to proper or improper suctioning techniques [1].

Canadian researchers used wearable inertial sensors to assess and identify motion during transfers of simulated c-spine-injured patient training. These sensors were able to measure acceleration and angular velocity which facilitated the estimation of patient orientation in a fixed and global reference frame [3]. Sensors were placed on specific locations of the standardized patient to provide the students with orientation tracking of the patient which ultimately provided feedback to the students on the effectiveness of their transfer technique [3]. These two examples alone give a clear insight into the ability to use technology to emulate certain health conditions or to provide feedback to the patient or caregiver.

V. EXPANDING THE ROLE OF HEALTH CARE EDUCATION SIMULATIONS WITH HYBRID SIMULATIONS

The literature confirms that the combination of technology and human actors can enhance health care education by providing the students with realistic patient symptom feedback, such as organ sounds, while at the same time cuing the patient to respond to certain procedures and scenarios [8]. Additionally, the students benefit significantly by being able to interact with a real human being who can talk and use body language to provide additional information to the caregiver [11].

Technology can be used to provide a variety of patient symptom feedback to the caregiver as well as a variety of cues to the patient to respond in a particular way, based on the procedures being carried out. Hybrid simulations, simulations which combine technology and standardized patients, have been shown to be beneficial in health care education in many focused areas, such as tracheostomy care [1], catheter insertion [2], and haemodialysis [5]. Additionally, there is much evidence to support the use of technology to cue human actors, who in turn can respond in prescriptive ways to what's going on in the room, adding realism to the simulation. These same actors can also interact with the care givers in the form of dialogue, body language and physical touch. These focused hybrid simulation examples along with others provide clear evidence that technology can emulate specific symptoms to the caregiver in support of a certain simulation theme.

VI. TOWARDS A HYBRID SIMULATION THEORETICAL FRAMEWORK

To leverage the advantages of the hybrid simulation approach, a theoretical framework is proposed that can be configured to support multiple educational scenarios instead of being tied to a specific scenario. With the appropriate wearable and web-based technology, a variety of patient cueing could be easily facilitated as well audio/visual feedback to the caregiver. Both the cues and the feedback can be altered by the trainer to meet the learning outcomes of different courses.

Table 1, adapted from the work conducted by Canadian Aviation Electronics Ltd, as reported in the Canadian Association of Schools of Nursing [12] illustrates some of the scenarios that may be supported through the implementation of this theoretical framework. (Through surveys and consensus-based recommendations, this information was developed to highlight "the most important complex clinical events for baccalaureate nursing students to experience before entering practice" [12]. To further validate the contents of Table 1, a medical doctor in Eastern Canada with 30+ years of family physician experience was asked to review the symptoms, vital signs, and physical data to further validate its content with what is typically seen in the field.

TABLE I POSSIBLE HYBRID SIMULATION SCENARIOS THAT MAY BE SUPPORTED THROUGH THE IMPLEMENTATION OF THE PROPOSED THEORETICAL FRAMEWORK (ADAPTED FROM THE CANADIAN ASSOCIATION OF SCHOOLS OF NURSING [12])

Patient Situation	**Technology - vital signs and physical data**	**Standardized Patient – symptoms**
Hypoglycemia	Blood sugar low, faster heart rate	irritability, hunger, lack of coordination, sleepiness, blurred vision, sweating, appearances of drunkenness, tremors in the hand
Hyperglycemia	Frequent urination, blood sugar high	Dry mouth, increased thirst, weakness, headache, blurred vision
Deteriorating patient (MVA from stability)	Varied blood pressure (may change up or down)	Irritability, restlessness, lethargy Increased respiratory rate
Postoperative Hemorrhage	Decreased blood pressure, increased heart rate, change in oxygen saturation	Increased respiratory rate
Respiratory – distress	Increased blood pressure due to anxiety or lowered due to condition, fever, fast pulse rate	Rapid breathing, general weakness, dry hacking cough, headache, shallow breathing
Postoperative Pulmonary Embolism	Pleural friction rub may be audible. Change in heart rate	Shortness of breath, pleuritic chest pain, Cough with blood streak sputum, chest pain
End-of-Life (Dying patient)	Incontinence, congestion, tea colored urine, fever, death rattle sound in chest,	Confusion, sleeping, shallow breathing, irritability, restless, breaths further apart
Cardiac arrest	Heart palpitations, no pulse, blood pressure dropped	Dizziness, shortness of breath, weak, feeling of nausea

The purpose of the original research, from which Table 1 was derived, was to provide health-care educators with a list of the most important scenarios that nursing students should encounter during their education journey. In the table presented here, column one identifies the patient situation to be simulated, column two outlines the vital signs and physical data associated with that patient situation, and column three lists the symptoms associated with that same patient scenario, symptoms which could be emulated by a standardized patient. In the context of this paper, the purpose of the table is to show that of the ten patient situations outlined in the original work, eight can be simulated using the proposed theoretical framework.

VII HYBRID SIMULATION THEORETICAL FRAMEWORK

The proposed theoretical framework provides the health care student with four channels of information. This information can then be used by the student to determine a course of action to address any health care concerns. Figure 1 illustrates these four channels of information as well as the role played by three actors, the student, the instructor, and the standardized patient, in any given scenario. The instructor can remotely edit and display patient information as well as cue the standardized patient to act in a certain way or deliver a verbal script to the student. The student in turn receives information from both the technology and the standardized patient to inform the students future actions.

Information received from the technology may come in the form of a simulated symptom such as an audible pleural friction rub which could be heard through a stethoscope or through a digital display of data such as oxygen saturation rates. This approach may be applied to a variety of simulation scenarios in health care education and provides the flexibility to be expanded based upon the ability of technology to simulate vital signs and physical data.

The theoretical framework of Fig. 1 may be seen as a generalization of the specialized simulation approaches seen in the literature, where hybrid simulation has been shown to be effective in a variety of focused simulation scenarios that use technology and human actors working together. The foundation of

this theoretical framework is the course learning outcomes. This informs the number of information channels, the content of each channel, the cues given to the standardized patient and the approach used to assess the student. Faculty interface with the technology to cue the standardized patient or to provide real time visual or audible cues to the learner.

The information of Channel C comes directly from the technology in the form of body sounds, which can be designed to only be heard with standard hospital equipment such as a stethoscope. Channel D information can be a variety of 'patient monitoring data' such as heart rate, blood pressure and respiratory rate. This information can be displayed on a 'bedside

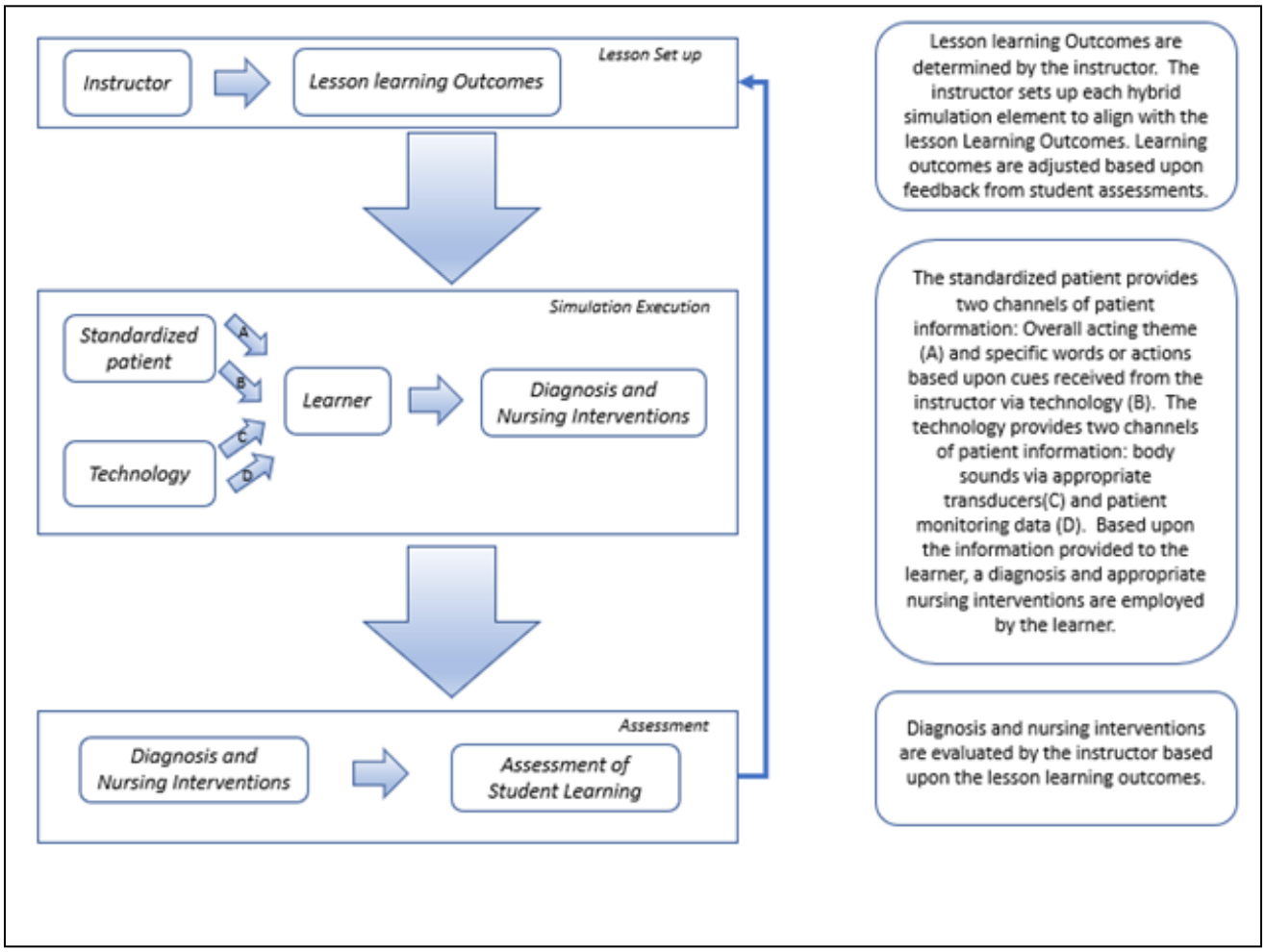

Fig. 1 Hybrid Simulation Theoretical Framework

The standardized patient and the technology work together as a whole to provide information to the learner through the four information channels. The information of Channel A comes in the form of specific words or actions, or both, that are enacted by the standardized patient based upon a cue(s) provided by the technology. These cues may be triggered by the faculty or by the technology itself. For example, the actor may be cued to "have an immediate need to go to the washroom" in line with congestive heart failure.

Channel B information is based upon the overall acting theme of the standardized patient, such as an overall feeling of fatigue or complaints of thirst, which would align with the simulation being enacted. monitor' and updated in real time in alignment with the progression of the scenario.

During the simulation scenario, the learner relies upon multimodal perception to synthesize the information from the four channels of information to form a possible diagnosis and short-term care plan for their patients' well being. This short-term care plan and diagnosis act as a feedback loop to the faculty to inform the assessment of the student learning, just as the four channels of communication is a feedback loop to the learner based upon their immediate actions as care givers.

VIII. IMPLEMENTATION EXAMPLES

This section provides the reader with two implementation examples based upon the theoretical

framework. In these examples, the authors propose specific technologies to communicate information to the learner based upon the example scenario. Learning outcomes and expected interventions are provided for each scenario to provide the reader with a wholistic view of a typical simulation lesson.

A. Hybrid Simulation Implementation for Congestive Heart Failure

The purpose of a simulation is to immerse the learner into a controlled scenario that reflects as close as possible how this scenario would look in the field. From a teaching and learning perspective, the instructor must determine appropriate learning outcomes for the lesson, which includes the simulation, and an appropriate mechanism to assess the students learning during and possibly after the simulation. For a congestive heart failure lesson, the following learning outcomes may be utilized:

- identify congestive heart failure as the root cause of patient discomfort when presented with a patient with congestive heart failure.
- implement appropriate interventions to make the patient comfortable.
- implement appropriate interventions to manage patient symptoms found with congestive heart failure.
- collaborate with the health care team to implement a long-term care plan.

The simulation is designed to support these learning outcomes. Therefore, all channels of information are aligned with a patient presenting with congestive heart failure. In this case, as illustrated in Fig. 2, channel A information, the overall acting theme, includes a history of family heart issues, difficulty breathing and general fatigue. The information of channel B, which provides specific acting cues given to the standardized patient, includes cues to spontaneously sit up-finding it hard to breathe and sudden onset of severe shortness of breath. These cues are triggered by the instructor and relayed to the standardized patient via wearable technology, namely a vibration motor connected to an Arduino microcontroller. Channel C information is made up of body sounds that again align with congestive heart failure, including an elevated heart rate, this information is sent to a Bluetooth earbud through a wirelessly connected personal computer. Finally, channel D information represents patient monitoring data, including heart rate, blood pressure and respiration rate, and is sent to a tablet as a published web page. Data shown on the tablet is updated in real time by the instructor as the scenario progresses.

B. *Hybrid Simulation Implementation for Postoperative Pulmonary Embolism*

A second proposed implementation, as illustrated in Fig. 3, is designed around a postoperative pulmonary embolism. Learning outcomes include:

- the proper identification of postoperative pulmonary embolism.
- implementation of appropriate interventions for postoperative pulmonary embolism.
- the implementation of appropriate escalation procedures.

In this scenario, the overall acting theme adopted by the actor, channel A information, is a shortness of breath and sharp, stabbing, or piercing chest pain that worsens with breathing or certain movements – pleuritic chest pain.

The actor is cued via a Bluetooth earbud, connected to a simulation computer, to cough with blood-streaked sputum (channel B information). A pleural friction rub is made audible to the learner via a Bluetooth earbud connected to the simulation computer (channel C information). Finally, channel D information, as displayed on a tablet connected to a web server, shows heart rate that is elevated beyond the normal range - tachycardia and low oxygen saturation - hypoxemia.

The information displayed on the tablet is changed in real time via the simulation computer through a web page editor. During the simulation the instructor observes the learners and assesses their diagnosis as being correct or incorrect and assesses the appropriateness of their interventions, symptom management and escalation protocol.

Upon completion of the entire scenario the instructor evaluates the students' performance and adjusts the simulation learning outcomes accordingly. These two examples illustrate that the four channels of information within the theoretical framework could be configured to simulate a variety of medical scenarios using a standardized patient and appropriate technology.

IX. CONCLUSION

Human actors have been shown to enhance health care education by presenting students with a real-life patient, one in which the student can easily and naturally interact with [8]. Additionally, research has shown that technology can be successfully employed to support hybrid simulation scenarios with

a view to increasing the overall fidelity of the simulation [3].

Health care education has improved over the years using both technology and human actors. This combination has been shown to enhance certain elements of realism in health care training scenarios.

the student to meet learning outcomes and improve student's confidence in their ability to handle real life medical scenarios. This may be accomplished in an affordable way through future implementations of this theoretical framework, which relies on wearable and web-based technology and human actors to bring the

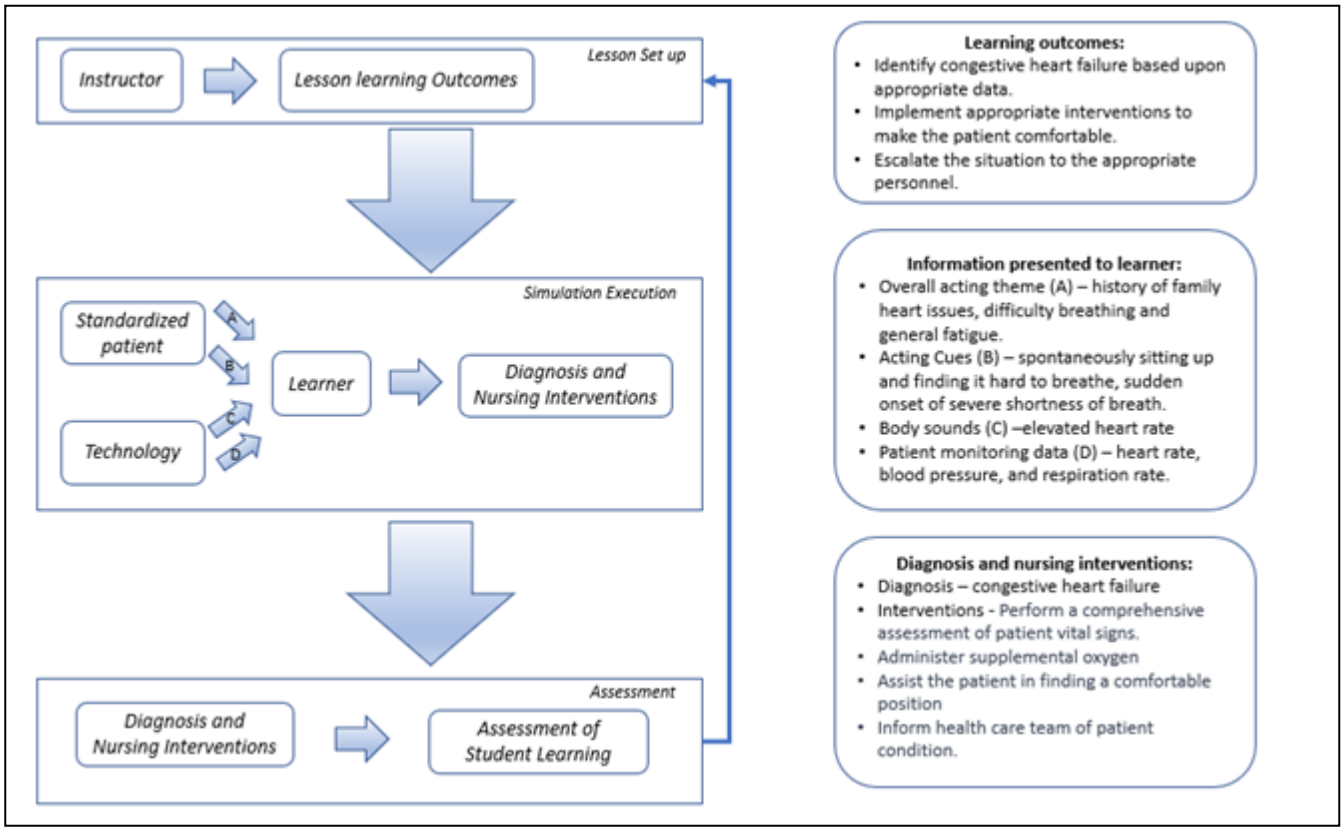

Fig. 2 *Implementation of Congestive Heart Failure Simulation*

Indeed, technology has been shown to provide the flexibility required to present the student with a range of health care scenarios with varied case elements. Additionally, the use of standardized patients in simulation-based training is associated with better post-test scores, higher realism perception [7], real-time recognition of error [1], and heightened awareness of patient interactions that lead to better communication and understanding of real-life patients [10].

Reference [1] posits that the "ideal educational tool would facilitate realistic patient interaction, both verbal and nonverbal, between the standardized patient and trainee" while at the same time allowing the student to participate in simulations involving medically complex patients in which invasive procedures can be conducted.

The advantages of hybrid simulation have not been fully realized as advances in wearable technology continue to develop. Further research is required to expand the role of wearable technology to better equip

worlds of technology and standardized patients together.

There are of course potential limitations to the implementation of this framework. Initial equipment cost may be beyond the financial means of the institution. One also needs to consider the cost of the possible development of observation, and debriefing rooms as well as possible costs associated with staffing, actors, and ongoing maintenance, all of which add to the total cost of ownership [13].

Additionally, instructors will need specific training to equip them to integrate simulators into the curriculum, and to use appropriate evaluation methods and assessment tools for simulation-based learning [13]. Standardized patients will also need to be trained to ensure standardizations and consistency between simulations. Finally, one needs to consider the technical support which may be required to integrate the various technologies and the standardized patient into a seamless simulation experience

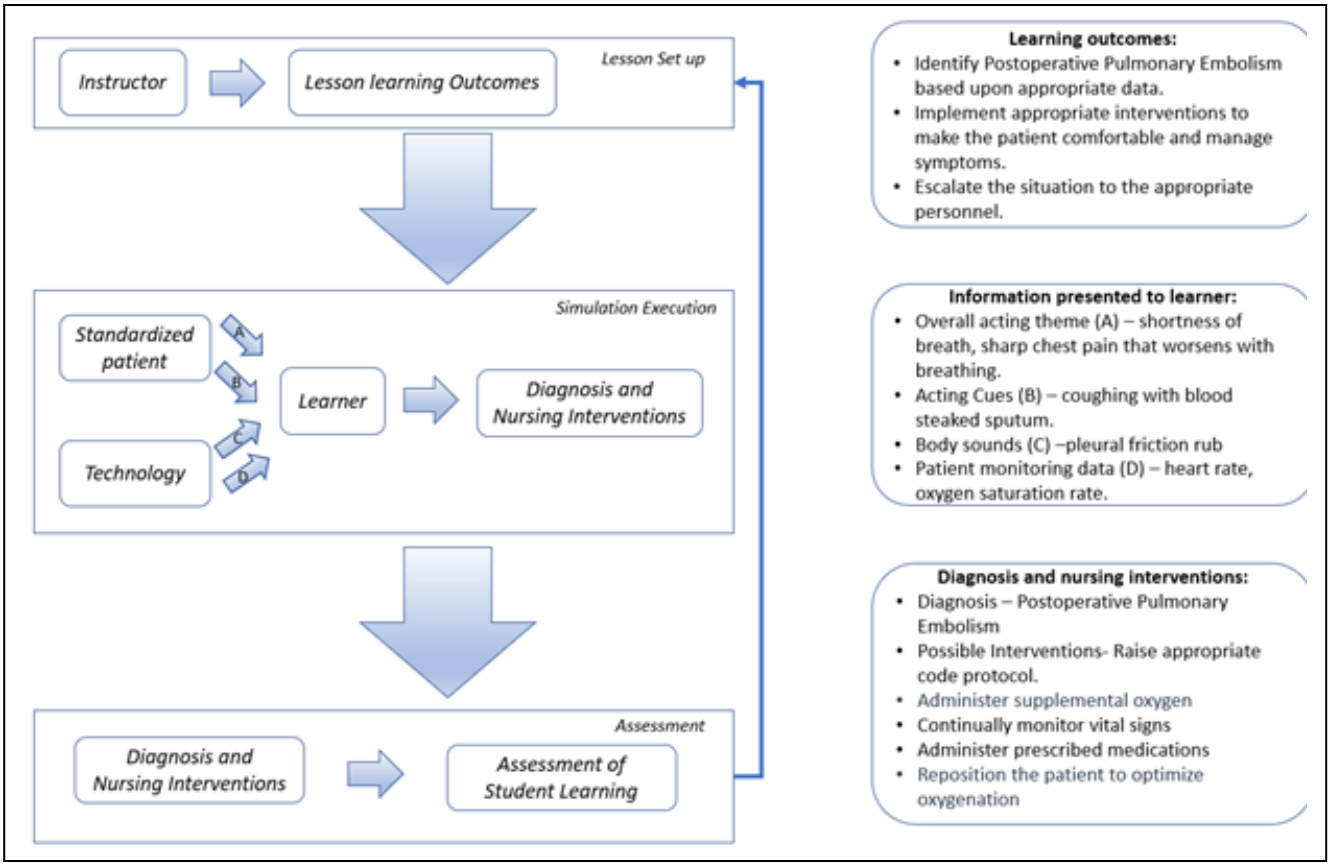

Fig. 3 *Implementation of Postoperative Pulmonary Embolism Simulation*

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Designing the Future: Investigating Budding Instructional Systems Designers' Sense of Agency and Learning in a Multi-cohort Complex Community

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***Abstract*— The field of Instructional Systems Design (ISD) draws from many theoretical models that are organically connected with the learning outcomes. However, in a regular ISD course, students are not given substantial practical exposure to apply theoretical insights. Hence, here we report on an atypical ISD course that targeted a real-life complex task of designing a website for the sensitization of teachers and peers towards disabled students. The participants of the course became the default IS designers, while the Persons with Disability (PwD) Cell of the Institute was the client. The class had people with different levels of expertise and, consequently, was divided into three cohorts- 'X'- had crediting students, 'Y'- had 2nd and 3rd year Ph.D. (auditing) students, and 'Z'- had students nearing graduation/post-doctoral fellows (sitting through). These cohorts were further divided into four groups with members from different cohorts, and tasked with the design of modules on ADHD, Autism, Locomotor, or Visual disability. Motivated by earlier research with the multicohort community, we were interested in investigating younger members' (cohort 'X') sense of agency and learning. We used a 'social practice theory' lens to conduct clinical interviews with all the 'X' cohort students and a few 'Y' cohort students (n= 10 + 4= 14). The qualitative data was analyzed using grounded theory methodology which suggests that the 'X' cohort students were able to exercise their agency while creating a troubleshooting space for their learning to flourish. The course's design and conduct have implications for both ISD practitioners and researchers.**

Keywords*— *Sense of agency, complex community, instructional systems design, grounded theory, problem-solving, training modules

I. Introduction

At the heart of any pedagogical reform lies the development of well-designed training modules or instructional resources that can be effectively and efficiently conveyed to the target audience. For instance, all curriculum reforms are hinged on large-scale teacher training programs, for say, the inclusion of ICT in education [1], upkeep of mental health [2], professional development [3], etc. Given the range of its impact, the design of the training modules is, therefore, a critical aspect that needs a systematic engagement with the needs of the target audience. Thus, the field of Instructional Systems Design (ISD), drawing heavily from different models and theories, utilizes a 'systems' approach, the practical origins of which can be traced back to the deployment of Systems Approach to Training (SAT) models by the US military [4].

Within the dynamics of the changing world, catering to the needs of diverse groups of people, embedded in complex environments, the role of IS designers is both far-ranging and challenging [5]. Multiple studies have been conducted to understand the challenges, constraints, and contextual issues that IS designers face at their workplaces [6]. A major challenge identified in the process concerns taking cognizance of the client's needs and mapping them onto the multiple small decisions that the IS designer must make [7]. A prime reason behind this challenge could be tracked down to the way the ISD courses are taught. For instance, [8] argue that the models used in the ISD courses do not draw from the field's practice and that the ISD practitioners' implicit knowledge needs to be translated back and integrated into the teaching courses.

This gap between the theory and the practice of the ISD field could be bridged by exposing budding IS designers to a real-life IS designer's task during the running of the ISD course. This would mean that students are exposed to the process of need analysis, have first-hand experience of undergoing the pressure of 'delivering' the product, and, of course, go through the rigor of content development, all in a limited time frame. A significant consequence of this process would be on students' concept of 'self', where they might experience a shift in their sense of agency as they get to perform a role that could bring about a change in the outside world, similar to the work of 'real' IS designers [9].

In a typical ISD class, the theories and models are learned individually, but in the field, it is mostly a team's effort that goes into the design process. Further, collaborative processes for design have been shown to be more successful than individual

processes [10], and working in collaboration is reported to be more effective for learning than working individually [11]. However, it is also reported that collaborative work makes more sense to 'low individual achievers' and to 'high team achievers' [12] and there's always a risk that low achievers could become passive in the presence of high achievers [13].

Being 'passive' in a group problem-solving exercise would mean that students score low on exercising their sense of agency, i.e., they no longer feel responsible for the task [14], have a low sense of ownership, are not confident about their learning, and consequently make a low contribution to the intended outcome [19]. Since this study is contextualized in an ISD course that had the responsibility of letting primary learners gain first-hand knowledge about IS models and theories, and since these learners were embedded in a multi-cohort community of members with diverse experiences and expertise, we were curious to investigate the agentic experiences of the young learners.

Hence, we engaged with students' sense of agency and learning as they set out to solve a real-life problem of designing a website for the sensitization of teachers and peers towards disabled students. The study involved groups of individuals placed at varying levels of expertise in the course which used a real-life design problem to expose students to both theoretical and applied aspects of the field. The design task was divided into modules which were assigned to four different groups of participants. These participants with varying expertise had different expectations from the course, some were crediting, some were auditing, and the rest were just sitting through (see Section 4 for details).

II. Sense of agency (SoA), Community, and learning

The psychological perspective of agency refers to the association between a voluntary action and an outcome or the feeling of controlling external events via one's actions [14]. In contrast, a sociocultural perspective of agency would refer to the socially mediated process that is constrained and enabled by the structures available to an agent [15]. In both these aspects, the belief in one's efficacy or the belief to effect change is one of the key mechanisms for exercising agency [16]. In this study, we are using explicit measures to assess different aspects of this belief and we call them the 'agentic experiences' of participants. These experiences are about solving the design problem, and about participants' learning during the design process while being embedded in a complex social community.

The study of learners' agency is quite popular in the research literature [17], However, within the specific domain of ISD, studies have reported on different forms of agency that are visible in the ISD practitioners and not ISD students. For instance, [9] have identified interpersonal, professional, institutional, and societal agency based upon practitioners' sense of commitment and control of actions pertaining to self, profession, their places of work, and society at large. Further, the concept of agency has been known to be at the core of successful execution of projects and learning. However, with no studies done with ISD students, it is hard to construct a theoretical trajectory of how this sense of exercising agency develops and further, how it might contribute to their learning and problem-solving. Hence, in this study, we are focusing on investigating different aspects of 'interpersonal' agency which is known to impact learning [9].

In the practice of ISD, a team of designers forms a community of practitioners who collaborate with each other on multiple steps of the design task and use each other's experiences as a learning resource to make sense of the problem at hand and troubleshoot the problems they face [18]. In the context of the present study, the participants placed at different levels of expertise in groups would form this 'community', and we will be looking at the interaction between the members within the groups and how their interaction influences the sense of agency of the junior members in the group.

To map participants' agentic experiences, we report on their sense of control, which can be defined as the feeling of initiating and being responsible for an action [14], sense of 'ownership' which is the feeling of 'mineness' or the feeling that something 'belongs to self' [19], sense of 'confidence' which is the belief of being able to achieve intended outcomes [16], and the sense of 'contribution' which concerns the judgment of one's share of work in the completed task [19]. To map participants' learning, we use grounded theory to identify themes in their self-report on different aspects of interaction with the community members, like focusing on the effect of being placed in a group with different academic levels of expertise, and the way they handle conflicts and disagreements and how it impacts their reaching of the intended goal. Since the IS literature reports the need to integrate implicit learnings from the practice into the course [8], we also focus on identifying aspects of participants' interaction that might mirror the implicit learnings made during any IS practice and, thus, our work also seeks to inform the IS community about such practices.

III. Theoretical framework

We use the theoretical framework of 'Social Practice Theory' [20] to capture the processes of junior participants' interaction within the multi-cohort group community, and, further, assess the impact of this interaction on their agentic experiences and learning. Social Practice Theory (SPT) has a central focus on participants' actions/interactions, which are made explicit in the form of gestures, speech, etc. The emphasis on differences among the participants is made explicit via the struggles and conflicts that appear during the interaction, and through the shaping of participants' actions around these differences. Using the SPT lens, we seek to understand how the junior members' agentic experiences are shaped by their interactions within the group community and how they are set on the path of becoming 'practice-ready'.

Situated within the interactive process, we also use the lens of 'contested' spaces [21]. Contested spaces are formed during the moments of interaction when participants question and challenge each other's ideas and processes in a community. The construction of a 'contested' space is a dynamic process that is mediated by the agentic moves of the participants, which in turn, shapes their sense of agency. We use this lens to uncover points of conflict and discussions with the group community that might have shaped participants' agentic experiences.

IV. STUDY CONTEXT

The present study draws from the running of an ISD course, which was offered by the Educational Technology program of the Institute during the spring semester of January-April, 2023. The course followed constructivist values by aiming to promote students' autonomy, providing relevant learning context, embedding reasons for learning in the problem-task, supporting learners' self-regulation by giving measured responsibility, and strengthening the learning process by enabling feedback on the designed product [22]. In the beginning, the instructor shared the goal of the course with the students as-

"To create awareness among the functionaries of higher education about the specific educational needs of differently-abled persons".

This larger goal was translated into an ISD task which involved designing a website, composed of different training modules, for the sensitization of teachers and peers towards disabled students. The training modules involved focus on four different forms of disability- Autism, Locomotor disability, ADHD (Attention-Deficit/Hyperactivity Disorder), and Visual disability. The students of the course were the default IS designers and the Persons with Disability (PwD) Cell of the Institute was the client.

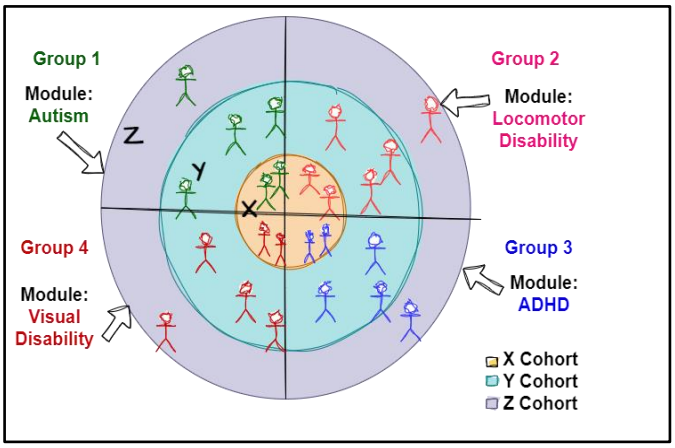

Figure 1. Illustrative visualization of the ISD class structure. Adapted from instructor's notes.

In addition to using a real-life ISD task for teaching disciplinary models and theories, this course was also atypical in its structural composition (see Figure 1). It was conducted in a hybrid mode and was open to all in the department who were interested in participating in the task. As a result, around 25 people, placed at different levels of expertise, participated in the class. To focus on the primary recipients of the course who were the Masters and the first-year Ph.D. students crediting the course, and to efficiently manage the conduct of the course, the instructor divided the class into three cohorts- X, Y, & Z. The 'X' cohort comprised of the primary recipients- students crediting the course, 'Y' comprised of the 2nd and 3rd year Ph.D. students, and 'Z' comprised of students nearing graduation and post-doctoral fellows. Further, the three cohorts were divided into four groups such that each group had members from all three cohorts. Overall, there were 5-6 members in each group, and the four groups were responsible for the development of the modules on Autism, Locomotor disability, ADHD, and Visual disability, respectively (Figure 1).

Situated in such a complex community of participants, there was a high risk of the 'X' cohort students, the youngest on the experiential scale and the budding IS designers in this study, to be overwhelmed by the presence of 'Y' and 'Z' cohorts in their groups. Also, with more experienced others in a group, it is not unnatural to let the sense of responsibility for the completion of a task at hand get diluted. Hence, being cognizant of the diversity in the attendees of the course and maximizing the learning opportunities for the crediting students, the instructor of the course pre-defined the roles of all cohorts at the beginning of the course by elucidating the learning objectives for all the cohorts (Table 1).

TABLE I. INSTRUCTOR'S OBJECTIVES FOR THE DIFFERENT COHORTS

Cohort	Learning Objectives (LOs)
X	Same as the objectives specified for the course. They should be able to apply ID models, create content, design small-scale instruction units, etc.
Y	Learn to plan larger-scale ISD training programs Gain mentoring skills- what prompts and scaffolds to provide to Cohort X for them to attain their (LOs) Gain teaching skills- by observation and practice (conducting workshops)
Z	Planning of courses- Making connections across topics Reflecting on the instructor's actions for their own teaching Improving mentoring skills by providing support to X and Y when required.

The learning objectives shown in Table I helped all the participants of the course to establish their commitments and manage their expectations from the course before getting to the real-life ISD task of designing training modules. However, since the task was to be performed in groups comprising members with diverse expertise and experience, there was a concern about the exercise of the sense of agency of cohort 'X'. This concern is based on earlier research findings which have suggested that younger members' sense of agency is reduced in a group with more experienced members [23].

Hence, in this study, we were curious to look at how 'X' cohort students exercised their sense of agency as they worked together with more experienced others while working on the module design task to be delivered within a limited time frame.

Specifically, our research questions were-

- RQ1- What was the 'X' cohort students' perception of their sense of agency as they performed the ISD module design task while being embedded in a complex multi-cohort community involving peers and seniors with differing levels of expertise?
- RQ2- What are the salient features of 'X' cohort students' interaction with the other cohorts?
- RQ3- How did the interaction with the other cohort members influence the learning of 'X' cohort students?

V. METHODS

A. Research Design

We use a grounded theory methodology which is appropriate when the purpose of a study is to construct an explanation grounded in the data to illuminate the processes involved in the focus of inquiry [24]. The focus of inquiry in the present study is measuring the agentic experiences of the 'X' cohort while being embedded in a multi-cohort community. To draw meaningful interpretations of the findings, we use the principles of grounded theory (GT) by systematically studying the processes in the time period pertaining to the exercise of different measures of agency by the 'X' cohort students [25].

In the design framework for using GT, the method and processes are intertwined and the analysis involves a non-linear pathway where the processes are 'recursive' and 'iterative' [26]. In the context of this study, we systematically analyze the process of Cohort X's interaction with other cohorts to reveal the quality of empirical relationships that emerged during their interaction and which contributed to the quality of exercise of different aspects of agency [27].

B. Participants

A total of 14 participants (8F, 6 M; Mean age = 30.33 years, SD = 4.27) were interviewed for the present study of which 4 (all females) belonged to the 'Y' cohort and 10 (6 males, 4 females) belonged to the 'X' cohort. All students were pursuing their Masters or Doctoral degrees. All the 'X' cohort participants were crediting the ISD course, while most of the 'Y' and 'Z' cohort participants were either auditing the course or were just sitting through the course. The motivation for being a participant in the course varied across the cohorts and within the groups.

C. Data Sources and Analysis

Semi-structured clinical interviews were conducted with all 14 participants individually, and each interview lasted for around an hour. The interview questions were divided into three sections, focusing on identity, sense of agency, and the community of co-designers-cum-learners. The interviews were conducted after the students presented and handed over the designed modules to the instructor. For the present study, we have used data from only the last two sections of the interview. The video and audio recordings of the clinical interview form the primary data sources for the present research study.

The interview videos were first run through the 'Otter' application to generate transcripts which were then cross-checked for language, grammar, and authenticity by the authors. The corrected transcripts were then coded to identify emergent categories by the researchers. The process involved constant back and forth among datasets to discover patterns in students' responses. We used the 'constant comparison method' of GT which involves continuously analyzing and examining the data collected to explain the emergent themes of interactions that had an impact on the 'X' cohort's learning process [28].

VI. FINDINGS

A. Students demonstrated higher scores on different measures of agentic experiences.

Under the section of agency for the clinical interview, students were asked direct questions about their sense of 'contribution' to the overall group task of module design, their sense of 'ownership' concerning the designed product - the webpage, their sense of 'control' during the design task and their 'confidence' to take on another similar design project. Students used a Likert scale rating to report on these measures. Figure 2 depicts bar plots of the average scores of students' responses to these measures of agentic experiences.

1) Sense of Contribution

Students were asked to rate their sense of individual contribution to the building of the PwD website. They were asked to rate their contributions on a Likert scale from 1-5, where 1 referred to 'zero' contribution, 2 referred to 'not much' contribution, 3 referred to 'neutral' or 'not much, not less' contribution. 4 referred to 'quite substantial' contribution, and 5 referred to 'extremely substantial' contribution to the building of the PwD website. The mean score of students' perception of their contribution to the task was 4.107 (SD = 0.79), suggesting a higher sense of contribution to the task (first bar from left in Figure 2).

2) Sense of Ownership

Students were asked if they had a sense of 'ownership', i.e., if they had the feeling that it was their own work when they looked at the built website. They were asked to rate their sense of ownership on a Likert scale with ratings from 1-5, where 1 referred to 'certainly not my work', 2 referred to 'not my work', 3 referred to 'neutral' or 'unsure about my ownership', 4 referred to 'partly my work', and 5 referred to 'completely my work'. The mean score of students' perception of their ownership concerning the built PwD website was 3.96 (SD = 1.008), suggesting a slightly lower sense of ownership than their sense of contribution to the task (second bar from left in Figure 2).

3) Level of Confidence

Students were asked about their level of confidence concerning their fluency in the execution of another similar task of designing a training module for a relevant stakeholder in the near future. They were asked to rate their level of confidence on a Likert scale from 1-5, where 1 referred to a 'very low' level, 2 referred to a 'low' level, 3 referred to a 'moderate' or 'not low, not high' level, 4 referred to a 'high' level, and 5 referred to a 'very high' level of confidence in executing a similar task on designing a training module. The mean score of students' perception of their level of confidence was 4.143 (SD = 0.663), suggesting a relatively higher perception of confidence than on the agentic experiences of contribution and ownership.

4) Sense of Control

Students were asked about their sense of 'control', or the feeling that they were driving the project in their group. They were asked to rate their sense of control on a Likert scale from 1-5, where 1 referred to 'no control', 2 referred to 'limited control', 3 referred to 'neutral' or 'unsure about the level of control', 4 referred to 'some degree' of control, and 5 referred to

'full control' concerning the driving of project in their group. The mean score of students' perception of their sense of control was 3.58 (SD = 0.736), which reflects the lowest measure of agentic experiences with respect to the level of confidence, sense of contribution, and sense of ownership in that order.

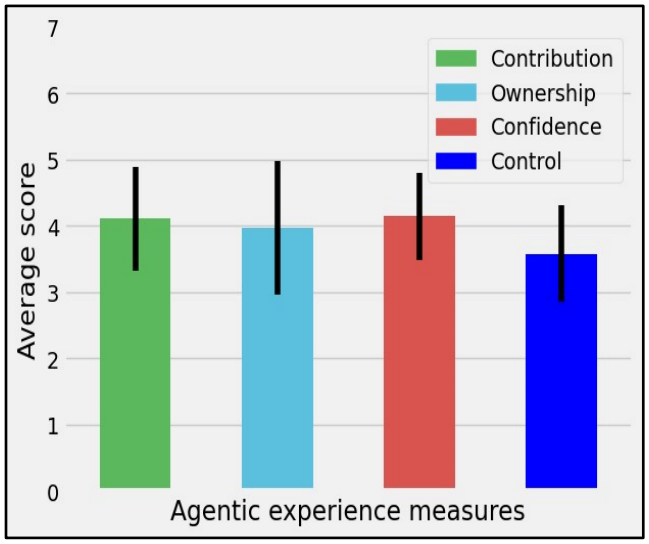

Figure 2. Students (n=14) perception of their agentic experiences. The X-axis depicts different measures of agentic experiences, while the Y-axis plots the average score of students' 5-scale Likert ratings (Maximum score = 5) about their perception of 'contribution', 'ownership', 'confidence', and 'control' concerning the task of designing the PwD website. The error bars represent the standard deviation.

As visibly evident from Figure 2, a one-way ANOVA comparing the means of the four measures of agentic experiences was not significant (F= 1.415, p = 0.249), suggesting that students' experience with different measures of the agency was more or less similar and that, the multi-cohort learning environment did not impede their sense of agency, rather students experienced a strong sense of agency as they navigated the problem-solving process.

We also compared the self-reports of students from both 'X' and 'Y' cohorts on the measures of agentic experiences. Table II compares the mean and standard deviation of students' responses to different agentic measures. Our Likert scale interpretation considered a score ranging from 1-1.80 as being 'very low', 1.81-2.60 as 'low', 2.61-3.40 as 'neutral', 3.41-4.20 as 'high', and 4.21-5.00 as 'very high' measure of experience. From Table II, we find that all mean scores correspond to a 'high' sense of agentic experiences, except for the measures of 'contribution' and 'ownership' for 'Y' cohort students, which are reported as 'very high' (mean scores above 4.20). Further, the table also reveals a high degree of variation in responses of students from the 'X' cohort in contrast to the 'Y' cohort (SD higher than 0.80) for all measures except on 'confidence' where we see a reverse trend, i.e., the 'Y' cohort has a higher variation than the 'X' cohort.

TABLE II. COMPARISON OF COHORTS 'X' AND 'Y' SELF-REPORTED LIKERT SCORES ON DIFFERENT AGENTIC EXPERIENCES.

Agentic Experience Measures	**Cohort X (n=10)**		**Cohort Y (n=4)**	
	M	**SD**	**M**	**SD**
Contribution	3.95	0.83	4.5	0.58
Ownership	3.85	1.16	4.25	0.5
Confidence	4.2	0.63	4	0.82
Control	3.58	0.85	3.59	0.43

Thus, our findings from this section answer our RQ1 and suggest that students from both the 'X' and 'Y' cohorts had a high sense of exercising agency as they performed the ISD module design task while being embedded in a complex community involving peers and different cohorts. This is also evident from students' explicit responses from the clinical interview. For instance, Student 8 ('X' cohort) shared- *"I was able to express myself at all times"* (sic).

B. *Students' responses suggest instances of both conflicts and support during interactions with other cohorts.*

The transcripts of the semi-structured clinical interviews were coded to identify different themes of interaction that emerged within groups during the problem-solving task. The qualitative analysis revealed that the 'X' cohort students' experiences with the other cohorts could broadly be categorized under 'conflicts and disagreements' and 'agreement and support'. Below we describe these broad categories of interactions through various instances and give evidence from students' (n=10) responses.

1) *Conflicts and Disagreements*

- Time: 'Time' was one of the major factors that led to disagreements or conflicts. Finding common slots for meeting outside the timings of the scheduled class to make progress on the project was hard. For instance, an 'X' cohort student revealed that her peers had almost little to no interaction with the 'Y' cohort members in her group. She said-

  "*But for them, I thought it was more of (an) optional thing..less outside the class as the timings were not matching for doing the task."* (sic).

  Here, the student also alludes to the less work pressure on the 'Y' cohort students as they were not crediting the course.

- Delayed Feedback: The timing of the feedback provided by the other cohorts was also crucial. So, for instance, an 'X' cohort student shared that it was 'frustrating' to receive delayed feedback from seniors. She elaborated-

"*We developed the whole thing and then the feedback is coming. So that is very demotivating for us because we dropped two videos like that which we created… but at the end it was like no, it is not going with the context or the script is not that great. So that was.demotivating*" (sic).

An interesting aspect to note here is that even though the 'X' cohort students found the delayed feedback to be frustrating, they agreed and followed the suggestion, notwithstanding the loss of their effort.

- Selection of content: The selection of concepts and ideas that eventually become part of the project outcome is both a consequential and contentious aspect of group interaction. This was visible in the 'X' cohorts' group interaction as well. For instance, a student explained-

  "we sure did have a lot of discussions..primarily related to the language.. because we had to be sure…about what that language communicates…So those kinds of discussions… So that was the result of that don't dismiss everything. So I wouldn't say conflict, but the battle of ideas" (sic).

2) Agreement and Support

In addition to the above instances of disagreements and conflicts, 'X' cohort students also reported agreement and support from the other cohort members. Below we discuss a few of these categories of interaction.

- Accountability: One of the many ways in which senior-junior interactions pan out, in reality, involves juniors being accountable for their actions to their seniors. Although there was no said rule to this effect, we found many 'X' cohort students admitting to being 'answerable' or 'accountable' to the senior cohorts. And, this role was shared in a positive light. Thus, one student shared-

  "There should be someone who can remind us time to time okay, this is what we have done and this is what we have done. So that control.sort of accountability was present." (sic).

  Dictated by the social norms of interaction, this sense of accountability was used as a tool to make progress on the project by the younger cohorts.

- Discovery of qualities: In a group problem-solving task, we may not always be assigned tasks that match our strengths, rather these decisions might be taken based on the demand of the time and the pressure of the deliverable. The dynamicity of group interactions at times leads us to recognize and acknowledge hidden abilities and talents both within ourselves and in other team members. This discovery of quality facilitates the learning process by adding to our experiential repertoire. A few 'X' cohort students also admitted to discovering new abilities during their group interactions. For instance, Student 1 shared-

  "*He made me do things that I generally otherwise don't do. He's a good leader"* (sic).

- Camaraderie: Increased frequency of interactions during a group task helps us to familiarize ourselves and connect with other team members. This step is crucial first in developing a sense of camaraderie and bonding within a community. We found that our real-world ISD task led senior cohorts to engage and connect with the younger cohorts. For instance, a senior student shared-

  "This course also helped me in getting to know first years closely" (sic).

Thus, our findings from this section answer our RQ2 where we found that the salient features of 'X' cohort students' interaction with other cohorts involved instances of both conflicts-disagreements and agreements-support.

C. Influence on learning due to the interaction with other cohorts

The interactions with other cohorts during the ISD problem-solving task contributed to both conceptual and social learning for younger cohorts. Their learning resulted from and was grounded in both conflicts and agreements that they experienced during their interaction with the other cohorts. Below we discuss such instances of learning.

- Learning from conflicts and disagreements.

  a) Managing expectations: Due to the mismatch of 'time' slots availability, the younger cohorts taught themselves to step up their work and since they were crediting the course, they felt more responsible. For instance, an 'X' cohort student shared-

  "So, things didn't match with them (seniors in the group) *and we didn't expect much from them*" (sic).

  b) Rules for interaction were designed: Having faced the 'frustration' arising due to the delayed timing of the feedback where the 'X' cohort had to discard their earlier work, they took charge and designed a new rule for interaction to solve the 'delayed feedback' problem. An 'X' cohort student shared how her group came up with a rule to handle the conflict –

  "Sometimes like your 'Y' cohort is saying this and 'Z' cohort is saying that. So for that..we come to..one ground - whenever meeting will happen all cohort will be there. So that anything will not be missed." (sic).

  With the new rule in place, everyone from the group had to be present for the group meeting, thus saving and optimizing everyone's efforts.

  c) Discussions: With conflicts concerning the selection of content, the groups worked around by actively engaging in discussions about different suggestions and evaluating the suggested concepts based on the requirements of the deliverable, as emphasized by the client. Thus, a student shared-

"*So since people…bringing their different perspectives..also have a different way of perceiving…we have like a back and forth going on with each idea whether we have to put it…whether it is conveying the appropriate message or not."* (sic).

- Learning from agreements and support.

  a) All ears! Open to corrections: Being 'accountable' to the seniors meant that the younger cohorts were quite attentive to the suggestions that came from seniors. For instance, Student 4 shared-

  "I would say when we ('X' cohort) *were coming up with ideas, we may have some sort of biasness (biases) with that so they* (other cohorts) *were the ones who were actually helping us to come out of that biasness and look at it from a different perspective. So their feedback was very helpful."* (sic).

  An interesting thing to note here is the 'openness to learn' with which the younger cohort approached the suggestions from the seniors.

  b) Learning about new concepts and ideas: Just as individual qualities were discovered during the process of interaction, similarly students were exposed to new ideas and concepts. These concepts/ideas added to the experiential repertoire of the students and, likely, facilitated learning. For instance, Student 11 shared-

  "I think, intellectual ideas… during discussions, the point of view that seniors bring in…helped us drive the conversation..I think the GIF idea (example of an idea that came from a 'Y' cohort member)..*a few unique ideas for sensitization I received from the seniors"* (sic).

  c) Sense of teamwork: Building on the camaraderie that was developed during the process of interaction in the problem-solving task, students developed a sense of 'team' which is known to play a role in developing identities and strengthening the sense of belonging within communities. For instance, Student 3 shared-

  "When I see the website, the faces of my all peers, you know, that is also there. So my individual work, maybe maybe that is there, but when I see the website, whole team comes" (sic).

Thus, our findings from this section answer our RQ3 where we found that the 'X' cohort students' interaction with the other cohorts had an impact on their learning which was both social, like making new rules to mitigate conflicts, and conceptual, like learning of new concepts/ideas (viz., using GIF) to develop content for the design of a training module.

VII. DISCUSSION AND IMPLICATIONS

In summary, in response to RQ1, we found that even in the presence of senior members, the 'X' cohort students could retain their agentic experience or exercise interpersonal agency [9]. With our findings corresponding to RQs 2 & 3, our use of grounded theory methodology helped us reveal the finer aspects of the 'X' cohort students' interaction with other experienced members of the group and their learning which might have played a role in their exercise of agency.

The Likert scale measures provide insights about 'X' cohorts' perception of different measures of agency. The comparison of the 'X' and 'Y' cohorts also suggests that the 'X' cohort's response was almost at par with those of the limited datasets of the higher cohort. However, the two cohorts differed in the degree of variations that were visible overall, i.e., the larger standard deviations in the 'X' cohort suggest that a strong sense of agency is not uniformly distributed across the 'X' cohort. Still, their lower variations on the level of confidence to execute a similar project and higher mean score suggest that the ISD course was able to meet the larger learning objective that the instructor had shared at the beginning of the course (Table I), which was about applying IS models, designing and creating content for relevant stakeholders.

The theoretical lens of 'social practice theory' [20] and 'contested spaces' [21] led us to use the constant comparison method of grounded theory to develop thick insights about the process of the 'X' cohort's interaction with the other cohorts. Our findings suggest that the budding IS designers' interaction with the senior cohorts was marked with multiple instances of both conflicts and support and that these interactions were connected with their learning at both social and conceptual levels. The recursive and iterative nature of our method led us to draw interrelationships between learners' interactions and learning outcomes.

Our work makes a contribution to the literature on the theoretical development of budding IS designers' or IS students' sense of agency. Further, it creates a basis for comparing the SoA of IS students with the SoA of IS practitioners e.g., [9]. Given the significant role of agency in learning outcomes, our work confirms that the presence of multi-cohort learning environments does not necessarily impede budding learners' SoA. We believe that the role of the instructor was equally crucial in the process as the explicit sharing of the expected roles and learning objectives for different cohorts might have provided an implicit scaffold for directing the actions of all cohort members in the group task. The deliberate and conscious action must have helped manage participants' expectations and establish their commitments and, hence, when the instructor moved away during the group task, the higher cohorts stepped into their expected roles of being 'mentor' (see Table I), while the budding designers actively wore the learner's hat.

The development of the sense of teamwork is a major differentiating factor between students' tasks and practitioners' tasks and our findings suggest that by the end of the ISD course and with the delivery of training modules to the relevant stakeholders, our budding designers were already visualizing the team to be present in the project deliverable. And, thus, we could say that the budding IS designers are 'practice-ready'.

Our work has implications for the design and conduct of the ISD courses. With real-life IS tasks, with a diverse group of participants, and with clearly laid learning objectives, we show that IS students' sense of agency could flourish and that they could still develop the confidence to lead similar IS projects by the end of the course.

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***Abstract*—E-learning is a popular and an effective method of transferring learning content over a virtual platform. Despite the easier access, it still comes with certain limitations. A survey identified four main problem areas in existing learning management systems: maintaining concentration during online lectures, preparing for exams, dynamic question generation, and addressing language barriers for non-native speakers of English language. Students needed a method to maintain their concentration and measure their progress throughout the online lectures. An automated process for evaluating student answers is ideal when preparing for exams. A random question generator can identify important areas and formulate questions based on them. A text simplification component can be implemented by training a model on input texts using reinforcement learning techniques. The goal is to implement a software solution, EduXpert that provides these functionalities to increase effectiveness in distance learning. The software will be designed to cater to the needs of non-native English speakers and improve the overall learning experience.**

Keywords— learning management system, dynamic question generator, speech recognition, face recognition, web scraper.

I. INTRODUCTION

EduXpert is a new software solution that enhances distance learning efficiency by allowing students to track their progress and self-assess themselves. It addresses challenges in online learning and provides tailored services like a Study tracker, question generator, viva automation tool, and document simplifier. The platform aims to fill gaps in existing learning management software systems, ensuring students can comprehend knowledge as receivers.

A. Study Tracker

Students may study, memorize, and take notes in the method that works best for them by using the website we provide. The same natural language processing (NLP) technology that translates transcripts may be used to help you memorize material, take notes, and create a transcript. Every translated word from speech to text is then verified for grammar errors using an API. We will highlight the key points in a book and make it easy for students to highlight them in the transcript itself by allowing them to input and record the sort of comments they want into the created transcript. Everything that professors cover in class can be found as a text and studied at your own pace with a transcript.

Lastly, the newest addition is the ability to monitor kids' concentration levels by tracking their eyes and faces as soon as they begin watching the movie. Students who look away from the camera will see a message reminding them to focus on the lesson displayed on their screen.

B. Question Generator

As exams approach, students' anxiety levels rise. To address this, an AI-powered question generator is proposed that can generate their own questions, helping students identify unclear aspects and topics to review. Current machine learning question generating systems cannot produce novel questions, as they construct question papers from a question bank and grade them based on difficulty. The proposed research will explore the qualities of existing question generators and propose an AI-powered question generator that can pick out important phrases from class notes. This technology generates brief summaries of lecture notes automatically, helping students' study. The system recommends more lecture notes and materials for users to review after uploading one, broadening their understanding and aiding in job search. This approach will be crucial as students prepare for exams and prepare for their exams.

C. Viva Automation Tool

Cheating, or academic misconduct, is a serious problem with giving tests and exams online. The use of distance education to cheat on exams has expanded dramatically considering the current pandemic of COVID-19 [1]. As a solution to this problem, instructional platforms and resources have been developed [2], [3]. The survey results reveal that students, even aware of their potential cheating, still attempt to cheat. This dishonesty necessitates oral examinations to assess their knowledge. If a student fails to answer viva questions, it's likely they engaged in cheating. The study suggests that individual skill assessment through viva sessions can be effective in detecting cheating. [4] The large number of students in viva sessions makes it challenging for examiners to manually evaluate each student and may lead to less attentiveness towards questions. Modern technology

could automate this question-and-answer procedure, eliminating the need for human intervention. A suggested software solution should use facial detection and recognition to easily identify participants, and real-time object recognition for crowd detection. Natural Language Processing methods can read in student responses via audio input, comparing responses to appropriate options, and automatically calculating and awarding grades. This would eliminate the need for human intervention in viva sessions.

D. Document Simplifier

The rapid advancement of technology has made job sectors more challenging, necessitating continuous selflearning. However, access to learning materials is limited due to language barriers, as English is not the primary language in most countries.[6]. The proposed method aims to address the challenges faced by non-native English speakers in communicating, by replacing difficult English terms with simpler words. This approach reduces the learner's reading pace, energy consumption, and disrupts the study. It also provides a simplified text, allowing users to read study materials without interruption. The proposed method is inconvenient and energy-consuming, making it a more effective solution for non-native English speakers. difficulty.

II. BACKGROUND STUDY AND LITERATURE SURVEY

Online instruction for most students and university students began in late 2019, but students are losing interest due to the platform's online nature and teachers' reluctance to prioritize it [7]. And because of the length of the lesson, the unwillingness to listen to it, and the difficulty in assimilating some of the information [8]. Online learning presents challenges for students as teachers often provide less attention, making it difficult for them to track their progress and receive necessary support [9] Online learning can be a rewarding experience, but students may need time to adjust. Comparing their class test scores to those after online learning can demonstrate this, as students often struggle with taking notes and paying full attention [10]. An automated question generator can convert administrative input into a Bloom's taxonomy-based exam format, allowing students to evaluate their learning abilities. This multi-agent system uses agents to generate questions, classify data, and handle documents. It replaces the time-consuming process of conducting physical viva sessions and requires real-time object recognition, trained on various datasets. Technological advancements simplify the process [11] Detecting objects in real time using techniques like YOLO and RCNN is challenging. YOLO is the most famous algorithm, with two types of detectors: one stage and two stages. It allows for the classification and name of all moving and stationary objects in a single step. YOLOv5 is more accurate than YOLOv4 and YOLOv3, and the detection speeds are equal for all detectors. Both YOLOv4 and YOLOv5 have been used as comparison tools. [12]. YOLO uses a loss function equation to boost confidence [13] Open Educational Resources (OERs) can reduce costs and address educational disparities, but 86% require advanced English proficiency, potentially impacting students' learning experience. [14]. Despite various methods for simplifying texts using basic English phrases, no system has been developed that integrates lexical simplification with a reinforcement learning strategy for continuous performance improvement.

III. METHODOLOGY

A. Study Tracker

The proposed component uses speech recognition, natural language processing, face recognition, iris recognition, and pupil detection to aid students in class engagement and ensure accurate pronunciation. It addresses spelling issues in transcripts through an API. [15] The study tracker component of this system should utilize machine learning (ML) for monitoring tasks. Users can check iris and pupil behavior using OpenCV, compute blink count, and monitor eye movements. OpenCV can also be used to monitor face expressions and motions. Pretrained models can be integrated into supervised learning for detection on both faces and eyes. The data set supplied by OpenCV is used for iris and face recognition, with pre-trained classifiers called haarcascade xml files. Students' GitHub-provided xml files can also be used to The proposed component aims to identify facial gestures using React, Python, OpenCV library, Laravel, MySQL, and Google Drive, with a user interface and data storage connected to Google Drive.

- The ease with which everything taught in a video may be converted into a transcript.
- Create and re-establish the option to download and utilize the transcript as a word document, with or without changes.
- Students' eyes and faces will be identified from the start of the video, and if their eyes and faces move during class, it will be reported.
- If this is the case, a notification will show on the screen.

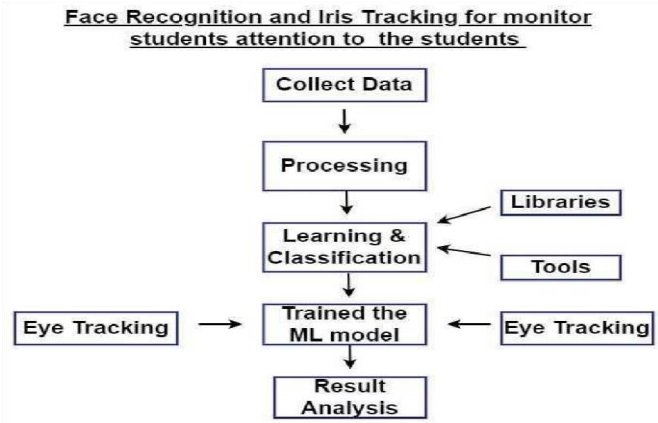

Fig. 1. Flow of Eye Tracking

B. Question Generator

The proposed system aims to assist students in generating theoretical questions from their lecture notes by providing brief notes and automated assessments. This method is commonly used in schools and universities, allowing for the creation of exam papers at any time and place. It can be beneficial for multiple-choice and radio button questions, allowing for more efficient and effective learning.

- Using lecture notes to generate brief notes
- Using Google to generate lecture subject suggestions

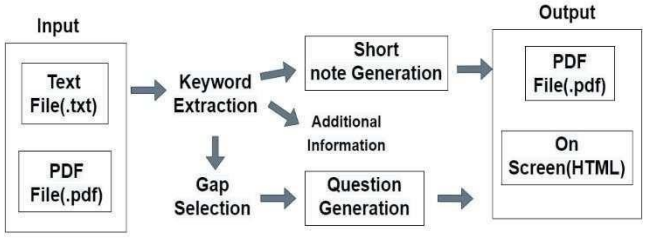

Fig. 2. Quick Note Assessment

The proposed component utilizes natural language processing to assist students in future study sessions, ensuring that this intelligent system can handle these tasks effectively, making it a valuable tool for students.

- Recognizing important phrases and keywords
- Including noun and adjective phrases in questions
- The system will use machine learning and AI for quick note-taking and automatic evaluation, with a React frontend and Python-based backend, Laravel optional, and MySQL, MongoDB for future features, and Google Drive for data storage.

C. Viva Automation Tool

Face recognition is a method used to identify people by their faces, and the viva automation tool uses real-time facial recognition to authenticate users. OpenCV library, and an API incorporating image processing and OCR, are used to distinguish individuals based on human face features. The initial verification stage uses an accurate API. An examination violation is counted if multiple people are spotted in the background during oral examinations, requiring object detection technology. The YOLO technique, with its single-layer process, is more efficient than the RCNN approach, but its inability to distinguish small objects is not significant in this context.

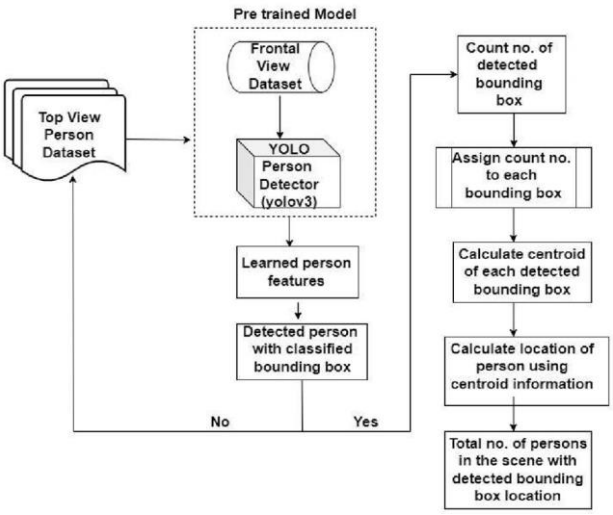

Fig. 3. YOLO algorithm flow diagram.

The Viva Automation Tool will be a database containing theoretical questions and solutions related to modules, with students receiving viva evaluation ratings. The pretrained model can gather the lexical meaning of a complex oral answer and compare it with the correct answer in the database, with the ultimate objective of scoring the student's answer. If the overall matching percentage of the answer is above 80%, it is considered as a correct answer and given a score accordingly. The frontend will be built using React, Python, OpenCV, or Laravel, with MySQL as the database and Google Drive as data storage.

D. Document Simplifier

The system is divided into three main components, each serving a specific purpose, providing a clear understanding of how each component operates.

1) Web scraping system.
   This component enables users to search the internet for learning resources using web scraping. It provides a list of search results, allowing users to select any reading materials from the list, thereby enhancing their learning experience.
2) Natural Language Processing Unit (NLP unit)
   The NLP unit aims to identify complex words in a text, replace them with simpler ones without altering the text's content or grammatically incorrectness, and create a streamlined document for easy user comprehension.
3) Reinforcement Learning Unit
   This component simplifies document searching by searching for new ones and storing them for future reference, resulting in improved system performance and improved overall user experience.

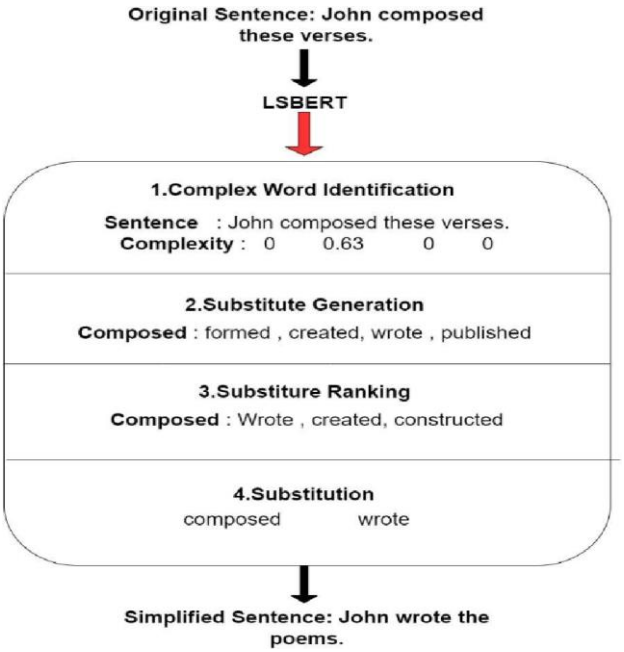

Fig. 4. Overview of Text Simplification process

The Study Tracker uses a React framework for a user-friendly frontend and Python for the backend. Laravel may be used for specific needs, and MySQL is used as the database. MongoDB and Google Drive manage data storage. Python was developed for ease of use and connection to the frontend. Amazon EC2 is used for scalability. The model trained for 3 epochs achieved 0.96% accuracy, and over 30 epochs, 0.99% accuracy, indicating significant improvement in the complex word identification model.

IV. RESULTS

The EduXpert learning management system is a novel tool for distance learning platforms. A user evaluation was conducted focusing on the usability and performance of the application. The system consists of four core modules that run independently, allowing users to explore the interface and test the functionality. The study tracker recorded user interaction and iris tracking, mimicking a virtual lecture session. A survey after the feedback session revealed that 80% of users preferred the overall study tracker component. The viva automation tool was preferred by those who found it intimidating to face oral examinations. The question generator was found to be very useful by users. The system's usability was over 80%, indicating its success in addressing gaps in current learning management systems which are aiding to keep the learner's concentration on the virtual lectures, generating dynamic questions based on the important sections of the lecture content, helping to prepare for examinations by automatic evaluation of answers and bridging the language barrier for the non-native speakers of English language. The system's convenience in retrieving summarized documents was also appreciated by most users. Overall, the EduXpert solution was preferred by all survey participants.

V. CONCLUSION

The 'EduXpert' solution offers four new components to enhance a typical Learning Management System, including a study tracker, quick note and automated evaluation, and a document simplifier. The study tracker gives users the advantage to improve learning capacity though monitored lecture delivering. It also measures students' attention and alerts them when their attention drifts away from the webcam. The device also allows for dynamic quick note generation and automated evaluation of theoretical difficulties, allowing for exam creation anytime and anywhere. The Viva Automation Tool acts as a preparatory assessment tool when preparing for exams. The document simplifier helps non-native English speakers view study materials without restrictions, and the system offers an online search function.

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Evaluating the Effects of Activity-Based Learning on Attainment of Course Outcomes for Third-Year B.Tech Students: A Case Study

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***Abstract*— This article presents a comprehensive case study conducted on third-year B.Tech Biotechnology students who faced significant disruptions in their education due to the COVID-induced lockdown. As a result, they missed out on first three semesters of in-person learning and had to adapt to a sudden transition from online to offline mode of education. Many struggled to cope with the shift from virtual classes to physical classrooms. Lack of familiarity, distractions, and diminished interest were observed, leading to lower grades and reduced academic performance. Therefore, this study focuses on evaluating the impact of activity-based learning on the students' ability to adjust to offline classes and improve their course outcomes. The study examines two courses, to assess the effects of activity-based learning on students' classroom engagement, learning, and participation. The following activities were implemented in the study: game-based learning, LCM model-based discussions, flipped classroom, and various in-class activities. The findings revealed a direct correlation between the number of activities incorporated, and the students' course outcomes. However, the study also identified certain challenges. Students exhibited a lack of self-motivation and required additional incentives to encourage their active participation in the activities. Addressing this issue is crucial to sustain the positive effects of activity-based learning. In conclusion, this case study provides empirical evidence supporting the effectiveness of activity-based learning in enhancing the attainment of course outcomes for third-year B.Tech Biotechnology students. By incorporating engaging activities into the learning process, educators can help students overcome challenges associated with disrupted education and improve their academic performance.**

Keywords—Activity based learning, Course outcomes, Student engagement, Engineering education, Game based learning, Flipped classroom, LCM Model

I. Introduction

The present study focuses on the experiences with the current final year B.Tech students during their prefinal year of study, spanning from July 2022 to April 2023. These students embarked on their college education amidst the challenging circumstances imposed by the COVID-induced lockdown. Initially, their first year commenced online, necessitating the use of gadgets such as mobile phones and laptops. Unfortunately, due to bandwidth issues, students faced limitations in interacting with their peers, rarely being able to see each other during online classes. Moreover, the examination process conducted online presented a potential breeding ground for malpractices and plagiarism. As the college reopened for the fourth semester, students encountered numerous challenges in transitioning to physical classrooms, leading to low attendance rates during the initial semesters. Moreover, distractions posed by the persistent use of gadgets remained a prevalent issue, hindering their engagement in class. Subsequently, a recurring pattern emerged where students failed to submit assignments, often attributing their inability to participate in learning activities to the repercussions of the COVID-induced lockdown. Consequently, instructors were compelled to devise innovative techniques to enhance student engagement within the classroom. The adoption of hybrid learning approaches aimed to address the students' low participation levels in activities and assignments. This study explores the impact of these strategies on improving student engagement and participation, as well as their academic performance.

The COVID-19 pandemic has profoundly disrupted the field of education, necessitating a swift transition to online learning to mitigate the impact of lockdown measures [1]–[3]. However, recent reports [4],[5] have shed light on the challenges faced by students in higher education, including increased anxiety, loneliness, and other mental stresses arising from the COVID-induced lockdown, especially among UG students [6]. While studies conducted in other countries, such as Peru, have shown significant improvements in academic performance during online learning, this was often attributed to the suspension of other activities, allowing students to focus solely on their studies [7]. In contrast, in India, where most students are primarily focused on academics and do not have part-time jobs, this aspect may not yield similar results.

Online learning platforms have demonstrated benefits for introverted learners, with some individuals opting to remain as "digital residents" in these environments [8]. However, it is worth noting that not all students favor online learning, leading to suggestions of integrating offline elements to create a more holistic educational experience [9], [10].

Various studies have highlighted the positive impact of gamification on engineering students' motivation, academic performance [11], [12] and problem solving skills 13]. Additionally, the use of online and offline case discussions has proven effective in enhancing learning outcomes in computer science postgraduate courses [14]. Interactive activities implemented through Jupyter Notebook have shown promising results in improving academic performance and engagement among Chemical Engineering students [15]. Similarly, collaborative learning approaches have yielded improved test results for Mechanical Engineering students [16], [17].

In light of these observations and the unique context of the current study, it becomes imperative to explore the impact of activity-based learning on the adjustment, engagement, and

academic outcomes of third-year B.Tech Biotechnology students. By addressing the challenges of disrupted education and leveraging the potential benefits of interactive learning approaches, this study aims to provide insights into effective strategies for enhancing students' educational experiences, academic achievements, and ultimately, the attainment of course outcomes (CO).

II. METHODOLOGY

A. Student Groups

The participants in this study were the pre-final year B.Tech Biotechnology students, who are currently in their final year. The total student population in this group consisted of 47 individuals. This particular student group was chosen due to their unique circumstances and challenges faced in readjusting to normalcy after the reopening of the college.

B. Courses

The author served as the instructor for two 2-credit courses: 19B504 Enzyme Engineering and Technology and 19B604 Bioprocess Design and Economics. Table I provides an overview of the course outcomes, as well as the teaching and evaluation levels associated with each course.

C. Activities

The activities provided to the students, along with the evaluation rubrics and their participation percentages, are summarized in Table II. The activities encompassed two types: classroom activities and online activities. Online activities were designed for individual completion, while classroom activities were conducted in groups of either 2 or 5 students, formed randomly. Various online tools, as listed in Table II, were utilized to facilitate these activities. For online discussions, the LxI (Learning Experience Interaction) framework from the LCM (Learner Centric MOOC) model was adapted, incorporating a focus question and a reflection quiz as described elsewhere [18].

To enhance student participation, bonus points were awarded for the Multiple Choice Question (MCQ) component of the Continuous Assessment, details of which are also presented in Table II. In instances where no activities were performed, traditional teaching methods such as lectures, assignments, and class quizzes were employed to deliver course content to the students. Further details regarding these traditional methods are not provided in this context.

D. Impact on Student Performance and Attainment of Course Outcomes

To evaluate the impact of activities on student performance, the pass percentage and the percentage attainment (based on average marks) for each course outcome were assessed across three continuous assessment tests.

III. RESULTS AND DISCUSSION

The following sections discuss the results of this study.

A. Student Performance and Course Outcomes

The relationship between the attainment of course outcomes, pass percentage, and the number of activities is illustrated in Fig. 1, encompassing both courses. The data reveals a positive correlation between the number of activities and pass percentage, as well as the attainment of course outcomes. Higher levels of student participation in activities generally corresponded to increased pass percentages and course outcome attainment, consistent with the literature[12].

TABLE I. COURSES AND COURSE OUTCOMES

CO No.	Description of CO	Teaching and Evaluation level
Enzyme Engineering and Technology		
1	Select and exploit suitable enzyme sources, their isolation, purification and characterization techniques for various commercial application purpose.	Knowledge Comprehension
2	Comprehend and apply enzyme kinetic models and inhibition kinetics for process development.	Comprehension Apply
3	Distinguish different immobilization techniques, their merits and demerits in industrial production with emphasis on surface immobilization kinetics.	Knowledge Comprehension
4	Identify and explain the various types of enzyme based biosensors for different applications	Knowledge Comprehension
5	Analyze various enzyme engineering methods for functional and stability improvement and use of enzyme based reactions in organic solvents.	Analyze
Bioprocess Design and Economics		
1	Describe the various requirements and regulations of a bioprocess industry	Apply
2	Define the types of design and design components of process industries	Apply, Analyse, Design, Evaluate
3	Describe and carry out optimization studies for process designs	Apply, Analyse, Design, Evaluate
4	Describe Biosafety regulations for operation of process industries	Apply, Analyse, Design, Evaluate
5	Perform cost and profitability calculations of process designs	Analyse, Evaluate

However, it is noteworthy that in certain instances, despite a high number of activities, there were dips observed in the pass percentage and course outcome attainment. Upon further examination, it was evident that these dips coincided with a low level of student participation. This suggests that active engagement and involvement of students in the activities are crucial factors influencing their performance and course outcome attainment. Interestingly, an analysis of the data also revealed that certain course outcomes exhibited high pass percentages and course outcome attainment, despite no activities performed, owing to their lower level of teaching or evaluation.

B. Student Participation and Preferences

Student participation plays a crucial role in the success of activity-based learning approaches. This section discusses the findings related to student participation and preferences, as illustrated in fig. 2.

The bubble diagram in fig. 2 provides a visual representation of the level of student participation in activities. Notably, students displayed a clear preference for classroom activities over online activities. It was observed that students were less inclined to engage in activities that involved more serious tasks, such as flowsheeting, which required learning a specific software. This hesitation may be attributed to concerns about the perceived complexity or unfamiliarity of such activities, in line with findings in the literature [11].

One interesting finding was related to the quiz games. Initially, students expressed apprehension and displayed a lower level of participation in the first quiz game, despite the offer of bonus points. However, in the subsequent quiz game,

TABLE II. DETAILS OF STUDENT ACTIVITIES

Course Name	CO	Activity	Mode of activity (Classroom/Online) (Group/Individual)	Description of activity	Tools used	Rubrics for evaluation	Additional incentives	Percentage of participation
Enzyme Engineering and Technology	1	Discussion 1	Online Individual	Discussion based on viscous fermentation broth	Padlet	5 points + 5 points for reflection quiz		Discussion – 51.06 RQ – 68.09
Bioprocess Design and Economics	1	Concept Mapping	Classroom Group	Submit a concept map based on the different types of bioproducts	Coggle	Map - 5 points + Speed - 5 points		70.22
		Discussion 2	Online Individual	Discussion based on viscous fermentation broth	Padlet	5 points	Best answer - 1 bonus point	38.30
		Discussion 3	Online Individual	Discussion based on economic impact analysis	Padlet	5 points	Best answer -1 bonus point	48.94
		Quiz Game 1	Online Individual	Play a quiz game on process industry regulations	Blooket	10 points	Best player – 1 point	34.04
	2	Design problem	Classroom Group	Identify and submit a design for downstream processing	Pen & paper	10 points		55.32
		Flowsheeting	Online Individual	Perform software simulation and submit flowsheets	DWSIM	10 points		29.79
	3	Flipped classroom	Classroom Group	Set a question paper on "Bioprocess regulations"	Pen & paper	Quality of question paper – 5 points + Answers – 5 points		76.60
		Quiz Game 2	Online Individual	Play a quiz game on process optimisation	Blooket	10 points	Best player – 1 point	59.57
		Discussion 4	Online Individual	Discussion based on regulations in bioprocess industries	Padlet	5 points	Best answer - 1 bonus point	40.43

the level of participation increased. It is plausible that students were motivated by the enjoyable nature of the game, consistent with findings in the literature [17].

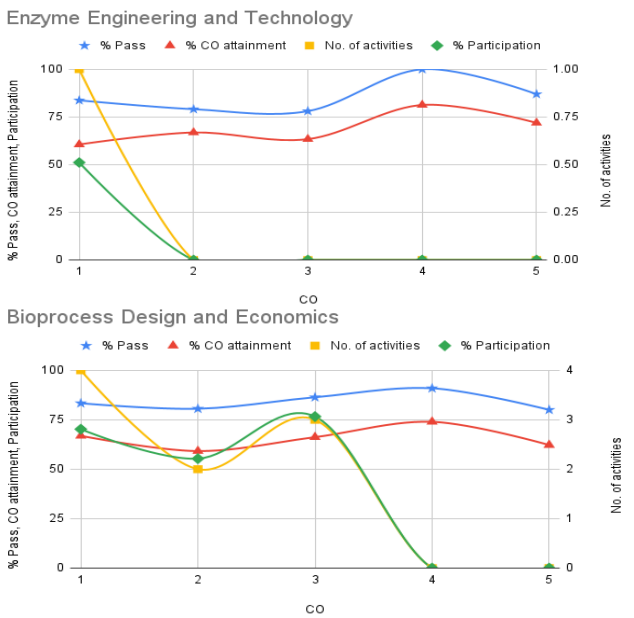

Fig. 1. Correlation between the number of activities and their level of participation on pass percentage, CO attainment

This highlights the importance of incorporating elements of enjoyment and entertainment into activities to encourage student engagement. Therefore it is important to consider students' preferences when integrating gamified elements into assessments, as evidenced by the study conducted by Udeozor et al. [17], which indicated engineering students' acceptance of games as a learning tool but a preference for traditional assessment methods.

Online discussions, despite offering bonus points for the best answer, yielded average participation. This suggests that

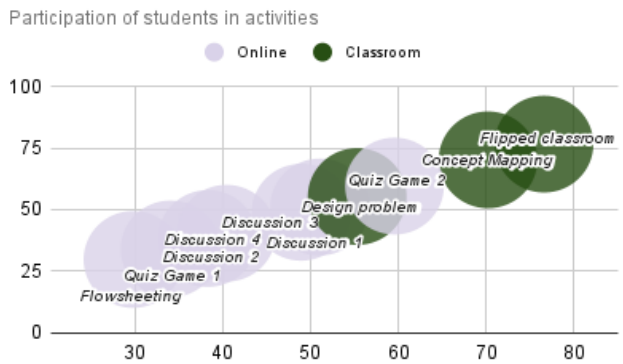

Fig. 2. Level of student participation in various activities

while incentives played a role in motivating students, they alone may not be sufficient to drive high levels of participation. It is evident that students are more likely to participate when they perceive an enjoyable and interactive element in the activities[17].

The results further indicate that additional incentives were effective only for the second quiz game. This finding underscores the need to carefully consider the design and implementation of incentives to ensure maximum impact on student engagement.

IV. SUMMARY AND CONCLUSION

In this study, the impact of activity-based learning on third-year B.Tech Biotechnology students was explored, revealing its pivotal role in enhancing student engagement, academic performance, and course outcome achievement. A direct correlation was established between the number of activities and pass rates, underscoring the importance of active participation. Notably, students exhibited a preference for classroom activities, emphasizing the need for enjoyable, engaging activities. Incorporating interactive elements, such as quiz games, boosted participation, while online discussions, despite incentives, yielded moderate engagement. These findings highlight the significance of activity-based learning in higher education and the need to tailor activities to student preferences for optimal results.

However, the limitations of this study include a relatively small and specific sample size, potential bias in participant self-selection, a lack of exploration into broader contextual factors, and a reliance on subjective measures. The study's findings may not be easily generalized to other populations or contexts, and the short-term focus may not capture long-term effects.

In conclusion, activity-based learning holds significant potential in enhancing student engagement, academic performance, and the attainment of course outcomes. By considering student preferences, addressing barriers to participation, and incorporating enjoyable elements into activities, educators can create a conducive learning environment that maximizes student motivation and success. The insights gained from this study provide valuable guidance for educators and institutions in developing effective strategies and interventions to enhance student experiences and academic achievements. Further research is recommended to explore additional factors influencing student participation and the long-term impact of activity-based learning on students' educational journeys.

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Nurturing Algorithmic Literacy: A Case Study on the Trends and Challenges of Artificial Intelligence and Machine Learning Education in Schools

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***Abstract*—In today's digital age, alongside the rising significance of technological literacy, algorithmic literacy holds great importance as artificial i ntelligence (AI) a nd m achine learning (ML) emerge as transformative technologies. This research paper explores the trends, challenges, and implications of AI and ML education in schools, aiming to cultivate algorithmic literacy among students. By conducting a survey, reviewing the literature, and examining classroom observations, this study provides insights into the integration of AI and ML into the K12 curriculum and offers recommendations for promoting effective instruction and preparing students for the digital future.**

This research paper provides an introduction to the rising importance of AI and ML, highlighting the need for students to develop relevant skills and critical thinking. The literature review explores government initiatives aimed at promoting AI education in schools and examines the current trends in AI and ML instruction. Additionally, it delves into the challenges educators face when integrating AI and ML into the curriculum, including the selection of technical platforms, accessing adequate resources, and identifying comprehensive teaching materials. Core concepts such as algorithmic literacy and ethical AI require careful consideration in the education space as they form children's ability to critically examine, interrogate, propose solutions for, contest, and agree with digital services that have become increasingly omnipresent.

***Index Terms*—Algorithmic Literacy, Artificial Intelligence, Machine Learning, K-12 Education**

I. Introduction

According to DeVito [1], algorithmic literacy refers to the ability and chance to recognize the existence and influence of algorithmically-driven systems on self-identified or collaboratively-identified objectives, as well as the ability and opportunity to solidify this comprehension into a strategic utilization of such systems to achieve those goals. Acquiring this foundational skill will be pivotal in attaining a comprehensive understanding and proficiency in artificial intelligence (AI) and machine learning (ML) systems.

After identifying a substantial disparity in public comprehension of AI, as evidenced by citizens' comments and concerns, the scientific community has recognized the need to actively participate in AI education [2]. This case study aims to examine the current state of AI and ML education in educational institutions and government initiatives, with a specific focus on fostering algorithmic literacy among students. By doing so, we seek to identify potential areas for improvement and provide recommendations to enhance the effectiveness of AI and ML education.

Through an examination and deliberation of the trends of AI and ML education associated with various approaches and experiences documented in the literature, including the integration of these subjects into the curriculum, hands-on learning experiences, and the interdisciplinary approach, our objective is to stimulate fresh initiatives and provide guidance to key stakeholders. It has also identified challenges such as teacher training, resource accessibility, and ethical considerations. By addressing these challenges and capitalizing on the identified trends, educational institutions can enhance AI and ML education and prepare students for a future where algorithmic literacy holds great significance.

To ensure a comprehensive understanding of the trends and issues in AI and ML teaching, this case study employed a mixed-method approach, combining classroom observations with quantitative data obtained through a survey administered to students and educators. This methodology ensures a thorough examination of the trends and challenges in AI and ML education.

II. Literature Review

The increasing number of AI-related jobs and their projected growth in the future have prompted researchers to argue that AI education should be considered as important as traditional literacy in reading and writing [3]. Consequently, there is a growing emphasis on developing the structure and content of AI education at the K-12 level, aiming to cultivate well-informed citizens equipped with a comprehensive understanding of the technologies they encounter in their daily lives [4].

Efforts to incorporate AI into K-12 education have been documented through interviews with practitioners and policymakers across America, Asia, and Europe [23]. Furthermore, research endeavors have focused on evaluating and comparing AI curricula across multiple countries [5]. Initiatives aimed at optimizing AI learning for K-12 students are also on the rise, with a focus on defining core competencies in AI literacy across three dimensions: AI concepts, AI applications, and AI ethics and security [6], [7]. As part of these efforts, AI is introduced as a distinct skill subject, spanning from middle school to senior level [19], [20].

To enhance the adoption of AI and ML, there is a growing emphasis on practical and hands-on learning experiences, involving activities such as coding, programming, and experimentation. Minimizing the cognitive effort required in ML adoption is seen as advantageous, allowing users to focus on problem-solving logic [8]. Visual languages have been introduced to facilitate this objective, enabling users to construct programs intuitively through the manipulation of visual elements [9], [10].

AI and ML education are increasingly approached from an interdisciplinary perspective, incorporating concepts from various fields of study to help students understand the broader implications of AI and ML technologies [21]. Furthermore, the exhibition and recognition of AI solutions in interdisciplinary domains serve to underscore the extensive applications of these technologies [22].

The rapid advancement of AI and ML technologies poses significant challenges, particularly for countries that have recently begun focusing on their development. One major challenge is the shortage of well-trained educators capable of effectively teaching AI and ML concepts.

To address this, investments are needed in professional development programs and initiatives to equip teachers with the necessary knowledge and skills [11]. Collaborative efforts involving teachers in training or practicing educators are suggested as viable solutions [11], [12]. Analyzing teacher competency through the Technological Pedagogical Content Knowledge (TPACK) framework and collaborating with AI experts are also recommended approaches [13], [14].

Current resources in AI education often lack an interdisciplinary approach and a comprehensive approach to AI development [15]. Furthermore, there is a lack of AI learning experiences that have been analyzed for learning outcomes, indicating the infancy of AI education at the K-12 level [16].

As AI-related jobs continue to grow, the importance of AI education in K-12 curricula is increasingly recognized. Efforts are underway to incorporate AI concepts, applications, and ethics into K-12 education, supported by practical learning experiences and interdisciplinary approaches. However, challenges such as a shortage of well-trained educators and limited resources need to be addressed to ensure effective AI education at the K-12 level.

III. Methodology

The research aims to make observations and provide recommendations to instructors who impart AI education to school students. To assess the algorithmic literacy of educators, the method proposed by the authors of [17] was employed. A dedicated section of questions was used to examine the challenges faced by educators while imparting AI education. This survey serves as the foundation for the research. The survey targets educators with experience teaching AI or Computer Science concepts. It is designed as a self-administered questionnaire consisting of various sections that delve into teaching methods, resource availability, challenges faced by educators, the significance of visual learning and graphical programming tools, ethical considerations, and algorithmic literacy. In conducting the quantitative research based on the survey, strict compliance with fundamental ethical rules was maintained throughout the process. The selection of participants was unbiased, diverse, and inclusive, with informed consent obtained, ensuring participants were aware of the research purpose, and data usage emphasizing transparency and respect. Additionally, we anonymized and secured data, removing any identifiable information.

Through meticulous analysis of the survey results, the research uncovered profound insights into teaching practices, algorithmic literacy among educators, challenges faced by educators, and ethical considerations in the domain of AI and Machine Learning education. This research aims to promote AI and Machine Learning teaching by developing effective techniques to upskill educators and address the issues they confront. Additionally, the goal of this research is to recognize the critical features of algorithmic literacy as well as the ethical considerations that must be incorporated into AI and Machine Learning programs.

IV. Findings and Analysis

The survey garnered responses from over 50 teachers, providing insights for drawing meaningful inferences. The first part of the survey focused on algorithmic literacy and consisted of 13 questions employing a 0-5 rating scale. Notably, over 50% of the respondents rated themselves 3 or lower for all but three questions, indicating a limited understanding of how algorithms drive the decision-making processes of personalized media experiences. Furthermore, 20% of the teachers admitted to having no knowledge pertaining to the working of algorithms in delivering targeted media content. Contrastingly, over 57% of teachers were familiar with the influence of their online behavior on the media they encountered. Similarly, over 51% of teachers exhibited awareness of

how their personal data is utilized to curate media recommendations and the consequences the same can have pertaining to privacy. Notably, over 53% of the teachers well well versed in how algorithms prioritize media differently for different people. These responses indicate a relatively higher awareness among the respondents regarding the influence of algorithms in determining media relevance.

The second section of the survey yielded similarly intriguing results. This section consisted of questions that shed light on how educators approach AI and ML education, the challenges they encounter, and their teaching preferences. This section also consisted of two multi-response questions in which it was inferred that more than 50% of the respondents expressed a preference for textbooks, online tutorials, and hands-on projects. In stark contrast, only 18% of the respondents were in favor of guest speakers as a teaching method. These preferences denote that the educators place a significant value on interactive and immersive learning, and don't favor a break in flow.

Notably, over 52% of the teachers identified the lack of AI and ML resources as a major hurdle in their educational endeavors, highlighting the need for increased availability and accessibility of learning materials. Along similar lines, 42.6% of the teachers cited the lack of appropriate training and the difficulty of integrating AI and ML topics into the curriculum as roadblocks, further emphasizing the need for professional development and support for educators.

An interesting trend that emerged from the survey was the strong inclination towards visual/graphical programming among the majority of teachers. A remarkable 70.4% of teachers deemed visual/graphical programming highly important, while 27.8% considered it somewhat important. This denotes the significance of incorporating visual programming elements into the curriculum and its importance in enhancing students' engagement and understanding of AI and ML concepts. A surprising contrast to this fact however is that nearly 50% of the teachers expressed a lack of proficiency in operating and teaching through said visual programming tools. This fact reinforces the need for appropriate support and training for educators. Furthermore, Scratch and PictoBlox emerged as the most popular visual programming tools among teachers.

The survey also pointed out that over 53% of the teachers deemed inculcating algorithmic literacy into their students as one of their primary teaching goals and over 24% of the teachers stated that although important, inculcating algorithmic literacy was not a part of their primary teaching goals. Similarly, over 51% of the teachers deemed inculcating ethical considerations of AI into their students as one of their primary teaching goals and conversely, approximately 23% of teachers acknowledged the importance of ethical considerations but did not prioritize it as a primary teaching objective.

These insights provide a deeper understanding of the state of algorithmic literacy among educators and emphasize the importance of providing adequate resources, professional development, and support to the educators taking up AI and ML. The study also indicates that visual programming can prove to be an extremely capable tool to further improve the understanding of AI and ML subjects among students.

V. Discussions and Recommendations

Based on the finding and analysis presented above, the following recommendations could enhance AI and ML education in schools and promote algorithmic literacy among both teachers and students:

- Increased understanding of algorithmic literacy: The development and implementation of curriculum content that explicitly addresses algorithmic literacy is the need of the hour. It is crucial for students to learn about the role of algorithms in their daily lives and the potential impacts of algorithmic decision-making.
- Increased availability of AI and ML resources: Integrating AI and ML topics into the curriculum is essential to forester AI development. Considering how the teachers favor experiential learning, resources like online tutorials and hands-on projects should be made available apart from high-quality textbooks. Efforts should be made to address the identified shortage of resources and provide educators with materials that suit diverse learning needs.
- Professional development programs: The shift to AI and ML requires skill development and hence, teacher training programs are essential. Teacher training programs should be established and expanded to equip teachers with the necessary skills and knowledge to teach AI and ML concepts effectively. These programs should cover both technical aspects and pedagogical strategies for integrating AI and ML topics into the curriculum.
- Visual Programming: Visual programming has emerged as a valuable tool for nurturing computational thinking skills and promoting active engagement among students, facilitating comprehensive AI and ML concepts [18]. Notably, PictoBlox, a prominent graphical programming platform as per the survey, offers comprehensive support for Artificial Intelligence and Machine Learning applications, providing students with hands-on programming experience and project-based learning. In particular, PictoBlox's Machine Learning Environment allows students to build no-code yet functional Machine Learning models, something that our survey deemed desirable. By investing in graphical programming tools and infrastructure, including comprehensive guides and tutorials, educational institutes can significantly enhance a student's understanding of intricate AI and ML concepts.
- Promote ethical considerations: It is essential for students to be well-versed in the concepts of privacy, bias, and fairness. Integrating case studies, real-world examples, and other ethical dilemmas into AI and ML lessons can promote critical thinking and responsible usage of AI among students.

Conclusion

This study presented a thorough analysis of AI and ML instruction in schools, with a focus on developing algorithmic

literacy. Insights into the present trends and challenges of AI and ML instruction in schools have been gathered through survey data, literature reviews, and analysis. The findings emphasize the importance of professional development, instructor support, more resources, and better integration of AI and ML issues into school curricula. The importance of visual and graphical programming tools, as well as ethical considerations and algorithmic literacy, has been emphasized. We expect that our research will help to further AI and machine learning education, increase algorithmic literacy, and prepare educators and students for the digital future. Continued research, innovation, and collaboration are required to ensure that students have the skills and knowledge required to flourish in an AI-driven world.

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Right Design of Assessment can facilitate Students to take more Responsibility for their Learning

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***Abstract*—It is widely recognized that assessment drives learning. The quality of assessment and evaluation plays a significant role in the quality of learning. Any decline in quality also negatively impacts student motivation to engage in effective learning practices. One way to improve assessment is to make all assessment instruments of low stakes and increase the role of formative assessments. However, these assessments will increase the workload of instructors. The paper presents an experimental design of an assessment and evaluation mechanism that can enhance the quality of learning. It is designed for a practical course on Full Stack Development in a BSc Honors program in Computer Science. The continuous assessment design was based on self-assessment, peer-assessment, behavioral assessment, live coding by students, and the explanation of submitted code by the students. In the semester-end examination, the students were allowed to work in groups and were given sufficient time to complete the assessment. The students were allowed to use internet resources and ChatGPT. Analysis of data indicates that the assessment methods and evaluation shift the responsibility of learning to students. The workload of the instructor can be addressed through the automation of grading based on consistency in submission, self-assessment, peer-assessment, and periodic instructor assessment.**

***Index Terms*—self-assessment, peer-assessment, self-regulated learning, co-regulated learning, low-stakes assessment**

I. Introduction

The rapid increase in enrolment into higher education programs in the last two decades led to a wider range of cognitive abilities and motivations of students. Pre-University education in India is driven predominantly by preparations for different entrance examinations for entry into Universities. This has led to the creation of coaching institutes that classify the assessment items from past examinations and prepare the students with procedures and strategies to perform well in the entrance examinations. Students expect similar teaching methods after they join the undergraduate programs. Some students coming to computing programs have very little exposure to computing courses at the high school level. They are exposed to education methods where questions and corresponding answers are given, which they understand and reproduce in the examinations. They tend to ask instructors for notes, assessment items, and also desired responses to them. They need to overcome these established strategies and behaviors and adopt new strategies and behaviors needed to learn well in undergraduate computing programs. They tend to blame the instructors for not teaching well since the instructors do not meet their expectations about the teaching and learning processes they are used to. Also, students tend to get very disturbed when only some portion of a program is wrong, and the instructor insists on a working program, which is different from other subjects in which a partially correct answer would get partial marks. The students need to accept that there is a need to change their learning strategies and behaviors to improve learning in computing subjects. They need to overcome the defensive postures for lack of progress in learning by accepting the change instead of blaming the instructor. In this article, we present the experience report of the implementation of self-assessment, peer-assessment, behavioural-assessment as continuous internal evaluation (CIE), and in the semester-end evaluation (SEE), students were allowed to use ChatGPT and the Internet. They were allowed to work in groups and were given sufficient time for completion.

II. Related Work

Low-stakes assessment is defined as the frequent use of assessments with a small impact on the final grades a student gets on completion of the course [1]. Reference [2] has noted that daily exams encourage compliance with expected student behaviors. However, in large class sizes (60), daily evaluation significantly increases instructor workload in our context. In the course, we adopted self-assessment and peer-assessment to manage the instructor's workload.

Self-regulation refers to the student's ability to understand and control their learning. Self-regulation requires the student to assume responsibility for their learning. Reference [3] states that self-assessment improves self-regulation. In the course, we used self-assessment with daily office hours for students to seek instructor feedback as a method of CIE. Reference [4] emphasizes the importance of co-regulation and social regulation of learning. In their work, they have elaborated guidelines for implementing practices related to co-regulation and social regulation of learning. Reference [5] has adopted self-assessment and peer assessment, teacher-student interaction for improving co-regulation of learning classroom.

In the course, students were organized as groups, and peer assessment was made a part of continuous internal evaluation (CIE).

III. Course Design

The introductory course on full stack development was designed as an activity/project-based course to learn javascript, node.js, express, mongodb, and react.js. The students will have tutorial-level activities in each of the technologies, followed by a guided project. The student will then be assigned features to be added to the baseline project. The course had the following course outcomes.

- Understand variables, expressions, if statements, loops, functions, objects, and classes in javascript using p5.js
- Create a frontend for a web application using react.js
- Create a backend for a web application using mongodb, express, and node.js
- Develop a simple web application using MERN stack.

IV. Continuous Internal Evaluation (CIE)

The course was divided into 55 submissions over the semester. 100 students registered for the course. The instructor was available for interaction for 90 minutes every day. Students were divided into groups of five to encourage working in smaller groups and conduct effective peer evaluation. It is the responsibility of the student to get their work peer-reviewed. Any gaming of the system by students will result in difficulties in subsequent activities, and the student will be found out during office hours interactions with the instructor.

Each submission was graded under the following rules.

- Each submission was graded for 3 marks.
- Students are given 3 marks if the submission meets all the criteria.
- Submission will get 1 mark less if it was not peer-reviewed
- Submission will get 1 mark less if it was submitted late
- Submission will get 2 marks less if it was submitted very late.

V. Semester End Evaluation(SEE)

Semester end evaluation covered all the course outcomes and allowed students to solve the assessment items in groups of their choice. They could use the internet resources and solve the problems. Students were evaluated based on

- Whether they have working code
- Whether they are able to explain the features of the language they have used in the code.
- Whether they are able to explain the control flow of the code submitted.

VI. Analysis of Student Compliance to CIE

Negative grading for late submissions and not getting submissions reviewed resulted in students becoming sensitive to deadlines. The deadlines were reasonable and demanded engagement during class hours. All activities were in class, and sufficient time was allotted to each activity. Hence, the students could not raise serious objections to the CIE method.

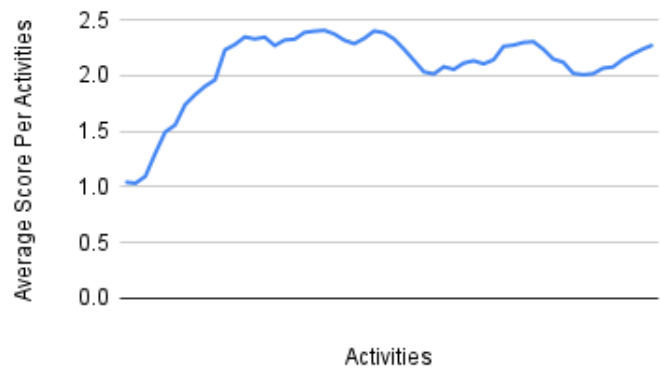

Fig. 1. Moving average of average scores of students for each submission through the semester.

Fig. 1 indicates students adjusted to the submission protocol and the marks stabilised between 2.0 and 2.5 out of a total of 3 indicating that students' compliance with the submission protocol is driven by the marks.

VII. Analysis of performance of students in CIE and correlation with SEE

Traditionally, in our context, the quality of learning was measured by measuring the cognitive outcomes of the student. This uni-dimensional approach to measuring the quality of learning could be a contributing factor leading to grade inflation and copying. CIE being entirely dependent on the instructor, it becomes necessary to understand data-driven mechanisms to detect grade inflation and copying without learning.

To understand the dynamics of assessment, we analyzed the data by grouping students into two groups based on the feedback (further elaborated in the next section) given by the students. Students who did not find the assessment method of the course as helpful to their learning (Group1) and students who found the assessment as helpful (Group2). Fig 2 shows the Scatter plot of Group 1. The trend line has a small slope, indicating less or no correlation between CIE and SEE. Fig 3 shows the Scatter plot of Group 2. The trend line has a positive slope, indicating a strong positive correlation between CIE and SEE.

Pearson correlation test was performed for Group 1 and Group 2 between CIE and SEE. The results are shown in Table I. For Group 1, Rho 0.04 and P value 0.75 indicate that H0: The CIE is correlated with SEE is false. For Group 2, Rho 0.53 and P value 0.00 indicate that there is a strong correlation between CIE and SEE. The Correlation between CIE and SEE for Group 2 indicates that the method of assessment helped 34 percent of students learn better.

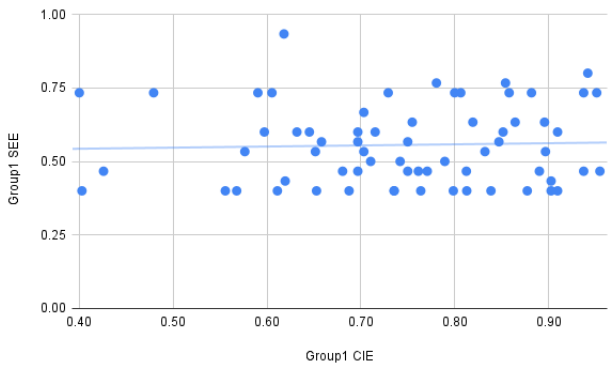

Fig. 2. Scatter Plot of Group1 Students' CIE vs SEE.

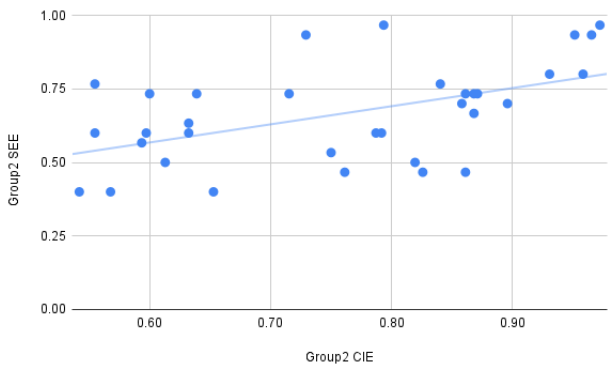

Fig. 3. Scatter Plot of Group2 Students CIE vs SEE

VIII. Analysis of Student Feedback Related to Assessment

Post SEE, a feedback form was shared with students to understand their opinions on the assessment method. Students were asked three questions to understand their feedback.

- Do you prefer a regular course with only periodic assessments and semester-end assessments?
- Do you prefer a course with CIE with self-assessment and peer assessment?
- What was your realization with respect to the responsibility of learning in the course?

39 out of 100 students responded to the form. 33 students preferred CIE designed in the course. 6 students preferred the regular assessment with periodic and semester-end assessments. Out of 33 students, 24 students were able to articulate their responsibility towards learning clearly. Table II shows some sample responses by the students.

TABLE I
Correlation coefficient between CIE and SEE for Group1 and Group2 students

Parameters	Group1	Group2
Pearson Correlation Coefficient (r)	0.03941	0.5082
Pvalue	0.7534	0.002153
Covariance	0.0007114	0.01172
Sample Size (n)	66	34
Statistic	0.3155	3.3377

TABLE II
Sample Feedback Responses

Sl.No	Feedback
1	If I had worked consistently, I could've done a lot more better
2	Self-directed Learning, Time Management, Feedback and Communication.
3	I take full responsibility for my actions and believe that it is more beneficial for me to figure things out on my own rather than solely relying on others for help. This approach has allowed me to gain a deeper understanding of the workflow and the overall purpose of the topic and course. Additionally, by helping my friends, I encountered various types of errors, which further enriched my learning experience. While it is important to acknowledge that the code part was generated by ChatGPT, I realized that without the assistance of ChatGPT within the given timeframe, completing the course would have been challenging.
4	It is a very important course in order to make a strong hold on the entirety of the subject
5	Since the marks were based on submission timings, no one actually learned anything. We just submitted activities for the sake of it.
6	learning on my own made me realize there are so many things to learn
7	I was okay with learning without the teacher, and it helped me learn better than the teacher sitting and explaining

IX. Summary

In the course, students had self-assessments and peer-assessments of learning. The CIE marks only measured the compliance of the student to the submission protocol. In the initial stages, the students submitted assignments without putting an effort into understanding the concepts or applying them. As the semester progressed, the students realized they were not learning enough to pass the SEE. Since the instructor was available for extended office hours throughout the semester, the instructor could not be blamed for the lack of learning. The situation resulted in some students to work with the instructor during the office hours and with peer groups. While it is significant that 34 percent of students benefited, we still need to find out how to reach out to the other 66 percent of the students. Student feedback indicates that the assessment method would have been more effective if there were more periodic assessments instead of a single semester-end examination. The data collected from the course was analyzed post facto to draw the conclusions. From the data, the only way two groups could be formed was based on the perception of the students about the assessment method. This study should be considered exploratory, and further study is required to establish relationships between the proposed assessment method and the quality of learning. In conclusion, assessment plays an important role, and the assessment with self-assessment for CIE and instructor assessment for SEE gives students actionable feedback on their learning, leading them to accept responsibility for their learning.

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Empowering Teachers to Identify Quality Game Based Learning Solutions

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***Abstract*—There has been a significant increase in the development and usage of educational technology applications, with game-based learning solutions being one major category. Game based learning solutions have been known to provide stimulating and dynamic environments that give learners engaging and interactive experiences. They can have different learning objectives and contain a diverse set of features. At the same time, teachers may wish to use game-based learning solutions in their classes in different contexts such as topics and learner age groups. Such a diversity in game-based learning solutions and the varied needs makes it challenging for a teacher to decide a suitable game-based learning solution for her context. While various evaluation frameworks and guidelines exist, they typically address the requirements of researchers or designers of game-based learning solutions. Certain checklists also exist for generic educational technology applications. In our previous work, we found a lack of solutions for teachers in the Indian context who need easily usable evaluation frameworks that can help them select quality game-based learning applications for their students in their classes. In this paper, we present our efforts under the EdTech Tulna project to address this need. We report the design of a research based index (Tulna GBL index) to evaluate the quality of maths game-based learning solutions, followed by the details of a training session for teachers to use the index. We conducted a study to analyze teachers' perceptions regarding the usability and usefulness of the Tulna GBL index. Our findings show that the Tulna GBL index can be a practical and easy-to-use tool for teachers addressing their goals of selecting effective learning solutions.**

Keywords— Game-based learning, EdTech evaluation frameworks, Teacher use of educational games

I. Introduction

In recent years, the usage of games in educational settings has become more widespread. Educational games and game-based learning (GBL) solutions have shown to have positive impacts on students' motivation, engagement, information retention, and overall academic achievement [1]. Numerous GBL solutions are available for different subjects in various languages of instruction targeting different age groups. While there exist global standards and frameworks for evaluating the quality of educational technology (EdTech) solutions, their adoption is hindered due to the contextual nature of teaching and learning [2]. Researchers have created and validated evaluation frameworks and instruments [3][4], but are they often generic across different types of EdTech products. Quality frameworks specific to GBL solutions mostly cater to researchers and designers.

The National Education Policy (2020) [5] by the Indian government encourages the use of affordances of technology in schools. Hence there is a requirement to sensitize teachers and school officials about good quality EdTech solutions to aid in informed decision-making. In this paper, we present our efforts to support teachers to make systematic decisions on selecting quality GBL solutions for their context. This work is part of the broader EdTech Tulna project [6]. We designed a research-backed context-specific evaluation index which we will refer to as the Tulna GBL index. We also conducted a training session to sensitize teachers in identifying quality EdTech GBL solutions for teaching mathematics using the Tulna GBL index. Participants included 45 teachers spanning grades 6-10. The training session provided insight into specific challenges that teachers face while choosing and using GBL solutions. As part of the session, we conducted a study to understand teachers' perceptions regarding the challenges they face while choosing and using GBL solutions, and to analyze the usability and usefulness of the Tulna GBL index.

II. Literature Review: Evaluating Quality of Game-Based Learning Solutions

Numerous frameworks addressing different aspects of GBL solutions have been created. Some frameworks provide design principles and recommendations for the key considerations needed for the design of GBL such as game motivators or give pedagogical considerations [7-12]. Others are evaluation instruments and checklists [8][9]. Some evaluate the pedagogical and technological design of the solution while others evaluate the learning outcomes, learning interaction, learning experience, etc. [10]. Also available are studies that provide empirical evidence for the value of games and simulations in teaching [11]. Some instruments such as the four-dimensional framework [8] and Guidelines for developing Content for school and Diksha (ver. 3.0) [14] address the needs of the teachers but they are in the form of binary checklists. Frameworks such as 'game object mode II' [9] and Pre-MEGa Framework [12] are detailed but may need significant interpretation by teachers. Also most of the frameworks do not include subject specific and grade specific criteria thereby failing to capture recommended age-specific pedagogies which are related to learning outcomes. We need a framework that addresses teachers' needs and context, and also incorporates criteria to accommodate the features of available GBL solutions.

III. Tulna Game-Based Learning Index

A. Background: The EdTech Tulna initiative

India has seen an increased market for EdTech products, which has been further fueled by the pandemic [15]. Yet making informed decisions about adoption is challenging for various stakeholders such as schools, teachers, parents, and governments due to inadequate quality standards and lack of unbiased reliable product evaluations. The EdTech Tulna initiative was conceived to address these challenges, and is a research-practice partnership between academic researchers and an NGO, with inputs from teachers and state education departments [16].

EdTech Tulna consists of a set of research-based frameworks to set quality standards for different educational technology usecases such as personalized and adaptive learning, digital classrooms, game-based learning etc, and specific to subjects such as mathematics, language and science. Different views of the frameworks cater to different stakeholder needs. Corresponding to these frameworks are evaluation indexes. These are informed by: i) research on learning theories, multimedia learning, human-computer interaction, and disciplinary teaching practices, ii) recommendations by educational policies in India, and iii) insights gained from various stakeholders and product landscape in the Indian Edtech ecosystem.

B. *Design of Tulna game-based learning index*

The Tulna GBL index in this study was designed to be used by maths teachers who need a systematic method to identify good quality GBL solutions for their context. The index consists of criteria categorized under three dimensions: Content quality, Pedagogical alignment and Technology & Design, to capture a holistic view of the quality of the design of the GBL solution. The focus of the index is on learning via educational games and includes criteria such as learner autonomy, situating game activities in appropriate context, motivational features, and providing adequate multi-modal, constructive feedback in the game activities, opportunities for collaboration, competition and team-based play to achieve learning goals. In addition, broader criteria related to the three dimensions such as accuracy of content, comprehensibility of language, alignment to national standards, addressing learning gaps, guidance to teachers to integrate the GBL solution, interface design, learner navigation & pace, and universal design.

Each criterion contains guidelines and indicators for reviewers on how to evaluate the GBL solution. The guidelines also include examples to assist teachers in differentiating between solutions of varying quality. Fig. 1 provides an overview of the guideline by showcasing one criterion from one of the constructs: learner agency under Pedagogical Alignment. Evaluation is on a 3-point scale. When all the indicators are met, a GBL solution is considered to *fully incorporate* the criteria. If some indicators are met or found inconsistent in the product, the GBL solution is deemed to *partially incorporate* the criteria. Finally, if very few or none of the indicators are met, the GBL solution is classified as *not-incorporating* the criteria.

Pedagogical Alignment				
	Not at all or minimally incorporated (Tick or leave it blank)	Partially incorporated (Tick or leave it blank)	Completely incorporated (Tick or leave it blank)	Rationale for the score
Learner agency **Q. Does the product provide adequate learner autonomy?** 1. The game allows learners to make various types of choices/decisions to shape their game world. 2. The game allows setting/resetting learners learning goals themselves like choose which mathematics skills they want to practice as game activities 3. The game allows the learner to decide which topic to do and in what sequence. 4. The game allows the learner to choose which challenge levels to attempt 5. The game allows the learner the feeling of being part of the game world.				

Fig. 1. Criterion of Learner agency in Tulna GBL index

C. *Design of training session*

The training was designed as a 1.5hr interactive session to explain the criteria in the Tulna GBL index. Evaluation guidelines were explained using examples from available GBL solutions. The session included multiple activities to encourage active participation from the attendees (see Fig 2 for an example).

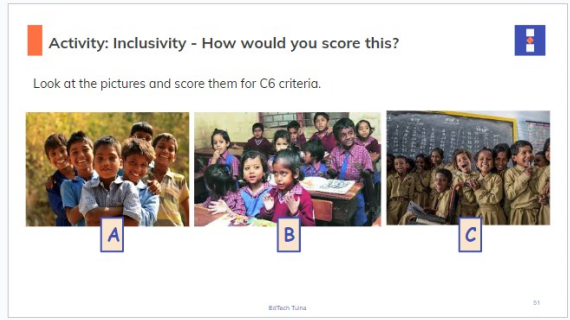

Fig. 2. Example of activity in training session

IV. METHOD

The study investigated the perceptions of usefulness, usability, and relevance of the Tulna GBL index among in-service mathematics teachers. The study used a mixed methods approach [17]. Data were collected and analyzed from a pre-survey before the training, and a post-survey and interview after the training session to answer these research questions: Do teachers find the Tulna GBL guidelines useful and usable to identify quality EdTech GBL solutions? How can the teachers adopt it for their use?

A. *Participants*

We advertised the Edtech Tulna GBL training session, emphasizing its benefits in identifying quality mathematics GBL solutions on social media platforms. Participants included teachers from government, government-aided and private schools from urban and semi-urban areas of India. While the teachers had varying levels of teaching experience, they all had some familiarity with using games.

B. *Training session*

The teachers who registered were invited to the online training session. During the training session, the criteria in Tulna GBL index were explained using examples from GBL products available to the public. Activities to engage participants were included, such as participants had to choose a good quality product among the two Edtech game solutions presented to them based on the discussed criteria.

C. *Data collection and analysis*

Participants were requested to complete a pre-survey along with their registration. A total of 141 teachers registered by filling out the pre-survey form. The pre-survey questionnaire consisted of 8 questions aimed at gathering information about the teachers' backgrounds and their perceptions regarding the use of GBL in the classroom.

Out of 141 registered participants, 45 attended the training session. Post the training all 45 teachers were requested to fill a detailed post-training session survey form with the aim of understanding the usefulness and usability of Tulna's GBL index. Additionally, we conducted semi-structured interviews with 15 interested teachers for 20 to 30 minutes in online mode. The researchers prepared a set of 8 questions to guide the interviews, and they also encouraged participants to elaborate on their responses as needed. Some of the interview questions included, "Did your perception of

the quality of GBL solutions change after attending the training session?" and "In what ways does the Tulna GBL index help you address the challenges you encounter when selecting game-based learning solutions?" The audio in the recorded interviews was transcribed, and content analysis [18] was followed to analyze interview responses.

To assess the perceived usability of the Tulna GBL index, we administered the System Usability Scale (SUS) to the teachers after the training session. The SUS is a widely recognized and versatile tool that can be utilized for evaluating the usability of various products [19]. The survey consists of 10 items, and participants are asked to rate their agreement on a 5-point Likert scale, ranging from strongly disagree to strongly agree. The survey includes both positive and negative statements, such as "*I thought the Tulna GBL index were easy to use.*" and "*I think that I will need support in the form of training or a technical person to be able to use the Tulna GBL index.*"

V. Findings

A. Results from pre-survey

1) Teachers' demographics and background

The majority of the registered participants specialized in teaching mathematics to students in grades 6-8 and 9-10 and had a wide range of teaching experience from 1 to 32 years. Among the participants, 21.4% had prior experience using EdTech GBL solutions, while the remaining teachers relied on gamified quizzes, simulation games, puzzle games, and similar resources. The consensus among the teachers was that integrating EdTech GBL solutions into their teaching had numerous benefits for students.

2) Teachers' perception about the benefit of using GBL

An overwhelming majority of the teachers (68.3%) agreed that using EdTech GBL solutions proved beneficial for their students. One teacher highlighted integrating educational content into games motivated learners to actively participate, remarking, "It has helped me a lot in making mathematics more joyful and understandable for my students." Another teacher pointed out that games fostered a sense of connection among learners, as students became actively involved in finding solutions. They stated, "Some students have Math's phobia, and games create interest in mathematics among students."

3) Teachers' challenges and difficulties in choosing Edtech GBL solutions

Despite their willingness to embrace EdTech GBL solutions, teachers faced various challenges in implementing them. These challenges included issues related to network accessibility, open access, interactivity, time constraints, platform feasibility (such as ease of app installation and use), and the availability of smartphones among students. Additionally, a few teachers mentioned the need for training in using EdTech GBL solutions.

From the feedback received, we find that teachers struggle to find appropriate games that align with their students' context and relevant topics. One teacher mentioned, "*Sometimes it's difficult to relate games to a topic, and difficult to identify the age-appropriate game, the focus is diverted from learning to play*". Another teacher mentioned "*Can't understand which game they have to select for a particular topic and difficulty level*". "*Choosing the best-suited GBL applications is the most challenging task that I've ever encountered. I thus look for the Learning Objective and then choose the suitable application but face challenges like time constraints, non-availability of games.*"

4) Teachers' perception of quality of GBL solutions

One of the questions in the pre-survey was, "According to you, what features contribute to a good quality EdTech GBL solution?". Frequency analysis of the responses that were provided in text form shows that the most frequent (more than 50%) quality indicators that were used were Engaging/interesting and Easy to understand/clarity/clear instructions. A few other important (n>30) quality indicators were age appropriate, relevant/educational goals/, interactive, user-friendly/easy of navigation, visual/graphics. Features such as learner agency and storyline were mentioned infrequently (n<4).

B. Results from post-survey

1) Usefulness of Tulna GBL index

To gain insight into the usefulness of our Tulna GBL index we collected both open-ended responses and also questions to be answered in likert scale was done post training session. When asked if the Tulna GBL index help them in selecting suitable EdTech GBL solutions for their use, 19 teachers strongly agreed, 20 agreed, 2 were neutral, 3 disagreed and 1 strongly disagreed on a 5-pt Likert scale. When asked about "How does the Tulna GBL index help you to overcome challenges in selecting GBL solutions" one of the teachers said that *"I think this a robust framework to evaluate any EdTech game-based learning solution. I have gained insight of all domains & subdomains of all three pillars i.e. Content Quality, Pedagogical Alignment, and Technology & Design. This will help me to choose appropriate EdTech games for my students."* Further, the teachers were asked, "*The following criteria are important for selecting edTech GBL solutions.*", to which the teachers responded on a 5-pt Likert scale from Strongly Disagree to Strongly Agree. The results are summarized in Fig. 3.

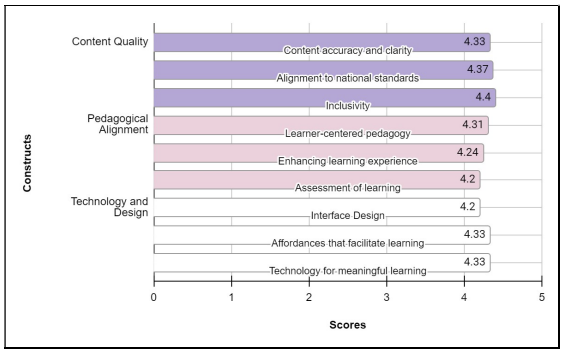

Fig. 3. Teachers' perception of relevance of criteria in Tulna GBL index on 5-pt Likert Scale (N=45)

We observed a change in the teachers' perception regarding the quality of Edtech GBL solutions. 19 teachers agreed that their ideas about the quality of EdTech GBL solution change in any way after the training session. Elaborating on their response, one of the teachers said "*Yes, after the training program I have learned many new parameters which were not known to me earlier which we need to select an EdTech product.*" Another teacher said, *"Yes, the dimensions and construct-wise rubric were very appropriate and aligned to TPACK model so I'll remember it easily while selecting and sorting the GBL tools."*

2) Usability Tulna GBL index

Teachers found Tulna GBL index usable as per the SUS (N=45) survey. Overall, the SUS score of the Tulna GBL index was found to be 71.83, which corresponds to a "good" usability score. The SUS score can be decomposed into usability and learnability [20]. The Tulna GBL index scored high on usability i.e. 80.90, while it scored low on learnability i.e. 35.55. The two questions that measure learnability are, "I think that I will need support in the form of training or a technical person to be able to use the Tulna GBL index" and "I needed to learn a lot of things before I could get going with the Edtech Tulna GBL index." the low scores on these two items emphasize the requirement of training for teachers

VI. Conclusion

Research has shown that teachers' perception of the impact of games in the classroom is closely linked to their actual utilization of games [21]. The outbreak of the Covid-19 pandemic has compelled teachers across the world to embrace EdTech game-based learning solutions as part of their instructional practices. However, the lack of proper guidance and support has made the selection of high-quality EdTech games a challenging task for teachers. This paper reports the design of Tulna GBL index, a research-based and context-specific tool, which is used to assist teachers in selecting effective EdTech game-based learning solutions for their classrooms. The study conducted with in-service mathematics teachers explores the effect of a training session on teachers' perceptions of EdTech game-based learning solutions, as well as the usefulness and usability of the Tulna GBL index. Our interviews with teachers revealed that they found the Tulna GBL index highly useful, indicating a strong likelihood of its adoption in their teaching practices [22].

There were limitations in our study that should be acknowledged. Firstly, the sampling process relied on teachers who were already interested in using EdTech games, which may have resulted in a biased sample. Therefore, our findings may not fully capture the changes in perception among teachers who are not inclined to use EdTech games. Additionally, the majority of the participating teachers were from urban and semi-urban schools, limiting the generalizability of our results to rural areas. Despite these limitations, our development of the Tulna GBL index specific to mathematics, along with the training session that guides teachers in evaluating game-based learning solutions, contributes towards addressing teachers' needs in selecting quality learning solutions. It also provides a starting point for future research in supporting teachers' adoption of game based EdTech solutions.

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Orchestrating Active Learning in Hybrid Classroom: A Case Study and Recommendations For Instructors

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***Abstract*—Implementing active learning (AL) strategies in hybrid classrooms is a challenging endeavour that holds immense potential for enhancing student engagement and learning outcomes. However, the hybrid classroom, which merges the physical and virtual realms, introduces a distinctive set of complexities for educators. Instructors grapple with the task of seamlessly integrating AL methodologies to ensure that both online and offline s tudents r eap t he b enefits of ac tive le arning. Th is paper delves into the practical implementation of AL strategies within the framework of a semester-long project-based course designed for postgraduate students, thereby proposing guidelines on the effective orchestration of AL activities in a hybrid class. In this observation and reflections b ased s tudy, t he f ocus remains on three core AL activities: (a) in-class discussions, (b) project discussions, and (c) the cultivation of student reflection f or both online and offline s tudents. T he r esults s howed t hat implementation of AL strategies through a project-based course in a hybrid classroom setting had (i) a positive impact on learners' engagement, (ii) increased interaction with content, peers, and instructors, (iii) led to promoting student reflection, a nd (iv) contributed to maximising student engagement and learning outcomes.**

***Index Terms*—Active learning, Think pair share, Hybrid classroom, Recommendation, Instructors.**

I. Introduction

Active learning (AL) strategies, such as Think-Pair-Share (TPS) and Peer Instruction (PI), have been widely acknowledged for their benefits i n c lassroom e nvironments, fostering increased learner engagement, interaction, and enhanced learning outcomes [1]. As education continues to evolve in the digital age, researchers have diligently explored the nuances of AL in various contexts, encompassing traditional classrooms, online platforms, and remote learning environments.

Extensive research has focused on the challenges faced by instructors when designing and implementing active learning strategies in various educational settings, including face-to-face, online, and remote classrooms. However, hybrid classrooms, which combine the physical and virtual teaching-learning aspects, initiate a new set of challenges for educators. Instructors struggle to seamlessly integrate AL methodologies for both online and offline s tudents. S tudies h ave observed that it is essential to incorporate an active learning environment as it has been reported to increase student involvement, responsibility, and enthusiasm in projects [2].

Thus, a significant gap remains in the understanding of how to effectively design and implement AL activities in hybrid classroom environments. This is evident where both online and offline students are present synchronously while ensuring optimal and meaningful interaction between both groups of learners, as well as between learners and instructors. This also raises the question – *what pedagogical approaches should be implemented to address this challenge?*

This study discusses the factors that underplayed the design of AL activities in a semester-long hybrid classroom with 27 postgraduate students. The focus was on activities that were adapted to promote student engagement, interaction, learning, and reflection. This paper presents the Literature Review in Section II, Course Design in Section III, Teaching Learning Activities for Course execution in Section IV, simultaneous semester-long course Project execution in Section V, and Our Learnings and Recommendations in Section VI, with the conclusion in Section VII.

II. Literature Review

A. Active Learning as a pedagogical tool

The research by [3], and [4] showed that "Active learning encompasses pedagogies focusing on student activity and student engagement in the learning process". Active learning activities also enhance the chance of a deeper understanding of the subject [3]. It improves the following major areas in students' learning - (i) improvement in higher-order thinking processes [5], [6], (ii) promotes creativity and critical thinking, (iii) provides feedback, and (iv) increases student engagement and learning outcomes [6], [7]. Also, the active engagement of students with the instructor, course content, and their peers plays a pivotal role in creating meaningful and impactful learning experiences [8].

B. Implementation of active learning in Hybrid classrooms and their challenges

The convergence of active learning and technology in the hybrid mode represents a promising paradigm shift in education. Researches [9], [10] have consistently depicted the transformative potential of active learning in hybrid education settings, as it plays a pivotal role in not only drawing remote students into the learning process but also in significantly enriching the teaching-learning experiences for all participants. Various implementations, such as the use of wiki platforms,

have been explored to overcome the complexities of in-class discussion for students on distant campuses [10].

However, there are challenges in adapting AL strategies in interaction with student-content, and student-student and student-teacher interaction in online mode [1]. There is still a lack of clear guidelines on designing and adapting active learning activities in a hybrid classroom to ensure engagement, interaction, and learning for in-person and online students [11]. There are also significant challenges in implementing AL strategies in hybrid regarding creating collaborative groups, executing project-based learning, and encouraging reflection, interaction, and engagement among all students.

III. Course Design

The course "Instructional System Design (ISD)" is co-designed and co-taught by two instructors, author three and author four. Assisting them is a senior student who serves as the teaching assistant. This semester-long course spans 15 weeks, with approximately 3 hours of synchronous class time per week. Twenty-seven postgraduate students enrolled in the course in different categories (Credit = 10, Audit = 6, and sit-through = 11). Table I shows a breakdown of the student details. A hybrid learning approach is adopted during the course, with a few students attending the class online via Zoom video conferencing while the majority attend in person. The online students were either audit students or full-time faculties of other institutes currently enrolled in doctoral studies with the department under the 'College Teacher' category (E.g. Author 2). To ensure the effectiveness of the course for this hybrid audience, the instructors make deliberate decisions to leverage technology and AL activities effectively. This course is a semester-long project-based course, with the final output being the design of a training module for disability awareness in the form of a website.

TABLE I
DEMOGRAPHY OF THE STUDENTS

	Age Range	Credit	Audit	Sit-through	Total
Online	33-43	–	M = 0, F = 2	M = 1, F =2	M = 1, F = 4
Offline	27-50	M = 6 , F = 4	M = 1, F = 3	M = 3, F = 5	M = 10, F = 12

A. Teaching Learning Activities

In order to implement AL in hybrid mode, instructors used the following:

- First set of Google slides - Containing all the class contents such as topics from ISD (e.g. ADDIE model)
- Second set of Google slides - To record all the class responses by both online and offline participants
- Google doc - To record all responses for '*Homework 0*'
- Zoom Online Meeting - For class and breakout rooms

At the start of each class, the instructors shared the first set of Google slides with all the students. This slide contains the following - (i) the class content, (ii) activities, and (iii) a designated section for students to write and share their responses during the class. This allows for synchronous participation and engagement from both the in-class and online students. To further enhance participation, breakout rooms in Zoom are created on multiple occasions for the online audience to interact effectively.

B. Reflections on Learning

Additionally, the instructors create a post-class common document, '*Homework 0*', maintained throughout the course. This document provides a shared platform to post the reflections and learnings to others. Students and instructors can post their reflections asynchronously, providing an opportunity for further engagement and reflection beyond the classroom. The instructors also designed a few deliverables for groups as checkpoints to meet the project's end goal.

IV. Teaching Learning Activities for Course Execution

A. Classroom Based Activities

1) A discussion-based active learning strategy: In a traditional face-to-face Think Pair Share Activity, instructors can interact directly with students, dynamically controlling their thinking, pairing, and sharing phase [12]. Instructors can identify students' confusion and learning by class discussions. However, in a hybrid classroom model, this activity needs to be adapted and structured to ensure both sets of students are participating and are engaged synchronously. The instructors ensured that the online students did not deviate or were not overlooked and hence had to make use of slides and virtual breakout rooms to facilitate this activity. In the hybrid mode, the thinking phase remains the same, wherein the students are individually thinking in their own space. During the pair phase, students physically present in the classroom are paired together, while online students are facilitated by a teaching assistant (TA) who creates virtual breakout rooms in platforms like Zoom. This enables pairs to collaborate virtually. In the sharing phase, each pair writes their answer in the shared common slide deck accessible to the class. This provides an opportunity for instructors to attain class responses from all students in a structured manner. The average time duration of a TPS session was approximately 30 minutes. After this phase, the breakout rooms are disabled (in the online mode), allowing all students to reconvene. At this point, all the students read the publicly available responses of all pairs on the common slide projected in the class. The instructors initiate discussion among students on every response on the slide. Figure 1 shows a pictorial representation of the Think-Pair-Share in a hybrid classroom.

2) Individual reflection activity: Promoting in-class reflection poses challenges in a hybrid classroom setup, as online students may face disparities in active participation and engagement during class discussions, feeling disconnected in the discourse. To address this, the instructors systematically and regularly present thought-provoking questions as '*Reflection Spots*' in their slide deck. This approach aims to facilitate conscious participation from in-class and online students by bringing their attention to a focal point in the slide, encouraging reflection, and identifying potential misconceptions.

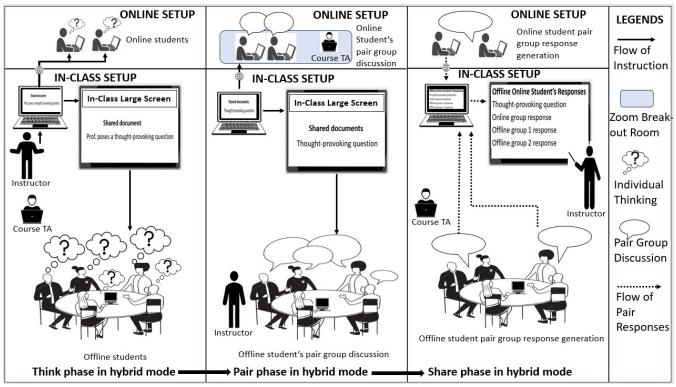

Fig. 1. A pictorial representation of the Think-Pair-Share in a hybrid classroom.

Students are given a minute or two to contemplate their responses individually during these reflection moments. They then write their answers, labelled with their names, in the class responses slide deck. In this form, the instructors ensure that each student not only thinks over his answer but also contributes their responses publicly to the rest of the class. The class response slide provides a platform to foster extensive interaction among both in-class and online students, as well as with the instructor, creating a dynamic learning environment. It promotes open dialogue and engagement as students can share their thoughts and engage in discussions based on those responses.

Findings: – There is a positive response among students on the value they see in making their class responses public with comments. According to the observations made by credit students, the following points were significant outcomes as it leads to "*..recall of the discussion..*," "*..construct on various ideas,..*" "*Enforces Peer learning,..*" "*Expands our thinking..*," "*Encourages to think of ways to incorporate others' ideas to my solution,..*", " *Help students and instructors to construct more knowledge about the topic,..*" "*Identify my mistake..*" and "*Integrate all the ideas and incorporate any new model/idea into one's thinking*" etc. The TA also responded that it builds a shift from individual to community when everyone discusses responses publicly and collectively as "*collective knowledge creation adds up to the shared knowledge for everyone such that knowledge points have transformed from individual to community*."

B. After-class reflection activity: The concept of 'Homework 0'

In hybrid learning mode, to ensure that students have learned the intended concept, instructors here use a unique approach called '*Homework 0*'. Homework 0 took the form of a shared Google document accessible to all students asynchronously serving as a platform for them to reflect on their learning after attending each class. The guidelines for this activity are explicitly outlined on the document's first page. The instructors broadly have two essential questions tailored to different sets of students based on their involvement with this course credit, audit, and sit-through. Every student has to write their reflection in two aspects – (i) what they did in the class, and (ii) followed by what they observed happening in the class. Doing this was strongly recommended after every class. Additionally, students have to articulate their learnings in terms of actively engaging in assigned activities, participating in group discussions, listening to other groups' conversations, and attentively observing the instructor's actions. They were also encouraged to share their expectations for the next class and any confusion or doubts they had, referred to as '*muddy points*'. All students and instructors provided feedback on each other's reflections in the form of a comment in the Homework 0. The document also captures written excerpts from students who had missed the class but claimed to have learned from the slides, class discussions, and the reflections from Homework 0. A snippet of the reflections made in Homework 0 is shown in Figure 2.

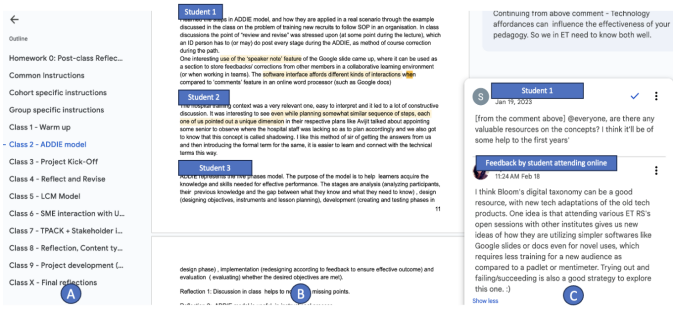

Fig. 2. A snippet of Homework 0 with the structure of the class on the left (A), reflections of learning by students in the centre of the document (B), and feedback in the form of comments by the instructors and other students on the right (C).

Findings: - Post-class asynchronous discussion with peers using shared document Homework 0 helped students collaborate, ask questions, seek feedback, clear their misconceptions, and meaningfully engage in the content regardless of their class attendance. It was also observed that many students reported the number of skills they learned in the course in the Homework 0 activity. They also mentioned the usefulness of interacting with other groups: "*...commenting or giving feedback to other groups' ideas helped to understand what are the things in common, how our groups' ideas differ from others and are able to identify important things which our group might have missed*". Many students reported their reflections in the form of meaningful diagrams and handwritten notes, making it a structured yet flexible mode of communication.

V. Simultaneous Semester-Long Course Project Execution

The course included a major group project. It required students to develop a website[1] for disability awareness. For this, both synchronous and asynchronous modes were used.

[1]https://sites.google.com/view/iitb-pwdcell-training/

A. Synchronous Mode

The course aimed to enhance collaborative learning for both online and in-class students by utilizing technology and organized group discussions. The TA began discussions by dividing the class into groups of five, with at least one online student per group. Each group was assigned a designated area in the classroom, where one laptop connected the online student to the rest of the group via Zoom link. The instructors then presented a specific question related to the project on a shared Google slide, which served as a focal point for group discussions. The online student in most groups guided the discussion to ensure it stayed on track and avoided any potential distractions. Additionally, online students actively monitored the discussion and contributed to the group's collaborative efforts. At the end of the activity, all teams shared their insights with the instructors and other teams for feedback.

Findings: - When the online students were asked how they collaborate, a common answer that was emphasised was their focus on the question posed by the instructor on the common side deck. Most of them talked about the effectiveness of assigning roles in the group to address different tasks: Example – Online Student (Audit): *"...it was relatively easier because while we collaborate online, we have the slides in front of us as default. So we began reading the question first and then started with the discussion. Two of us were taking notes of the discussion in separate sections - what fits the broad question and what would fit the specific first module question, which we pasted in the class response slide at the end.*"

B. Asynchronous mode

To promote effective project discussions outside of class hours, the instructors implemented a clear role allocation strategy for individual team members. These roles are intended to organize team collaboration and ensure that specific deliverables are met. For example, in-class credit students are responsible for asking multiple questions to their teammates and completing final tasks such as inserting content into the training module. Other team members monitor discussions to ensure that the output meets the instructors' expectations for the project. These deliverables act as checkpoints for the instructor to monitor progress and ensure that the project is moving in the right direction. While the roles provide structure, they are flexible, allowing students to switch roles as needed to meet deliverables.

Findings: - This approach facilitates an organized workflow and enhanced accountability within the teams. Each team member has a clear responsibility, ensuring that no student encounters social loafing or overlaps and that everyone actively contributes to the project.

VI. Learnings from this study

Shared Google Slides and Homework 0 document promote synchronous and asynchronous participation, engaging all students with course content, peers, and instructors. Break-out rooms and feedback guidelines aid learning, while instructors facilitate active learning with overall reflections. Based on this, we have listed a few recommendations for instructors which are as follows:

- **Usage of low-tech collaboration platform**: Utilize a common shared platform, like Google Slides, to collect students' responses during class activities like TPS, encouraging active participation through public sharing of views, fostering clarifications, and facilitating meaningful discussions among students and instructors.
- **Stakeholders driven open resources**: Design and maintain shared documents, such as Homework 0, accompanied by clear guidelines throughout the course. This approach promotes meaningful post-class asynchronous reflections, fostering peer learning and knowledge construction with students and instructors.
- **Continuous shared actionable responsibility**: Divide actionable deliverables for small group projects, ensuring progress in the right direction.

VII. Conclusion

This study may not work for all levels and streams of education. It's helpful for corporate training with diverse stakeholders, but may not apply to a specific group like middle school students in one grade.

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Impact on Students' Academic Performance in Blended Learning Using MOOCs

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***Abstract*— Blended learning, combining online and face-to-face instruction, has revolutionized the educational landscape by providing a flexible and personalized learning experience. Integrating Massive Open Online Courses (MOOCs) provides students access to lectures from renowned experts and educational institutions that may not be available in their traditional learning. Evaluating students' academic performance is a critical aspect of education, providing valuable insights into the effectiveness of instructional methods. This article presents a comprehensive analysis of assessing students' academic performance using Massive Open Online Courses in a blended learning environment for undergraduate and postgraduate students. The result shows a variation in the influence on students' academic performance between different types of courses. Moreover, it evaluates how assessment methods like quizzes, assignments, and exams effectively gauge students' active engagement and promote a more comprehensive understanding of the subject matter.**

Keywords-blended learning, MOOCs, Academic performance

I. Introduction

The advent of digitization has revolutionized education by integrating digital technologies into traditional teaching and learning methods, thus altering how knowledge is acquired, shared, and imparted. Information and Communication Technology (ICT) has made educational resources more accessible, facilitated collaborative learning, enabled personalized learning experiences, provided flexibility, and enhanced assessment processes [1]. This digital transformation, encompassing various elements such as digital devices, software applications, online platforms, and multimedia resources, has prepared learners for the digital age. Digitization has expanded educational resources, including digital libraries, open educational resources, and Massive Open Online Courses (MOOCs), which enrich traditional classroom instruction [2]. These technological advancements have created dynamic and interactive learning environments accessible to learners worldwide, eliminating geographical and financial barriers [3]. E-learning, comprising synchronous and asynchronous online, MOOCs, and blended learning, offers flexibility, personalized experiences, interactivity, collaboration, and catering to diverse learning needs [4]. Blended learning combines face-to-face instruction with online activities, creating a hybrid learning environment [5]. Despite its increasing use, there is a need to investigate the impact of blended learning with MOOCs on academic performance. Empirical evidence is scarce, and a comprehensive analysis is lacking, necessitating a systematic examination of its influence on student learning outcomes and assessment practices. Blended learning, harmonizing traditional and digital instruction, offers a holistic educational approach [6]. A research gap exists in understanding the relationship between blended learning with MOOCs and academic performance. A systematic investigation is essential for informing educational stakeholders about its effectiveness in improving student learning outcomes. This study also explores factors influencing MOOC selection and assesses diverse assessment practices.

II. Literature Review

Blended learning combines in-person and online instruction to enhance the learning experience. MOOCs (Massive Open Online Courses) offer flexible, open-access learning experiences to a global audience, typically including video lectures, quizzes, discussions, and assignments [7]. Researchers like Graham [8], Vaughan [9], Garrison [10], and Picciano [11] have defined blended learning as a combination of traditional teaching and online activities. MOOCs accommodate thousands of participants worldwide and offer flexible, self-paced learning. They include video lectures, quizzes, and discussion forums [12]. Means and Toyama found that blended learning, including MOOCs, yields better student outcomes [13]. Bolliger and Martin reported positive experiences incorporating MOOCs into blended learning [14]. Early exposure to MOOCs positively impacts learning engagement and correlates with improved academic performance. Swan's study (2014) [15] emphasized the need for further exploration to understand how age influences academic performance in MOOCs and blended learning. Bunce's research in 2016 [16] highlighted the necessity to investigate mechanisms linking age to performance in blended learning. Dugan [17] stressed the importance of understanding factors contributing to gender-based differences in online and blended learning. O'Dwyer's study [18] called for further research to identify the causes of gender disparities in blended introductory physics courses. Bernard's research in 2017 [19] suggested investigating specific components of blended learning affecting K-12 academic performance. Yau's study [20] urged further investigation into how course design affects performance in mathematics courses. Bourne's analysis [21] highlighted the need to identify effective course design strategies in blended learning environments. Lai's proposal [22] called for empirical research to validate a blended learning framework's

effectiveness. Creswell's study [23] emphasized exploring computer literacy's aspects affecting academic performance in blended learning. Vannet's research [24] sought to understand how computer literacy impacts student performance and the digital divide. Rizzuto's investigation in 2017 [25] called for more studies on computer literacy's role in online and blended learning. Metros' study [26] underlined the need for further research on the effectiveness of digital literacy programs in blended learning.

III. Research Methodology

This paper delves into Graphic Era Hill University's (GEHU), Dehradun, innovative approach to integrating blended learning with Massive Open Online Courses (MOOCs). Students have the freedom to choose MOOCs from three categories: (i) aligned with their hobbies or interests, (ii) related to their academic field but not covered in the syllabus, and (iii) directly relevant to their coursework. These MOOCs are credit-based, with course completion mandatory, while the optional presentation of certificates accommodates courses with associated certification fees.

The learning process and progress in MOOCs are assessed through formative assessments, divided into three phases: initial registration and subject introduction, tracking progress, and final report submission upon course completion. Marks are assigned for each phase, contributing to credit allocation. Faculty members guide students in course selection, promoting confidence in the subject. This paper focuses on implementing single-credit courses in the School of Computing, explicitly targeting students unfamiliar with online classes. The study analyses data from 200 first-year students pursuing MCA and BCA during the July-December 2022 academic session. The research aims to explore the influence of demographic data on students' academic performance in blended learning using MOOCs, addressing the following questions:

Research Question 1: How does age influence students' academic performance in blended learning using MOOCs?

Research Question 2: Is there a significant difference in academic performance between male and female students in blended learning using MOOCs?

Research Question 3: What is the relationship between the course and students' academic performance in blended learning using MOOCs?

Research Question 4: To what extent does computer literacy affect students' academic performance in blended learning using MOOCs?

IV. Data Analysis

Research Question 1 analysed the relationship between age and academic performance. Negative correlation values indicate that academic performance tends to decrease as age increases. The regression analysis produced the equation: Academic Performance = -1.15 * Centred Age + 12.85. Here, "Centred Age" subtracts the mean age from each individual's age, where the centered age coefficient (-1.15) implies that academic performance is expected to decrease by 1.15 percentage points for every one unit increase in age. The p-value for the Age variable is 0.037, indicating a statistically significant effect of age on academic performance in blended learning using MOOCs. The R-squared value of 0.168 suggests a moderate association between age and academic performance. In summary, age significantly influences educational performance, with older students generally achieving lower academic performance in blended learning with MOOCs than younger students.

Research Question 2 investigates the difference in academic performance between male and female students in blended learning using MOOCs. The analysis implies that gender has a limited impact on academic performance, with male students showing a slightly weaker correlation with their gender and performance than females. Additionally, a t-test analysis revealed a statistically significant difference between the two groups (p-value = 0.023). On average, female students outperformed male students, indicating that gender may have some influence on academic performance in blended learning using MOOCs.

For Research Question 3, which explored student satisfaction differences between BCA and MCA courses, the statistical analysis involved both ANOVA and Tukey's HSD tests. The ANOVA test aimed to determine if there was a significant satisfaction difference between the two courses. The results revealed a p-value < 0.05, indicating a statistically significant difference. The ANOVA test showed an F-value of 4.22 and a p-value of 0.042, marking a significant difference in student satisfaction between BCA and MCA courses. Tukey's HSD test was conducted as a post hoc analysis. Tukey's HSD results indicated a significant difference in student satisfaction, with MCA students scoring an average of 7.31 points higher than BCA students. The p-value of 0.023 further confirmed this significant satisfaction gap, suggesting that MCA courses in blended learning using MOOCs generally foster higher student satisfaction than BCA courses.

For Research Question 4, which assessed the impact of computer literacy on academic performance in blended learning with MOOCs. The ANOVA test showed a significant effect of computer literacy on academic performance ($F = 3.98$, $p < 0.05$). Students' varying computer literacy levels notably impacted their academic performance. Students with low computer literacy had a relatively higher mean performance than those with medium computer literacy. However, students with high computer literacy achieved slightly higher mean performance than low and medium computer literacy groups.

V. Result and Summary

This study examined students' academic performance in blended learning with MOOCs, yielding the following insights: Age (RQ1): Age does not significantly affect academic performance, emphasizing the need for adequate support for all students. Gender (RQ2): No significant gender-based difference in academic performance was found, highlighting the importance of equal opportunities and inclusivity. Course Selection (RQ3): Specific courses influence academic performance, emphasizing the role of course design and content. Computer Literacy (RQ4): Computer literacy significantly impacts performance, underscoring the importance of digital skills training. In

summary, age and gender do not considerably affect academic performance, while course and MOOC selection and computer literacy play crucial roles. Educators should focus on effective course design, digital literacy promotion, and strategic MOOC selection to optimize student performance in blended learning with MOOCs.

VI. Future and Limitations

This study relied on self-reported data and had a narrow focus, suggesting potential for broader research with diverse data sources. In summary, age and gender do not significantly affect academic performance, while course and MOOC selection and computer literacy play crucial roles. Educators should focus on effective course design, digital literacy promotion, and strategic MOOC selection to optimize student performance in blended learning with MOOCs. Further research can explore effective instructional strategies and consider additional variables like prior educational background.

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Building Inclusive Learning Environments: A Pedagogical Strategy for Educational Equity

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***Abstract*— Educational equity helps each student receive what they need to develop to their full academic and social potential. Equity has been the goal of all Indian National policies on education including the recent National Education Policy (NEP 2020). But it is far from even reasonable attainment. Working towards equity involves ensuring equal outcomes for all students. Universal Design for Learning (UDL) is the expression of a belief that all students are capable of learning and that instruction, when crafted and implemented with this belief in mind, can help all students succeed in inclusive and equitable learning environments. UDL and digital technologies together can effectively address the issue of equity. This paper makes a case for the integration of UDL, ADDIE model, Outcome Based Education (OBE), and Merrill-Kolb principles of learning which can offer a comprehensive framework for designing and facilitating courses in higher education programs in blended learning mode. If students have smart internet devices, access to the internet, and systems are in place, blended learning can promote equity in education without burdening teachers.**

Keywords—UDL, ADDIE, Equity, Blended learning

I. INTRODUCTION

The National Equity Project (2022) defines educational equity as helping each student receive what they need to develop to their full academic and social potential [1]. Equity has been the goal of mostly all Indian National policies on education including the recent National Policy of Education (NEP 2020) [2]. But it is far from even reasonable attainment. It is so because the existing methods of instruction, systems, and technologies do not enable the teachers to respond to the needs and concerns of students individually. Differentiated instruction is the method followed by many institutions and is also a requirement of accreditation. It involves categorizing students into three classes based on perceived abilities or grades that can lead to stigmatization, low self-esteem, and limited expectations. Working towards equity involves ensuring equal outcomes for all students. Social, cultural, and economic factors should not influence success or failures. Specifically, it means eliminating inequitable practices, assessment biases, creating inclusive institutional environments, and discovering and cultivating every student's unique ability, talents, and interests. Tenets of equity are accelerated teaching, and a "whole person" approach to student learning and engagement. Acceleration may be defined as "preparing students for new learning and getting them ready for success in the present" and does not concentrate on a litany of items that students have failed to master [3].

Universal Design for Learning (UDL) is the expression of a belief that all students are capable of learning and that instruction, when crafted and implemented with this belief in mind, can help all students succeed in inclusive and equitable learning environments. UDL requires one to believe that all students can become expert learners who can make effective decisions, a skill set to eliminate barriers that prevent students from learning, and to support students academically, behaviourally, socially, and emotionally, and systems that constantly monitor the barriers to learning and can take actions to reduce/ eliminate those barriers. UDL reminds us of the goal of any institution is to teach students, whatever the instructional situation, how to become motivated, resourceful, innovative learners and help them prepare for the lives they want to live [4]. UDL with appropriate use of digital technologies together can effectively address the issue of equity. Blended learning offers us a vehicle to seamlessly traverse across face-to-face, hybrid, and online modes of instruction and addressing issues of equity.

Major concerns of National Education Policy (NEP 2020) of India include equity and inclusion, holistic and multidisciplinary education, vocational education, teacher education, governance and leadership, learning Environment and student support, and technology use besides others can all be addressed though UDL and blended learning.

If students have smart internet devices and access to the internet, and systems are in place, and skills and strategies exist to provide support to students, digital technologies can be leveraged to promote equity in education without overwhelming and burdening teachers. We make a case for the integration of UDL, ADDIE (Analysis, Design, Development, Implementation, Evaluation) model, Outcome Based Education (OBE), and Merrill's principles of learning which can offer a comprehensive framework for designing and conducting courses in higher education programs in blended learning mode [6]. Through this integrated framework educational institutions can create a cohesive approach that addresses equity, personalized instruction, and effective learning experiences for all students.

II. UNIVERSAL DESIGN OF LEARNING

The term Universal Design was coined by architect Ronald Mace in 1988. He defined it as the '*design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design*.' UDL adapts Mace's definition to learning [4]. UDL is a *framework for inclusive education that aims to lower barriers to learning and optimize everyone's opportunity to learn*. UDL recognizes the need for authentic, self-differentiated, flexible learning to provide equal opportunities for all learners to succeed, regardless of the learning landscape. UDL provides a vision for breaking the 'one-size-fits-all' mold and therefore expands the opportunities for learning for all students with learning differences. Recognizing and responding to diversity is a core motivation for engaging in UDL practices.

CAST's philosophy of UDL is embodied in principles that serve as the core components of UDL:

- Multiple means of **representation** give learners various ways of acquiring information and knowledge.
- Multiple means of **engagement** to tap into learners' interests, challenge them appropriately, and motivate them to learn.
- Multiple means of **action and expression** to provide learners alternatives for demonstrating what they know.

Multiple means of Representation is to provide options for Perceptions (customizing the display of information, and offering alternatives for auditory information and visual information), options for Language and Symbols (clarifying vocabulary and symbols, clarifying syntax and structure, supporting decoding of text, mathematical notation and symbols, illustrating through multiple media), and options for Understanding (activating or supplying background information, highlighting patterns, critical features, big ideas, and relationships, and maximizing transfer and generation). Multiple means of Engagement is to provide options for Recruiting Interest (optimizing individual choice and autonomy, optimizing relevance, value and authenticity, and minimizing threats and distractions) options for Sustaining Effort and Persistence (heightening salience of goals and objectives, optimizing challenge through varying demands and resources, fostering collaboration and community, and increasing mastery oriented feedback), options for Self-Regulation (promoting expectations and beliefs that optimize motivation, facilitating personal coping skills and strategies, and developing self-assessment and reflection). Multiple means of Action and Expression is to provide options for Physical Actions (varying the methods for response and navigation, and optimizing access to tools and assistive technologies) options for Expression and Communication (using multiple media for communication, using multiple tools for construction and composition, and building fluency with graduated levels of support for practice and performance), and options for Executive Functions (guiding appropriate goal-setting, supporting planning and strategy development, facilitating managing information and resources, and enhancing capacity for monitoring progress). The principles are elaborated through the graphic organizer shown Figure 1.

UDL can be layered into any of the Instructional Systems Design (ISD) models such as ADDIE, Backward Design, and Fink's Integrated Course Design [5]. *In this paper, we propose a plan for layering UDL into ADDIE.*

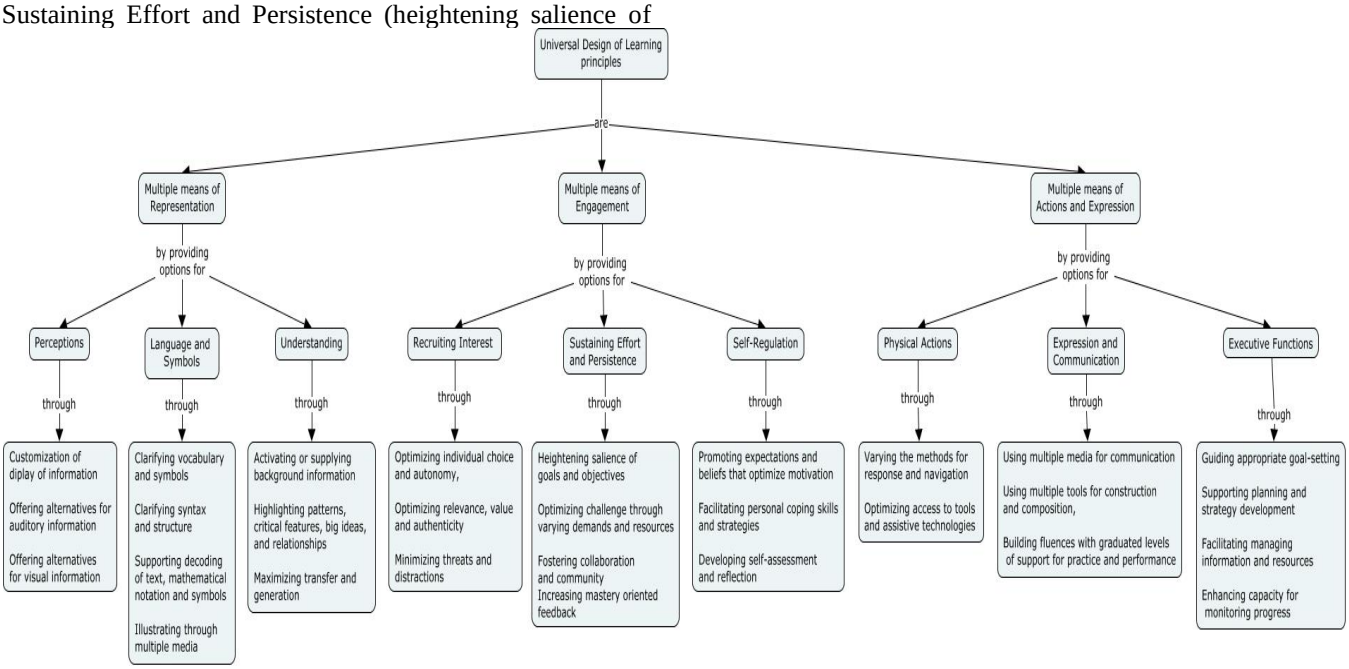

Figure 1: CAST principles of Universal Design of Learning

III. UDL AND BLENDED LEARNING

Blended learning is the combination of active, engaged learning online combined with active, engaged learning offline to provide students with more control over the time, place, pace, and path of their learning. It reflects a constructivist perspective, placing emphasis on the student's role as an active participant in the learning process. It recognizes learning need not be restricted to a particular time or place, values the student's ability to control the pace of learning, and acknowledges that a student can personalize her path of learning. While blended learning has been around for three decades, technologies and COVID-19 have massively accelerated online instruction and blended learning. Such learning models enable shift from teacher-centered to student-centered learning, which is critical to increasing student engagement. Teachers can use the time, space, and flexibility afforded by blended learning models to increase student engagement by teaching self-regulation skills, fostering communication and collaboration among a community of learners, and prioritizing student agency. *The principle of providing multiple means of representation, an essential feature of UDL, is easier to accomplish when teachers use blended learning models and online resources available [4].*

IV. UDL AND MERRILL'S AND KOLB'S PRINCIPLES

According to Merrill [8] and Kolb Principles [7]:

- Learning is promoted when learners acquire knowledge and skill in the context of real-world problems or tasks. These are represented as **Course Outcomes**.
- Learning is promoted when learners are motivated about competency (**attention**) and **activate** the mental model of their prior knowledge and skill as foundation for new knowledge and skills.
- Learning is promoted when learners observe a **demonstration** of the knowledge and skill to be learned.
- Learning is promoted when learners **apply/ engage** with their newly acquired knowledge and skill.
- Learning is promoted when learners reflect on, discuss, and defend their newly acquired knowledge and skills (**Integration**).

Students will learn better when following five elements are integrated in instruction [8]:

- Course Outcome
- Attention and Activation
- Demonstration
- Apply/ Engage
- Integration

The sequence of steps towards attaining a course outcome as per Merrill/Kolb principles of learning is presented in Figure 2. A well written course outcome is the starting point for any instructional unit. The instructor will gain attention of students through answering the Why question (through online or face-to-face; through motivational stories (multimedia presentations) and simulations), and activate the prior knowledge (through simulations, class discussions, group discussions, recapitulations, data analysis, graphic organizers etc. either face-to-face or online). Several Demonstration and Applications/Engagements will follow this. Demonstrations are done online using several instructional components arranged in multiple pathways. Student chooses the learning path based on his/ her preferences. Students will test their understanding of concepts and their application in a scaffolded manner using formative assessments. The responses of students are automatically evaluated, and feedback is given to the students. Students may revisit the demonstrations based on the given feedback. A report is generated for the instructor on learning activities and performance of each student. Online activities leading from demonstration to application are presented in Figure 2. The instructor can plan for Application activity after combining the student feedback after each demonstration with the generated report. This leads to students engaging immediately with the new knowledge gained during demonstration. The instructor can choose application activity from many instructional components available. This is done face-to-face in blended mode of learning providing an opportunity for better tutoring.

After going through all Demonstrations and Applications as planned based on the scope of a course outcome the instructor organizes Integration. It involves reflection on new knowledge and skills, defending new knowledge, and linking it to other competencies/outcomes. This can be done through one or more activities indicated in Figure 3.

V. PEDAGOGICAL STRATEGY THROUGH UDL, ADDIE, AND BLENDED LEARNING

Instructional Systems Design (ISD) Models are the systematic guidelines instructional designers follow to create a workshop, a course, a curriculum, an instructional program, a training session, or the instructional materials and products for educational programs. The "ADDIE Model" is a colloquial term used since the 1980s, also known as a military model of instruction, to describe a systematic approach to instructional development. It is not a specific, fully elaborated model, but an umbrella term that refers to a family of models that share a standard underlying structure. ADDIE is an acronym referring to the five stages that comprise the generic ISD: Analyze, Design, Develop, Implement, and Evaluate. These stages are sequential and iterative. One semester course in formal programs will be our focus. All formal higher education programs in India are required to attain a set of Program Outcomes (PO), and a set of Program Specific Outcomes (PSO). As per Outcome Based Education, a requirement of both the UGC and the AICTE, all courses in formal programs have to be described in terms of a set of Course Outcomes.

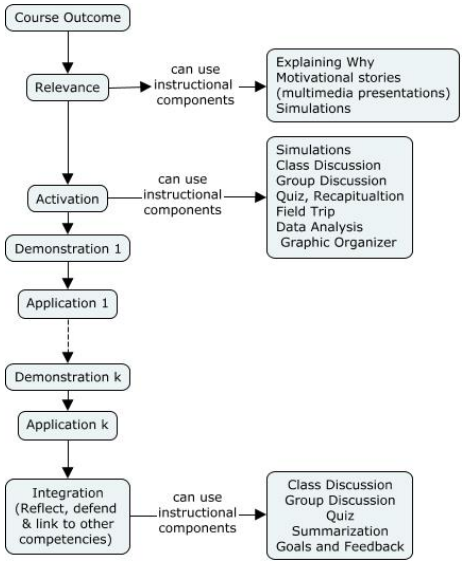

Figure 2: A plan of instruction as per Merrill/ Kolb principles

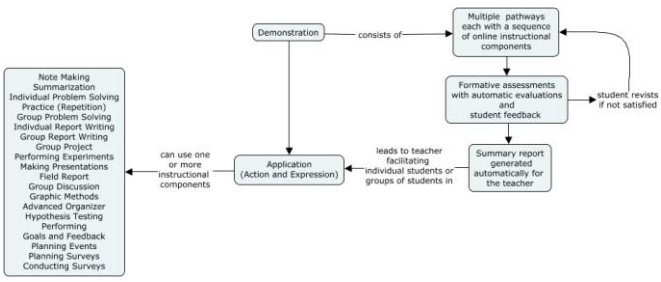

Figure 3: Demonstration to Application in blended mode

A. *Proposed sub-processes of Analyze phase*

1. Write the course context and overview.

2. Record student learning variability. A survey questionnaire can be used to tap the learning preferences and motivation of students.
3. Write 6 to 8 Course Outcomes for a 3-credit course that can be measured for attainment, and tag them with relevant POs, PSOs, Cognitive Level, Knowledge Categories, and the sessions (classroom, tutorial, and laboratory) required.
4. Create a concept map of the course to help students see the structure of the course.
5. Write a minimum of four test items at the mastery level for each course outcome at its cognitive level and sample solutions to these test items that would reflect the instructor's way of integrating course outcomes and selected POs and PSOs.
6. Elaborate Course Outcomes into 15±5 Competencies of the course to facilitate instructional planning.
7. Have the output of the analyze phase peer-reviewed and make the changes needed.

B. Suggested sub-processes of the Design Phase

1. Generate an instructional plan/ schedule.
2. Set targets for CO attainment.
3. Determine an assessment plan that reflects mastery learning.
4. Create sample structures of Assessment Instruments
5. Create an Item Bank as per the assessment plan and formative assessment incorporating scaffolding.
6. Plan for mastery-oriented feedback to the students on their responses to both formative and summative assessments. The rubrics for assessment wherever relevant should be shared with the students.
7. Have the outputs of the design phase, peer-reviewed, and modify them if necessary.

C. Suggested sub-processes of the Develop Phase

1. Identify instructional activities for online and face-to-face sessions for each instructional unit.
2. Plan for access (classroom, IT tools, Internet access, and resource materials).
3. Prepare a script with provision for options for multiple means of Representation, Engagement, and Action and Expression for each instructional unit using Merrill's principles of learning that emphasises Activation phase (addressing Why).
4. Prepare instructional materials as per the script for all Instructional Units.
5. Select and prepare multimedia learning materials for all Instructional Units of the course.
6. Have the outputs of the develop phase peer-reviewed and modify them if necessary.

D. Suggested sub-processes of the Implement Phase

1. Prepare the Syllabus of the course.
2. Prepare an Instruction Schedule for blended mode of instruction.
3. Record observations on instruction on a regular basis.
4. Collect student feedback at least twice during the semester.
5. Create Assessment Instruments both for formative and summative assessments proposed to be used.
6. Record observations on Assessment Instruments and Student Performance
7. Give feedback to students after every assessment.
8. Track students' progress through the semester for any possible mid-course corrections.

E. Suggested sub-processes of the Evaluate Phase

1. Collect student feedback at the end of the course.
2. Compute CO attainment and from there PO and PSO attainments
3. Make summary observations.
4. Collect peer feedback.
5. Plan for reducing the CO attainment gap or increasing CO attainment target.
6. Have the outputs of evaluate phase peer reviewed and modifying them if necessary.
7. Additional sub-processes can be added as per the accreditation requirements and institutional context.

VI. CONCLUSIONS

Equity at all levels of education, a national goal, can only be attained by recognizing that all students are individuals, and their motivations, abilities, skills, preferences, and social contexts vary. Instruction cannot be to a mythical average student. UDL with blended learning offers a solution that can facilitate all students to become mastery learners. UDL can be implemented through designing and conducting courses in the ADDIE ISD model and the instruction through blended learning following principles of learning of Merrill and Kolb. Appropriate mindset of teachers and dedicated support from the system are prerequisites for attaining equity.

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What Really Matters: Reflections from Large-Scale Online Learning Implementation on FramerSpace

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***Abstract* — Web infrastructural functions are an invisible interface between learners and online learning platforms, and their performance is pivotal in shaping learner experience and overall learning outcomes. Existing studies have revealed that longer page load times were associated with higher bounce rates and reduced average time on the webpage. Considering the impact of Web Infrastructure Management (WIM) on user experiences, educational technology research must further examine and address this aspect. This research examines the impact of WIM on user experiences in the online learning environment. We present an analysis of changes in course completion time across different courses on a learning platform before and after a set of web infrastructure optimizations. Our findings show that the time required for course completion has statistically significantly decreased. This suggests that optimizing web infrastructure can significantly enhance online learning platforms' effectiveness by ensuring seamless access to learning content and fostering a positive user experience.**

Keywords — Online Learning Environment, Web Infrastructure Management, Large Scale Implementation, User Experience, FramerSpace

I. Introduction

Research in the learning sciences and educational technology has explored and studied a wide range of factors that impact the learning experience and the learning process itself. These factors include but are not limited to the quality of pedagogy, content, assessment methods, and technology integration [1]. Researchers underscore the significance of understanding the dynamic interplay between technology, pedagogy, and content knowledge to enhance the learning experience [2]. Moreover, Katsarou and Chatzipanagiotou (2021), in their critical review of learner-centered interactions in online learning, emphasize the crucial role of interactivity in knowledge acquisition and cognitive skills development [3]. Consequently, the educational technology research community has conducted in-depth investigations into the intricate relationship of learner experience with pedagogy, content, assessment strategies, and technology affordances. These studies contribute significantly to the rigorous understanding and advancement of educational technology in fostering effective learning environments.

Much research on online learning environments (OLE) focuses on studying learner interactions, technology affordances, and their coupling with pedagogy and assessments. However, one critical aspect of technology that significantly impacts learner experiences has received limited attention: web infrastructure management (WIM), which is often studied as a sub-domain within the computer science domain. WIM functions as an invisible interface between learners and learning platforms, and its performance is pivotal in shaping user experience and overall learning outcomes.

Some studies have examined the relationship between WIM performance and user satisfaction [4]. For example, users' satisfaction was examined in online learning platforms in China during the COVID-19 epidemic [4]. There was a decrease in user experience and utilization rates when there was network congestion or flashbacks while using the platform. In another study [5], although not specifically related to online learning, page load speed was studied in relation to web user experience. The study revealed that longer load times were associated with higher bounce rates and reduced average time on page, where bounce rate refers to the percentage of visitors who leave your website. A slow server response results in long waiting periods for users, during which web pages may display incorrectly, causing half-loaded images and broken layouts. The existing literature on response times indicates a consistent pattern over the last three decades, as evidenced by various studies [6][7]. Users typically perceive the system's responsiveness as instantaneous when the response time hovers around 0.1 seconds, necessitating no further feedback apart from displaying the result. A response time of roughly 1.0 seconds allows users to perceive a slight delay without interrupting their train of thought, although it may lead to a diminished sense of direct data operation. However, if the response time exceeds 1.0 seconds but remains below 10 seconds, users may tend to perform other tasks while waiting, making it crucial to provide feedback that informs them about the anticipated completion time. This feedback assumes even greater significance when the response time is expected to vary significantly.

Considering the impact of web infrastructure management on user experiences, it is imperative that educational technology research examine and address this aspect further. Better understanding and optimizing web infrastructure can significantly enhance online learning platforms' effectiveness by ensuring seamless access to learning content and fostering a positive user experience. Literature on WIM within the computer science domain provides detailed accounts of optimizing web infrastructure for various purposes and scales. However, for the educational technology community, it is crucial to study the impact of web-infrastructure optimization

on learner experiences. In this paper, we use course completion time as a proxy for learner experience quality. We present an analysis of changes in course completion time across different courses on the learning platform FramerSpace, before and after a set of web-infrastructure optimizations. As a result of the web-infrastructure optimization, we have found that the time required for course completion has statistically significantly decreased.

II. FRAMERSPACE

FramerSpace (www.framerspace.com) is an indigenous platform developed by UNESCO MGIEP, enabling the creation and hosting of online courses accessible to learners globally. It is a co-creation platform that provides building blocks to support creating and hosting online courses. It is designed to empower course creators by providing them the tools to create and share their online courses. It allows users to create courses using a variety of building blocks, including videos, quizzes, and interactive exercises. FramerSpace offers the affordance to design assessments seamlessly interleaved with the learning building blocks. Creators can create diverse assessment strategies tailored to the needs of their courses and target audiences. The courses can be created free of cost and can be freely accessible to learners around the world. Learners can sign up and navigate FramerSpace on their mobile devices or computers. Including the 20+ public courses created by the institute, FramerSpace currently hosts 3263 courses.

Courses on FramerSpace are available in two modalities: self-directed and facilitated. In the "self-directed" modality, learners can enroll in a course without a designated facilitator. Learner progress is not tracked or guided by a specific facilitator. On the other hand, the facilitated modality allows learners to join a cohort only with a unique invite code. Cohort facilitators monitor learners and provide guidance as needed. It is essential to note that FramerSpace adheres to the General Data Protection Regulation (GDPR). A unique ID identifies each learner, and the platform does not require learners to provide personal identifiable information (PII), such as names. As a result, even facilitators need access to learners' PII in their cohorts. Instead, they can access anonymized individual trends and overall cohort trends for effective facilitation.

Guided by the vision of "Building Kinder Brains," UNESCO MGIEP focuses on achieving UN Sustainable Development Goal 4.7, promoting education for peaceful and sustainable societies. Their programs and products emphasize social and emotional learning, innovative digital pedagogies, and youth empowerment backed by science and evidence-based research. Through FramerSpace, the institute provides a range of courses addressing important issues like Climate Change and Biodiversity loss, catering to diverse stakeholders, including K-12 students, youth, and educators. Most of these courses are designed for participants aged 13 years and above; these online interactive courses aim to employ engaging, immersive, interactive digital pedagogies.

In this paper, we include the data from the courses with the highest number of learners enrolled in the “self-directed” modalities. These courses include (i) Climate Change Course for K12 learners, (ii) Digital Teachers course for teacher professional development (Hindi and English versions), and (iii) A course on “Self-directed Emotional Learning for Empathy and Kindness” for youth. The details of these courses with their exact titles are as follows.

A. *Climate Change: Understand, Reflect, Empathise, and Act*

The Climate Change course aims to enhance understanding of essential climate change concepts like carbon footprint and international treaties and focuses on building skills such as emotional regulation, critical inquiry, perspective-taking, and compassion. The course is designed as a stand-alone module or an additional resource to support teachers and learners in comprehending climate change and adopting pro-environmental behavioral actions for positive change.

B. *The Digital Teacher*

The 'Digital Teacher' course empowers educators to harness digital technologies and create meaningful, authentic, and engaging learning experiences. Aligned with four international standards of digital competencies for educators, it fosters the ability to use technology to enrich choice and engagement, promote collaboration and creativity, provide support and scaffolding, and design formative assessments.

C. *Self-directed Emotional Learning for Empathy and Kindness (SEEK)*

This course aims to nurture skills such as empathy, mindfulness, and compassion, equipping youth with better coping mechanisms for their emotional well-being and enabling them to contribute towards developing peaceful and sustainable societies.

III. FRAMERSPACE WEB INFRASTRUCTURE

Much like any other web service, we have consistently maintained and enhanced the web infrastructure of FramerSpace since its inception. However, significant upgrades were implemented in and after May 2022. For this research, we focus on two periods of FramerSpace: the first between May 2021 and May 2022 (Period #1) and the second between May 2022 and May 2023 (Period #2). In Period #1, we deployed the application over a single Linux-based cloud server and served user requests using NodeJS. In Period #2, we started using multiple (4 to 8) Linux servers to serve user requests. All these servers were being called round-robin by a load balancer. Along with that, we shifted our database over to a cloud server as well.

A. *Node Process Manager implementation*

In the past, the FramerSpace application used to run directly on a program called Node [8]. However, we improved by using a process manager called PM2. PM2 is a smart helper that monitors FramerSpace processes while running in the background. PM2 can run multiple copies of the FramerSpace application simultaneously, and each copy runs on different parts (cores) of the computer's processor. This way, FramerSpace can work faster and perform better.

B. *Migration from a local database instance to a cloud-hosted database*

We migrated our database from a local instance to a cloud platform known as Mongo Atlas. This helped in decreasing database query execution time.

C. *CDN Implementation*

We started serving our static files (images and others) using CDN. CDN stands for Content Delivery Network. This is like storing many copies of our website on a geographically

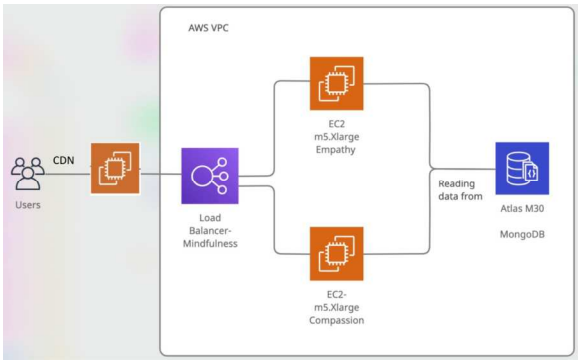

FIGURE 1. FRAMERSPACE'S AWS CLOUD INFRASTRUCTURE IN PERIOD 2

dispersed network of proxy servers and their data centers. The goal is to ensure high availability and optimal performance by geographically distributing the service close to end users' locations.

D. *Horizontal and Vertical Scaling*

We employed both horizontal and vertical scaling approaches [9]. Vertical scaling involves upgrading a single machine's hardware to handle the workload, such as enhancing processing power by increasing the CPU in a server. In contrast, horizontal scaling entails adding more machines to distribute the database load and boosting storage and processing power, achieved through sharing, replication, and clustering.

FramerSpace is hosted on the cloud infrastructure of Amazon Web Services (AWS). As shown in Figure 1, during Period 2, the components included a CDN layer between the learners and AWS Virtual Private Cloud. The virtual private cloud encompassed a load balancer responsible for directing user requests to more than one (in the figure, we have shown two machines for simplicity) application machines (EC2 m5.Xlarge). At the same time, a separate database server, Atlas M30, was used for data storage and responding to database queries.

IV. RESEARCH METHODOLOGY

A. *Research Question*

Our objective was to assess the impact of web infrastructure changes on the learner experience. The specific research question (RQ) we answer through this research is as follows.

RQ: How do course completion times vary across different courses on FramerSpace with changes in web infrastructure between period 1 and period 2?

B. *Data Collection*

We used the course completion duration data, i.e., the difference in time when a learner enrolled in a course and when they generated the certificate.

C. *Sample*

Until May 2023, FramerSpace had 196,660 enrolments in various courses, with 89,219 enrolments in facilitated cohorts and 107,441 in self-directed cohorts. We noted that different cohorts may have been facilitated by different facilitators, resulting in different factors affecting learner experiences. Given that we were interested in studying the impact of web infrastructure changes only and no other factors, therefore, we narrowed down our analysis to the enrolments in the self-directed cohorts during Period 1 and Period 2 (May 2021 to May 2023). We excluded enrolments that started before Period 1 or completed after Period 2, as well as those that started in Period 1 and completed in Period 2. Additionally, we removed courses with less than 100 learners during Period 1 or Period 2. Consequently, Table 1 shows 15,583 learners across four courses and periods #1 and #2 for our analysis.

D. *Data Analysis*

For each included enrolment, we computed the time the enrolled learner took to complete the respective courses. We created a list of course completion times for each enrolled learner for a given course during a particular period. For each course, we analyzed the difference in the means of course completion time between Period #1 and Period #2 using an independent sample t-test.

V. RESULT AND DISCUSSION

The results are shown in Table 1. We found that the course completion time has reduced statistically significantly in Period #2 ($p < 0.05$). This implies that the modifications to FramerSpace web Infrastructure during Period #2 have significantly improved learner experience. More specifically, "SEEK" and "The Digital Teacher – Hindi" were reduced to less than half.

It is essential to highlight that the three courses, Digital Teacher, SEEK, and Climate Change, differ in length and target different audiences, including teachers, youth (18+), and K12 learners (aged 13 to 18), respectively. Moreover, the Hindi version of the Digital Teacher course is primarily utilized by teachers from cultures with limited English proficiency. The statistical significance of our results across these diverse courses emphasizes the generalizability of our findings, encompassing different course contents, digital pedagogies, age groups, and language preferences of the learners. This strong evidence supports the idea that server infrastructure changes can influence learner experiences, particularly in course completion time.

The findings offer valuable insights for educational technology practitioners, highlighting the importance of investing in and optimizing server infrastructure to enhance user experiences and support effective online learning environments. We recognize the significance of optimizing digital pedagogical designs, content selection, and technology affordance designs to enhance learner experiences. However, one aspires to reach real end users after designing, developing, and evaluating these factors for an online learning environment. Our findings indicate that even with optimal pedagogy, content, and technology affordances, if the web infrastructure responsible for delivering the learning environment needs to be optimized, the outcomes may not be optimal for learning experiences.

TABLE 1. DIFFERENCE OF MEANS OF COURSE COMPLETION TIME BETWEEN PERIOD #1 AND PERIOD #2 ACROSS COURSES

	Number of Learners		**Completion Time** (Hours)			
Course	**Period #1**	**Period #2**	**Period #1 Mean**	**Period #2 Mean**	**Difference of Means**	**p-value**
Climate Change	177	1473	172.84	99.24	73.60	0.00068**
SEEK	1468	801	209.83	101.13	108.70	0.00000**
Digital Teacher - English	2989	6163	340.79	222.85	117.94	0.00000**
Digital Teacher - Hindi	683	1829	234.35	87.17	147.19	0.00000**

While this research has shed light on the impact of enhancing the web application server architecture on learner experiences, several limitations should be acknowledged, and areas for future research can be identified. Firstly, the study focused solely on course completion rates as the primary metric for learner experience, neglecting other potential variables such as learner satisfaction, engagement, or knowledge retention. Future work should consider a more comprehensive set of indicators of the quality of learner experiences to gain a deeper understanding. Secondly, the research was conducted within a specific technology context of the FramerSpace platform, and a similar analysis needs to be carried out on a few other web-based educational platforms.

Furthermore, in Section III, we discuss four distinct techniques used for web infrastructure optimization. The impact of these individual techniques on learner experiences will be examined in future studies. Additionally, while the research demonstrates statistically significant improvements in course completion time, it needs to fully uncover the underlying mechanisms responsible for the observed effects.

Moreover, the research primarily focused on traditional course completion rates without unpacking the potential impact on learners with diverse needs or those facing various barriers to online education. Future work should include a more comprehensive examination of user experiences for diverse learners to ensure inclusivity and accessibility in the educational technology domain.

VI. CONCLUSION

Factors like web infrastructure that maybe crucial to consider before we go into real-world implementation include, but are not limited to, learners' access to power, devices, and quality internet. Issues with these may hamper learner experiences and limit the intended outcomes of the online learning environments. Explicitly referring to our research, it's essential to message the educational technology research community that the actual user experience must be discussed in the context of such external variables. This also suggests how digital readiness at such a level is crucial. A mere website presence is inadequate; a comprehensive infrastructure is imperative for ensuring a satisfactory user experience.

In conclusion, while this research has significantly contributed to understanding the influence of server infrastructure on learner experiences, there are several opportunities and limitations that warrant further investigation. Addressing these limitations and expanding the research scope will advance the educational technology field and emphasize the importance of considering the actual user experience in conjunction with external variables when designing and implementing web applications for education.

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Designing a constructionist epidemiology curriculum with Agent-based Models: An exploratory study

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***Abstract*—Constructioninst pedagogy have been effective in engaging learners in teaching of complex scientific phenomena, such as spread of diseases. Though Agent-based models (ABMs) provide the means to operationalize this pedagogy and support the scientific investigation, their integration into a curriculum and subsequent effect on various learning aspects still have the scope for investigation to improve this integration. In this study, we developed a curricular unit using the CT-STEM platform, which is a web-based tool for creating curriculums with the integration of ABMs. This was followed by a pilot study to understand learners interactions and their ways of participation during the session. The analysis of this exploratory study is presented through the analysis of the learner's responses, and their perceived mental load (measured using NASA-TLX). Key contributions of this work includes the design of a constructionist curricular unit, and the pilot study to gain insights on the learners' participation. The paper concludes by presenting possible limitations (such as the need for scaffolding for some learners, technological accessibility, etc.) and possible ways in which this can be extended.**

***Index Terms*—Microworlds, Constructivism, Agent-based Modelling (ABM), Constructionism, Interactive Learning Environment, Constuctionist Curriculum**

I. Introdution

In the traditional teaching and learning of scientific concepts, the "knowing" approach is preferred. This has been mostly due to the lack of resources, resulting in a dearth of opportunities for exploring scientific c oncepts t hrough interactive tools and scientific p ractices t o c onstruct o ne's own understanding. Constructionist curricula have the potential to engage learners in scientific i nquiry a s w ell a s computational thinking practices [1], by providing this opportunity. Studies have explored the potential use of agent-based modelling, constructivism, constructionism, the emergent system microworld, and the benefits of CT STEM curricula [2]. However, the scope of designing curricula that allow learners to play, explore, and reflect t o l earn c omputational t hinking i n a systematic and contextual manner is still less explored. Hence, this paper discusses the design and development of such a unit, named epiDEM explorer, with a broad learning objective to understand the spread of an infectious disease. For this, we utilised the "epiDEM basic" model [3], which was available on the CT-STEM platform. The work also presents insights from a pilot study based on the same curricular unit.

A. Theoretical Frameworks: Constructionism and Computational Thinking (CT) practices

Constructionism emphasises the fact that learning is the outcome of the learner's meaningful engagement that happens through hands-on experience [4]. Microworlds can be described as a sandbox where the learner interacts with the artefacts in the environment to get this hands-on experience, which caters to the curriculum's learning objective. The feedback provided by microworlds provides learners with an opportunity for the development of personal knowledge, and it also promotes a culture where science and mathematics are talked about consciously [4]. Computational thinking (CT) refers to the skill of thinking so that the problem is formulated in a way that it can be solved systematically [5]. In the context of the STEM curriculum, computational thinking practices are divided into four categories, namely: 1) data practices, 2) modelling and simulation practices, 3) computational problem-solving practices, and 4) systems thinking practices [6]. Constructionist environments have the potential to integrate CT and related practices for teaching scientific concepts, which can be an added benefit of such curricula [7].

II. Design and development of the curriculum

A. Goals of the Curriculum

A curriculum titled "Epidemic Explorer" was developed by using the NetLogo [8] model, epiDEM, on the CT-Stem platform, with the broad goal of teaching how a pandemic spreads. This curriculum platform provides a learning-by-doing experience about the curricular content (epidemiology) by engaging the learners in CT practices. The specific learning objectives for the curriculum are as follows:

- Understand the basic principles and assumptions for modeling the spread of disease in a closed population.
- Describe how changes in the model parameters can affect the outcome of the epidemic.

- Analyze and interpret the data from the COVID-19 epidemic using the concepts and tools learned in this curriculum.

These learning outcomes are deliberately defined in such a manner that they are above the recall level in Bloom's taxonomy [9]. The curriculum unit was divided into 'five pages'. These pages had individual learning objectives that were derived from the specific learning objectives of the overall curriculum. The design of this curriculum supports the pedagogy of guided discovery, wherein the instructor primarily supports and facilitates the activities and learner actions in the corresponding learning environment.

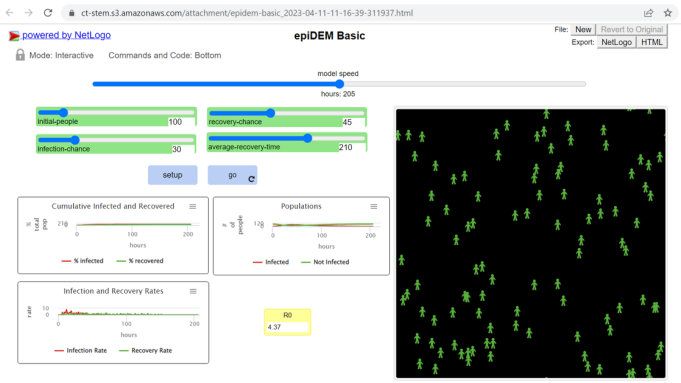

Fig. 1. Screenshot of the epiDEM Basic model on NetLogo web platform; model parameters can be manipulated using sliders; visualisation can be seen on the right hand side, and the output can be accessed in the form of graphs.

B. Alignment of Learning Theories with Curriculum

The NetLogo model "epiDEM" is embedded in the CT-Stem curriculum. The model shows how a disease spreads by setting up the parameters "initial people, recovery chance, infection chance, and average recovery time" and then running the model. The slider can be used to adjust each parameter. The model is coded in a way that allows the learner to manipulate the parameters and observe the effects. This interaction with the model titled "epiDEM Basic" allows learners to construct mental models. Specific instructions added to different pages of the curriculum make the interaction meaningful and interactive. The learner has the opportunity to learn by observing the effects and constructing knowledge themselves. Learning activities on page 3 are designed based on the principles of constructivism. Here, the instructions are added in the form of questions that allow learners to perform and analyze the results of the infection spread. Learners will have to write their reflections on the same page to move forward in the model. Additionally, the "objects to think with" in these learning activities are the epiDEM Basic model through which this curriculum is operationalized using constructionist principles.

C. Assessment of learning

The curriculum has integrated assessment and reflection. Each page of the curriculum asks for the learner's response in some form of questionnaire (either objective or subjective). "Page 0" provides an external information resource to the learner and is accompanied by prompts to guide the learner through reading the information on the web resource. On "Page 1", true or false questions are provided to the learner to gauge their understanding of the mechanism by which a disease spreads after reading the content on the previous page 0. "Page 2" allows learners to interact freely with the integrated NetLogo model [10], and some follow-up questions guide them on how the interface works. "Page 3" also has the same NetLogo model and questions for systematic exploration of the model, and "Page 4" has questions on how the understanding can be applied in the broader context of infectious diseases like COVID-19. Lastly, "Page 5" asks learners to reflect on what they did while interacting with the curriculum and mention what they think is their learning. The systematic coherence between curriculum pages allows learners to move from simple to complex problem solutions. Alignment between the learning objectives, learning activities, and assessments was ensured before the pilot study.

III. Study Design

For the pilot study, six participants (enrolled in postgraduate university programmer) were chosen through convenient sampling procedure. The interaction data with the constructionist unit was captured in various forms, such as the students' response sheet generated automatically through the CT-Stem platform, screen recording, direct observation, the participants' notes sheet that was given to them beforehand, and the feedback form. The student's response sheet shows the participants response to the questions added in curriculum, time spent, student ID, student name, curriculum page number, etc. The screen recording captured the total time taken to complete a task, student interaction with the epiDEM explorer unit and agent-based model, and student's facial expression. Direct observations helped in analysing students' emotions while interacting and clarifying their doubts. The feedback form collected students feedback on the curriculum unit, agent-based modelling, learning, and cognitive load during interaction. Consent was also taken from the participants before recording the data. The students' response sheet was analysed along with the screen recordings to triangulate **a)** the overall learning objective of the unit, **b)** the objectives of different pages of the unit to what learners were actually doing in the curriculum, and **c)** their feedback about learning. However, no separate pre-post test was conducted to check learning gain as it was not within the scope of the research question. The screen recording data has not been interpreted in this study; however, it can be used to investigate other aspects of the students' interactions with the curriculum. For the assessment of the perceived workload by the learners, the NASA Task Load Index (TLX) was used [11]. To make the survey easy to understand for participants, the scale range was converted to Likert Scale 1 (very low) to 7 (very high), and this feedback form was provided to the participants upon completion of the unit.

Curriculum Page	Learning Objective	Instructor Does	Learner Does
0- Context	NA	1. Direct the students to the link. 2. Troubleshoot any issues.	Go to the WHO link and read the provided question prompts from FAQ webpage. Download the additional resources (NetLogo model) for self exploration.
1- Teaser: How does an epidemic spread	Learner will be able to- 1. State their understadning of the spread of disease	1. Check for learner misconceptions (or alternate conceptions) through response sheet post this segment 2. Clear any possible doubts that the students may have regarding questions.	Answer three questions based on the readings/ references from the previous page.
2- Freeplay: Discover the spread of infection in a population by manipulating the model	Learner will be able to- 1. Locate different parameters of the model and familiarize themselves with model 2. Execute the program and observe the variations through unstructured exploration	Clear any possible doubts or queries on the workings of the model, or interface elements (eg. buttons, sliders, etc.)	"Play" with the model and answer the questions that are related to the familiarity of the Netlogo Model interface.
3- Explore: Exploring different dimensions of epidemic model (epiDEM)	1. Systematically execute the model by implementing specified conditions 2. Compare the results obtained through different execuation 3. Explain the model based on self-understanding	Ensure that students have correctly explored (in the intended manner) the model	Systematic manipulation of the model parameters based on the questions, and answer the questions that follow.
4- Reflect: Check your understanding; Covid-19	1. Investiagate the impact of other parameters in the model 2. Develop an understanding of how this model can be applied in real-world	1. Provide an explanation of the NetLogo model to the students. 2. Establish the connection of this agent-based model to the real-life scenario 3. Clear any possible misconceptions/ alternate conceptions of the students	Student will reflect upon their understanding by answering questions related to the real-life context.
5- Reflect: About your learning	1. Recall and organize learnings in the real-life context	1. Help learner to recall specific learnings from each curriculum page 2. Allow the learner to establish a connection between the model and real-life	Student will reflect upon their new knowledge by answering the guided question.

Fig. 2. Aspects of the CT-STEM curriculum: Epidemic Explorer, based on the epiDEM NetLogo model.

LO 1. Understand the basic principles and assumptions for modelling the spread of disease in a closed population				
Construct	**Construct Description**	***Learner Response***	**Themes**	**Interpretation of learning**
Principles of modelling	Transmission of disease by coding the interactions between agents	*R1*	Playing with the model	1. Learner was able to explore the model through at each page of the chapter
Assumptions of modelling	Abstrations of entities in ABM	*R2, R3, R4, R5, R6, R7, R8, R9, R10, R11*	1. Assumptions by changing the paramters mathematical modelling & assumptions 2. Detailed description through chapter 3. Factors of infection spread: Close contact, Movement of people, Spread from one to other, Near vicinity, In contact with infected person, close contact, Get in contact	1. Learner was able to analyse the results by interacting with the model throughout the chapter 2. Learner was able to compare, extend his exisiting knowledge through the scafold i.e constructionsit chapter 3. Learner was able to extend his knowledge 4. Learner was able to identify the multiple factors of infection spread by interacting through the chapter
LO 2. Describe how changes in the model parameters can affect the final outcome of the epidemic				
Construct	**Construct Description**	***Learner Response***	**Themes**	**Interpretation of learning**
Model Parameter	Initial People Infection Chance Recovery Chance Avg. Recovery Time	*R12, R13, R14, R15, R16, R17, R18, R19, R20*	1. Statistics through model 2. Running the model and observing effects 3. Change in parameters and resulted effects 4. Population efffects on infection 5. Relationship of infection rate and spread 6. Effects of infection chance on spread 7. Relationship of population density with recovery time 8. Parameters effects 9. Defining parameters	1. Learner was able to analyse the graphs 2. Learner was able to observe the effects of parameters on final outcome 3. Learner was able to observe the relationship between two or more factors 4. Learner was able to explore and define the paramters
LO 3. Analyse and interpret the data from COVID-19 epidemic using the concepts and tools learned in this curriculum				
Construct	**Construct Description**	***Learner Response***	**Themes**	**Interpretation of learning**
Data	No of people infected (& recovered) over time	*R21*	Changing the parameters	Learner was able to manipulate the data and analyse the graphs to understand the infection spread
Concept & Tools in Curriculum	Concept of spread of disease	*R22*	Infected population & Recovery Rate	

Fig. 3. Analysis of Learner responses in the CT-STEM curriculum: Epidemic Explorer. Responses corresponding to individual codes R1, R2, etc. can be accessed from this link: Learner response.

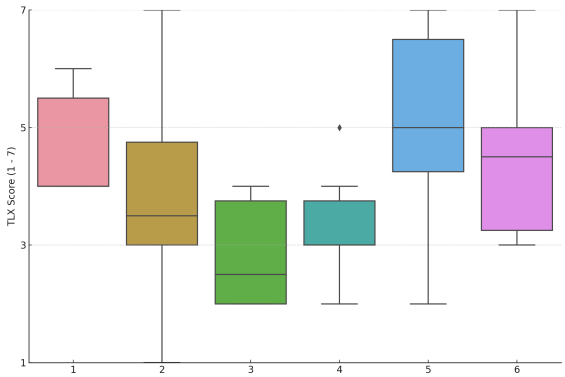

Fig. 4. Summary statistics of the participant's responses for each question on the NASA-TLX scale. X axis values are: 1- Mental Demand, 2- Physical Demand, 3- Temporal Demand, 4- Performance, 5- Effort, and 6- Frustration.

IV. Results

The design of this curriculum contained five pages with their respective learning objectives (highlighted in Section 2). Participants spent around an hour going through various course pages and performing respective learning tasks. From the system log data, the timestamps of the participants' responses indicated that the total time spent on pages Freeplay and Explore (mean 19.83 and 17.50 minutes, respectively) was more than the following two pages (mean 8.33 and 3 minutes, respectively). The analysis of learners' subjective responses was done using reflexive thematic analysis [12], for the responses corresponding to each learning objective, as indicated in Figure 3. This analysis helped in understanding the overall learning outcome as well as the multiple aspects of the chapter and model that the learners found interesting and helped in building knowledge. Additionally, results from the NASA-TLX scale indicated high mental demand (mean score 4.7), effort (mean score 5), and frustration (mean score 4.5) for the participants. Figure 4 provides a summary of the scores of participants for each aspect of the TLX. These preliminary results point towards the fact that such a constructionist curricula requires high involvement from the learner and may lead to frustration if not designed with due consideration of the learning experience.

V. Discussions and Conclusions

This paper presents the design of a constructionist curriculum called "Epidemic Explorer" on the CT-Stem web platform. This curriculum allows learners to play, observe, analyze, interpret, and use reasoning skills to interact with the agent-based model, "epiDEM Basic", and apply their understanding to solving problems provided in the curriculum. From the results of this preliminary study, it can be said that such a constructionist curriculum can provide learners with the opportunity to construct their understanding of a topic and apply it. The presence of real-world context in the curriculum can help students relate to the topic, and an appropriate agent-based model with its ability to act as an "object to think with" is suitable for supporting a constructionist pedagogy. The context of the unit grabbed the learner's attention, the content flow allowed them to freely play with the model and explore different parts systematically, and the reflection upon understanding and overall learning helped the learner navigate the unit with minimal hand-holding from the instructor. However, users with less technological awareness might require various scaffoldings to understand and complete these exercises. In conclusion, this exploratory study has provided possible directions to explore comprehensively, the results of which will enrich our understanding of "doing science".

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Students' Point Of View of Real-Life Project-based Learning

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***Abstract*—Project-based learning (PBL) is known to be effective because learning is driven by active engagement and collaboration. Real-life projects are known to be motivating for students as they work on authentic problems to address societal issues. Teachers sometimes hesitate to implement them because of time constraints and doubts about whether course learning will be fulfilled. This paper is students' point of view of experience in developing a real-life online training program for Persons with Disability (PwD) awareness in an Instructional Systems Design (ISD) course. Students developed this training program in three phases, conducted a user study and reflected on their experiences. The user study results of the training program indicate that the developed content is useful for sensitization regarding the challenges faced by PwD and awareness of how to support them. The reflections indicate that it is possible to tackle real-life projects within the framework of a course without compromising on course objectives. Students' reflections proved that conceptual learning of the course topics was also achieved along with project development skills. This study is meaningful because it demonstrated the value of real-life project-based learning despite the time constraints of project execution.**

***Index Terms*—Students' POV, Project-based learning, real-life projects, Instructional System Design**

I. Introduction

In recent years, the integration of real-life projects in courses has gained significant traction as an effective pedagogical method. This approach provides an opportunity to immerse students in authentic real-life experiences and bridge the gap between theory and practice. However, teachers may have concerns such as time constraints of the project and whether all course objectives will be fulfilled [1].

This paper delves into the learnings from a real-life project-based course from the perspective of the learners themselves. The project was carried out as a part of the Instructional System Design (ISD) course; this course is at the introductory level and typically covers instructional design models, processes, tools and technologies. The project involved the implementation of a web-based training program aimed at creating awareness and fostering inclusivity for Persons with Disabilities (PwD) within a specific college environment.

We (the students) started with a high-level mandate: "*To create awareness among the functionaries of higher education about the needs of differently-abled persons*". The project was carried out using the ADDIE model. The ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation, serves as a guiding framework for the systematic and efficient delivery of instructional content [2]. We conducted stakeholder interviews, interacted with experts, and went through relevant websites to decide the sub-topics and format of the material. The design and implementation were carried out with periodic reviews and feedback. For the evaluation, we invited four experts to review the content, from the perspectives of instruction design, information accuracy, and usefulness to the PwD cell and to the student community. Within the group of four experts, there was one ISD instructor, one representative from the college's PwD cell, and two individuals affiliated with a non-profit organization dedicated to serving people with disabilities. Subsequently, we carried out a user study on the usefulness and usability of the material with thirty students and three faculty. Finally, we handed over the website[1] to the PwD cell of the institute for inclusion in their training programs.

We did this project over three months, while also doing other courses and academic work. We reflected on our learnings from the course and the project execution. We feel that having a real-life project results in significant engagement and learning, within the time constraints of a course. We share a few pointers for the successful implementation of project-based learning.

II. Problem Description

Our institution has a PwD cell. One of the goals of the cell is to sensitize students and staff members about the different challenges and support required for students with different disabilities. We, the students of the Instructional Systems Design (ISD) course (ET 614 Spring semester 2023 cohort), took up the important task of creating this sensitisation program as part of our course project. We had to create interactive digital content to provide accurate information about the challenges

[1]https://sites.google.com/view/iitb-PwDcell-training/

and support for different disabilities, in an engaging manner. We had to not only learn ISD concepts and skills but also apply them in a real-life project within a stipulated time. We also had the challenges of working collaboratively on this project along with diverse academic activities.

III. Related Work

Kokotsaki et al. [3] in their scoping review of PBL mentioned various studies conducted at schools (pre, primary, and secondary) and in higher education institutions, which establishes a relationship between positive learning outcomes and the use of PBL for a course. Almulla et al. [4] examined the effectiveness of PBL in enhancing student engagement by identifying multiple factors for the study, which were: collaborative learning, discipline subject learning, iterative learning, and authentic learning. Srinivasa et al. [5] have demonstrated the use of PBL in an undergraduate computer science course for Data Analytics and IoT topics. In this course, students were expected to apply their learnings of the content to a team-based project. Their understanding was assessed using surveys by the instructors.

PBL implementation challenges include insufficient training in collaboration and ineffective group rules leading to some students dominating projects. Student-related challenges include engaging different learners, suitable tasks based on skills, and difficulty working in pre-set groups [6]. This paper reports firsthand student accounts of real-life PBL pedagogy.

IV. Course Design

The Instructional System Design (ISD) course used a PBL approach. The course had different modules that covered various aspects of instructional design, including an introduction to ISD, an exploration of instructional design models such as ADDIE, SAM (Successive Approximation Model), and LCM (Learner-Centred MOOCs), and an in-depth analysis of the TPACK framework [2], [7], [8]. A unique feature of the course was the real-life project, which required us to develop an awareness program by utilizing the concepts learned throughout the ISD course. To aid our project, we were introduced to a PwD sensitization session from the UMMEED foundation[2] and other stakeholders in the disability community. We engaged with people with disabilities to understand their challenges and integrated insights into the course project. Assessments included reflections, project presentations, oral and mid-semester exams, evaluating both theory and practical skills for continuous improvement.

V. Course Implementation

During the implementation of this course, we experienced a lively and collaborative environment. Students were divided into three groups, each with different roles and responsibilities crucial to the progress of the project. Some senior students participated voluntarily in the course due to their interest in the project. They served as mentors and provided guidance to us. The presence of senior students ensured a diverse range of perspectives and expertise. Collaboration with the senior students allowed for the exchange of ideas and knowledge, enhancing the overall learning experience for us.

The PwD awareness website consisted of 4 divisions - Attention Deficit Hyperactive Disorder and Learning Disabilities, Autism, Visual impairment, and Locomotor disability. Overall there were twenty-three students, grouped into 4 for each category of disability. We presented the website to the stakeholders twice during this course. Their feedback helped us in making significant improvements to the website. We wanted to make sure it aligned with our goals and objectives. We were committed to continuously improving and reflecting on our work to become better at designing instructional systems.

Mapping the course to the ADDIE model: The first three classes focused on understanding our prior knowledge and setting the learning objectives. We were introduced to fundamental concepts such as instructional design, and universal models of project development like ADDIE and SAM. This introduction to different models was crucial in setting the stage for subsequent phases. ADDIE is a well-known instructional design model consisting of 5 phases - Analysis, Design, Development, Implementation, and Evaluation.

In the **"Analysis"** phase, we were introduced to the problem statement and we brainstormed on what might be a better way to create awareness for the target audience - college students. We also came up with iterations of defining the learning objectives of our targetted users. The entire process is depicted in Figure 1.

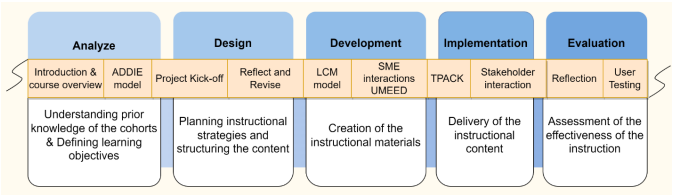

Fig. 1. ADDIE Model

In the **"Design"** phase, we planned the instructional strategies and structured the content. Designing content for the assigned project started at this stage. The sensitization for us regarding PwDs and their day-to-day life was introduced through an engaging session conducted by people from the UMMEED organization. Interaction with various stakeholders at this stage prepared us for the next development phase.

In the **"Development"** phase, we created and curated the instructional materials. We were introduced to various tools such as Animaker, H5P, and Canva, which are instrumental in developing and designing instructional materials. All these tools were learned on the go with the help of peers. While developing the content, the LCM model was also used in creating the materials. This course also emphasized the development of soft skills such as communication and teamwork, which were essential for the successful execution of the project.

The **"Implementation"** phase is characterized by the delivery of the instructional content. To ensure that the website

[2]https://ummeed.org/

achieves its objective of sensitizing people a three-stage instructional delivery was used. The first part of the website in each of the four modules had some introduction to the respective disability, followed by sensitization activity and finally how to support them.

For **"Evaluation"** with respect to the project was conducted in two major subject matter expert feedbacks in addition to multiple internal presentations and peer feedback. This took place in an iterative manner and the feedback informed us in updating our work. The final evaluation of the website was the usability study of the website. The results of the user study are explained in detail in the next section.

VI. User Study

The user study feedback was collected through a Google form that contained survey questions with Likert scale responses. In this context, the individuals being sensitized were users. We have at least eight users evaluate one module of the website, and overall 38 users provided feedback on different usability aspects of the project. In total, there were 15 survey questions for four disability modules - Locomotor Disability (8), Visual Impairment (13), ADHD (9), and Autism (8). The user study feedback contained questions that were categorized into five attributes - Easiness (Ease of use or Ease of learning), Integration, Interface Design and Usability, Content Comprehensiveness and Language Appropriateness. These attributes are vital in our user study because they determine the success of the instructional materials developed. Easiness ensures a smooth learning curve, while integration ensures seamless compatibility. A well-designed interface enhances user engagement and usability enables efficient navigation. Comprehensive content and language appropriateness facilitate effective communication and learning experiences.

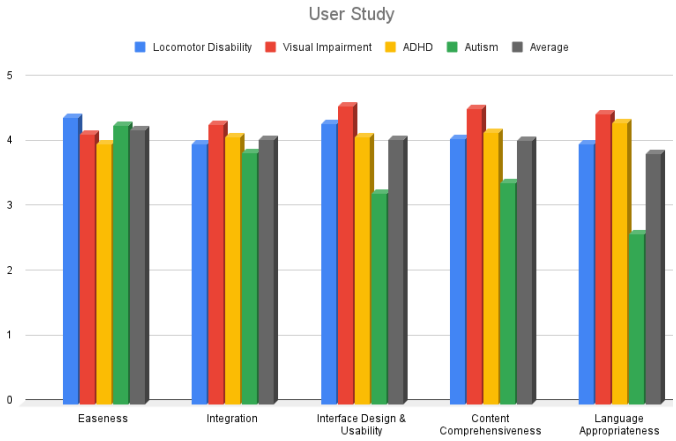

Fig. 2. User Study Results

In Figure 2, the x-axis shows the five constructs and the y-axis denotes the mean of the Likert scale scoring by the participants for each of these features on a scale of 5 (1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree). The figure indicates that most of the participants have agreed about the easiness, integration, interface design and usability, content comprehensiveness and language appropriateness of all four training modules with an overall average value of approximately 4 (as indicated by greyish black colour bars in the figure 2) for each attribute respectively.

VII. Challenges

The challenges are broadly classified into five categories: (i) Learning new tools and applying them, (ii) Making the content engaging while keeping it simple, (iii) Incorporating feedback, (iv) Executing a real-life project, and (v) Finishing within time constraints; and Managing diverse collaboration. Out of all five mentioned above, the first two were related to course-based challenges, and the last four were challenges that arose because of incorporating a real-life project in the course.

Learning new tools while producing videos and other content added to the development phase's challenges. Technical issues, such as syncing audio with scripts and depicting disabilities that are not physical or visually apparent like learning disabilities, required careful thought and consideration. Another challenge that we faced was creating a website with engaging content that captures attention, motivates audiences, and raises awareness about PwDs. We had to find a balance between simplicity and complexity in our training module. We also had to consider whether our content was too specific or too general and ensure that it was usable. We had to ensure that the information presented was applicable, the website was easy to navigate, and the contents flowed systematically to engage the users. To address this challenge we developed a template for the website. Each module of the website had the following sections - Introduction, Sensitization (How it Feels), Scenarios, Check your Understanding and Inspiring Stories. This ensured that the content was easy to navigate without compromising the accuracy.

This being a real-life project, redesigning the website based on their feedback, while considering design principles and usability, was a complex task. Reaching out to the target audience, and managing time effectively were additional challenges during the evaluation phase. We overcame this by a divide-and-conquer approach of assigning different roles amongst ourselves. In conclusion, the PwD project presented numerous challenges throughout its implementation. From creating engaging content to designing an accessible website and consolidating feedback. In the next section, we explain in detail our learnings from this real-life project-based learning course.

VIII. Learnings

A. Course related

This was our first experience with a course entirely based on project-based learning, which integrated a real-world project. Throughout our participation in the course, we had the opportunity to engage in hands-on experiences that made the learning process both interesting and inspiring. With respect to the course content, all of us felt that we learned about different ISD models and have also implemented a few of them in the course project. We acquired new skills in using

tools like Animakar™ and Canva to create engaging content. We gained insights into creating application-based multiple-choice questions using ChatGPT, exploring different features in Google Websites, and creating videos using Canva. Exploring AI powered tools for content creation, and incorporating reflection points using H5P proved effective in engaging users. Throughout the course, we discovered various tools and techniques such as Synthesia™ for AI voice generation, Animaker for character-based animation, BNIME for sketch-style videos, and H5P for interactive content.

B. Project-related learnings and skills

Collaborating with fellow participants was a unique experience as we engaged in discussions and debates that ultimately converged towards building and presenting various resources on the webpage. We learned to collaboratively work in a group setting effectively and also benefitted from diverse perspectives and ideas from seniors. We recognized the significance of receiving feedback to refine our work and achieve our goals effectively. As a result of executing this project, we learned to adhere to the timeline and utilise ISD concepts for research, design, creation and feedback.

This course transformed us by boosting our confidence, improving our collaboration skills, deepening our empathy, and broadening our understanding of the diverse needs of individuals with disabilities. We learned to create inclusive environments and embrace feedback to refine our work. These insights will shape our future endeavours and contribute to our ongoing growth.

IX. Reflections

Following the challenges and learnings discussed above, we share our reflections on what worked best for this real-life project-based learning course. One of the key aspects that we would like to stress upon is the commonality of goals among all groups. Having a shared objective allowed for meaningful discussions and collaborations. It created an environment where ideas could be shared, different perspectives could be considered. It encouraged open and constructive dialogue, leading to the exchange of valuable insights and the development of the project. The common goal served as a unifying force, fostering a sense of camaraderie among us learners. This also aided in delivering an acceptable online PwD awareness program instead of diverting our energy into various small products for awareness.

The scoping process of making decisions about what to include and what to exclude proved to be crucial factors that contributed to the overall success of the project. By scoping down the project, we define boundaries and set clear objectives, ensuring that we focus on what is essential and achievable within the given constraints. This process helped us to prioritize tasks and allocate resources effectively, maximizing the chances of project completion successfully.

During the course, several checkpoints were established to ensure the successful delivery of our projects. These checkpoints served as milestones to monitor progress and ensure that we were on track. Setting realistic deadlines that accommodate the availability of all team members also ensured that everyone had equal opportunities to participate and contribute, regardless of their schedule limitations. All of these provided opportunities for seniors and mentors to review our work and provide guidance and support when needed.

Two major feedback sessions from the client side heavily contributed to the completion of the project. Peer feedback was an essential component of the source, both within and across groups. By receiving feedback from individuals with different perspectives and skill sets, we gained valuable insights and were able to refine our projects further. Regular feedback sessions provided an opportunity for peers to review and critique each other's work. This feedback loop not only helped in identifying areas for improvement but also ensured that the project output was usable. Instructors may contemplate these concepts when crafting their courses, employing real-life problem-based learning (PBL) to achieve the intended educational outcomes for their students.

X. Conclusion

In this paper, we present the experiences and learnings of students who participated in a real-life project for an instructional design course. Despite concerns regarding time constraints and meeting course objectives, the students discovered that this approach yielded significant benefits for understanding course topics and acquiring practical skills, such as time management, communication, and collaboration. The challenges encountered during the project further reinforced the value of this instructional design approach. To ensure successful implementation of real-life project-based learning, shared objectives, scoping down the project, multiple checkpoints, and continuous feedback and reflection are crucial factors. These pointers are essential for achieving success with this approach.

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Demystifying of Multimodal Framework for Outcome-Based Education and Student-Centered Learning Approach for Sustainable Education

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***Abstract*—The global educational landscape currently has a lot of promise for Outcome-Based Education (OBE). At the policy level of the NEP-2020, adopting OBE and student-centered learning has also received priority in recent years. The current study's objective was to demystify the multimodal framework for this new-age education employing Indian faculties on the country's recent paradigm shift in education. The researcher used a questionnaire that received 280 responses from faculties and a few professors in outcome-based education from higher education institutions. The quantitative data show that teachers have positive views toward NEP education. The findings also indicate a direct and positive association between knowledge, beliefs, trust, willingness, and acceptance of OBE. The integrated model also established the mediating role of OBE between selected manifest and sustainable education. The findings will assist the NEP-MHRD in creating appropriate policies and emphasizing the current paradigm shift in the future while resolving the major issues to ensure the implementation's effectiveness. A broad understanding of OBE and new-age learning would benefit faculties engaging in higher education.**

Keywords—Sustainable Education (SE), Outcome-Based Education (OBE), Higher Education Institutions (HEI), Education for Sustainable Development (ESD).

I. Introduction

It is necessary to promote sustainability if the world is to overcome its environmental and social difficulties, such as climate change, environmental degradation, conflict and injustice, poverty, and education [1]. There are lots of ways to enhance and nurture the output of education. The buzzword' Sustainable Education, also known as education for sustainable development (ESD), is an approach to education that advances the principles and practices of sustainability. It aims to develop knowledge, skills, attitudes, and values that empower individuals to contribute to an environmentally and socially sustainable future. Sustainable education goes beyond traditional academic subjects and incorporates environmental stewardship, social equity, economic prosperity, and cultural diversity. It seeks to foster a deep understanding of the interconnections between environmental, social, and economic systems [2–4].

Outcome-Based Education (OBE) is an educational methodology that defines desired outcomes or competencies and designs learning experiences to achieve those outcomes. While OBE has been implemented in various disciplines, including world literature, it offers several benefits in the post-pandemic context [5]. The earlier research in higher education has been greeted as a promoter for teachers to reconsider, recuperate, reframe, and perhaps recalibrate how superlative to serve the people and planet by nurturing greater concern and association. OBE is an educational philosophy and approach that defines clear and measurable student learning outcomes. Instead of solely emphasizing content coverage or instructional methods, OBE emphasizes what students should be able to do or demonstrate because of their educational experiences. In outcome-based education, the desired learning outcomes are typically identified at the beginning of the instructional process. These outcomes can be specific knowledge, skills, or competencies that students are expected to acquire by the end of a course, program, or educational level [6]. The outcomes are often expressed as measurable statements to ensure clarity and assessment. Even so, there hasn't always been enough knowledge to support HEI in planning and developing OBE. Consequently, there have been imperative demands for more research to assist HEI in maximizing their favorable environmental and social impacts through efficient experiential-based programs that hasten the required behavioral changes among key stakeholders, including governments, organizations, communities, and individuals.

II. Overview of NEP-2020

The NEP-2020 is a comprehensive framework for the enhancement of education in India. It was approved by the Government of India in July 2020, marking a significant reform in the country's education system. The NEP-2020 aims to delineate the challenges and shortcomings of the previous education policy and provide a more holistic and flexible approach to learning. Some key highlights and objectives of NEP-2020: (i) shifting from a content-centric approach to a more holistic and multidisciplinary education system. It promotes the integration of different subjects and the development of critical thinking, creativity, and problem-solving skills among students, (ii) emphasizing a learner-centered approach to curriculum design and pedagogy. It encourages experiential learning, critical thinking, and skill-based education, moving away from rote memorization and examination-based assessment. (iii) The policy acknowledges the role of technology in education and emphasizes the integration of technology in teaching, learning, and assessment processes. It promotes the use of digital resources, e-learning platforms, and educational technology tools to enhance accessibility and quality of education; (iv) emphasizes the importance of research and innovation in education and aims to create an ecosystem that promotes

research culture, fosters innovation, and encourages collaboration between academia and industry [7]. The policy envisions a transformative and future-oriented education system in India. Its implementation requires collaborative efforts from various stakeholders, including government bodies, educational institutions, teachers, students, and communities, to bring about meaningful changes in the country's education landscape. The current study identifies the current classroom methods in the universities of India within the argument. It also examines the attitudes of Indian faculties and the perspectives of OBE specialists regarding the new educational system. The study is necessary because the national education policy (NEP) has recently shifted from outcome-based to content-based education, and Indian policymakers, curriculum developers, educators, and staff need to be aware of all the potential obstacles that could prevent OBE from being implemented successfully [8]. They should also keep in mind any helpful recommendations for adapting all the key steps in using OBE. Additionally, one of the difficulties that will complicate the method's proper implementation is the lecturers' perspectives. The fundamental shift in teaching and learning activities will result from the fact that the new system will put more emphasis on student participation than teacher engagement, which means that teachers will need to be prepared for this new shift in NEP-2020. Therefore, comprehension of student-centric learning, knowledge, and adjustment on the part of teachers will aid in the successful implementation of OBE-NEP and the areas in which they must be familiar with the phenomena. This study investigates this recent educational trend of NEP and seeks answers to the following research questions:

RQ.1: How do teachers at HEIs perceive new-age learning of NEP-2020?

RQ.2: How does NEP embrace OBE and new-age learning of NEP-2020?

RQ.3: What are new-age outcome-based learning and student-centered education challenges?

To identify knowledge gaps and prospective frameworks for guiding the design of OBE, the sustainability views of Higher Education (HE) were compared to published literature and sustainability models. In this regard, the next section offers an overview of the literature on outcome-based learning. The research methodology used is described in the next parts. Data analysis and interpretation are elucidated in the second last part of the paper. Eventually, discussion, limitations, future scope, and conclusions are outlined.

III. Review of Literature

Research on the factors influencing OBE attitudes and behaviors has increased as public awareness of the global sustainability challenge has increased. Numerous research studies have been conducted in the recent past emphasizing the need for OBE and sustainability to achieve the 17-UN SDGs. [9] established relationship between sustainable education (SE) and the five-pillar sustainability model. They examined students' perceptions of global sustainability by employing quantitative and qualitative analysis in one of the leading business schools in Australia. Recent papers have demonstrated the vital link between HEIs and outcome-based learning and found that sustainability education has grown to be widely acknowledged as a significant factor in developing more virtuous global citizens [10-12].

According to some prominent and advanced research, HEI should actively promote sustainability through outcome-based education programs. To align with the above thought, [11] assessed that higher education is often seen as OBE for imparting capabilities in engineering and management courses. According to the recent Principles of Management Education initiative [5], it has made it easier for technical education worldwide to include OBE in their curricula. As a result, studies on higher engineering have significantly increased recently. According to [12], OBE clearly defines what students are expected to learn. This involves identifying specific, measurable, attainable, relevant, and time-bound (SMART) learning outcomes. In the words of [6] and [13], OBE places the student at the center of the educational process. It aims to cater to individual student needs, interests, and abilities, allowing personalized learning experiences. [14–16] stated that OBE focused on developing and accessing competencies rather than just imparting knowledge. Competencies include knowledge, skills, and attitudes that enable students to apply what they have learned in real-world contexts. [17] concluded that OBE encourages a cyclical instructional design, assessment, and evaluation process. Educators regularly review and modify their teaching methods and curriculum to enhance student learning and outcomes.

IV. Research Methodology

A mixed-method technique was used in this research study to gather both numerical data. According to [18], learning more about teachers' views towards implementing OBE models in their classrooms is suggested in light of the research dilemma that emerges when employing traditional teaching and learning techniques in the current environment. The researcher instituted gathering quantitative data by sending a Google Form to 280 respondents during April-June 2023 who were faculties in private universities of Rajasthan. The snowball sampling method was utilized to obtain the quantitative data, and teachers from various organizations were asked to send and share the questionnaire with their colleagues [12]. A pilot survey of 50 respondents was conducted to measure the reliability of the questionnaire, and certain questions were reframed with the help of OBE experts of HEIs to enhance the description of the variables and their standard definitions. This qualitative aspect is necessary to standardize the final questionnaire of the study. A total number of manifests were divided into dependent and independent aspects of the OBE in which teachers' attitudes regarding knowledge, trust, beliefs, willingness, and acceptance of OBE to achieve sustainable education in the backdrop of NEP-2020.

V. Data Analysis and Interpretation

As advised in most current literature, the approximate sample size was determined using G-power analysis. According to [10], the study's model comprises five predictors for trust, a small effect size of 0.06, and a power requirement of 0.95. The G-Power study revealed that 280 samples are the bare minimum needed. This study had 35% female respondents and 65% male respondents. According to respondents' educational backgrounds, 18% were from social science, 42% were from commerce and management, 28% were from basic science, and 12% were from medical and nursing. 36% of the faculty had experience below 5 years, 48% were between 5-10 years, and the remaining 16% of teachers were above 10 years of experience. Further, most teachers were aware of NEP-2020 and OBE and their

implications. Each manifest is scaled and evaluated on a five-point Likert scale. SEM is a powerful statistical technique that enables researchers to examine complex relationships, test hypotheses, and validate theoretical models by integrating measurement and structural components in a single framework.

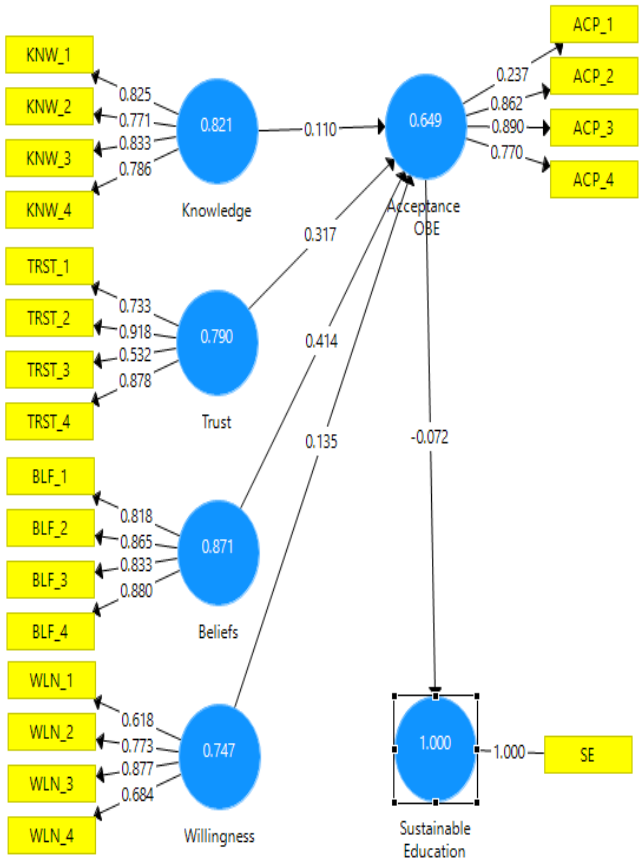

Fig. 1. SEM Conceptual Framework for SE-OBE

A. *Measurement Model*

The measurement model delineates the links between the latent variables and their observed indicators. It describes how the observed variables contribute to the measurement of the latent variables. Factor loadings, which represent the strength and direction of the relationships, are estimated in the measurement model. Table I delineated measurement model assessment findings, reliability, and validity criterion. Cronbach's-α and rho_A are reliability coefficients used to assess the internal consistency of a set of observed variables that measure a latent construct. All constructs met the criteria, with composite reliability (CR) above 0.7 and AVEs above 0.5. [14] states that outer loading larger than 0.5 indicates a satisfactory measurement of the latent construct. Moreover, [14-16] advised always removing exterior loadings below 0.5 from the construction. They emphasized that outer loadings between 0.5 and 0.6 can only be eliminated if eliminating the indication increases composite reliability (CR) and average variance extracted (AVE) above the acceptable range. Keep loadings above 0.7.

TABLE I. RELIABILITY AND VALIDITY CRITERION

Scale	Ch. α	rho_A	CR	AVE	MSV
Knowledge	0.821	0.532	0.560	0.552	0.565
Beliefs	0.871	0.521	0.625	0.420	0.506
Trust	0.714	0.508	0.506	0.450	0.659
Willingness	0.779	0.521	0.662	0.511	0.458
Sustainable Education	1.000	1.000	1.000	1.000	1.000
Acceptance of OBE	0.788	0.520	0.504	0.425	0.422

B. *Structural Model*

The structural model focuses on the relationships between the latent variables themselves. It specifies the causal or directional relationships between the latent variables in the model. The structural model consists of paths or arrows representing the hypothesized relationships between the latent variables, typically based on theoretical or conceptual considerations. This model examines the direct and indirect effects between latent variables, allowing researchers to test specific hypotheses or theories about how the constructs relate to each other. It provides insights into the underlying processes or mechanisms that drive the relationships between variables [09]. The parameters in the structural model are estimated using regression analysis techniques or path analysis. To assess discriminant validity using the Fornell-Larcker criterion, calculate the AVE for each latent variable and the squared correlation (r^2) between each pair of latent variables. The AVE for a latent variable should be larger than the squared correlation between that latent variable and any other latent variable in the model to establish discriminant validity (see Table II). If the AVE is greater than the squared correlation, it suggests that the latent variables are distinct and have discriminant validity.

TABLE II. DISCRIMINANT VALIDITY

Scale	KNW	BLF	TRST	WLN	ACP	SE
Knowledge	0.669					
Beliefs	0.548	0.521				
Trust	0.543	0.408	0.326			
Willingness	0.659	0.621	0.405	0.490		
Acceptance of OBE	0.748	0.812	0.814	0.568	0.625	
Sustainable Education	0.625	0.748	0.725	0.628	0.525	0.677

To assess discriminant validity using the HTMT criterion, compare the HTMT ratio to a threshold value. Typically, a HTMT ratio less than 0.85 indicates discriminant validity, suggesting that the latent variables are sufficiently distinct. HTMT analysis is a more relevant statistical method for evaluating both discriminant and convergent validity (see Table III).

TABLE III. HTMT CRITERION

Scale	KNW	BLF	TRST	WLN	ACP	SE
Knowledge	0.829					
Beliefs	0.725	0.712				
Trust	0.655	0.518	0.528			
Willingness	0.780	0.714	0.628	0.528		

Acceptance of OBE	0.807	0.730	0.789	0.668	0.722	
Sustainable Education	0.799	0.628	0.780	0.728	0.524	0.805

TABLE IV. HYPOTHESES TESTING

Scale	Sam. X	SD	T-stat	Sig
Knowledge → Acceptance of OBE	0.574	0.107	5.461	0.001
Beliefs → Acceptance of OBE	0.406	0.107	3.721	0.000
Trust → Acceptance of OBE	0.529	0.215	4.215	0.015
Willingness → Acceptance of OBE	0.169	0.134	1.498	0.001
Acceptance of OBE → Sustainable Education	0.245	0.249	3.214	0.003

The proposed model (see Table IV) was approved because the p-value was less than 0.05. (t.stat=5.461 p-value=0.001) indicates the substantial correlation between knowledge and acceptance of OBE. There is also a significant association between beliefs and acceptance of OBE (t.stat=3.721, p-value=0.00), trust and acceptance of OBE (t.stat=4.215, p-value=0.00), willingness and acceptance of OB-learning (t.stat=3.721, p-value=0.00). Eventually, acceptance is a mediator between proposed factors and sustainable education (t.stat=3.721, p-value=0.00). The path coefficient of SEM conceptual framework for SE-OBE was also deemed fit to the model (see Figure 1). To navigate these complexities, it is imperative to consider India's unique cultural and contextual nuances and foster collaboration among educators, policymakers, and communities to advance OBE for sustainable education effectively. This result has collaborated with earlier work [05-08] and [11–13].

VI. CONCLUSION

In the purview of NEP-2020, OBE implementation in India has much potential in the future. To successfully deploy OBE, the drawbacks—which include standardized examinations, infrastructure issues, faculty training requirements, and societal expectations—need to be addressed. However, the future potential of OBE in India has some encouraging ramifications. OBE may respond to the requirements and interests of each student by having a flexible curriculum, resulting in more individualized and comprehensive education. Focusing on skill-based, value-added, ability enhancement courses gives students the competencies they need for the next century, improving their employability and preparing them for the changing work market. The continual improvement of OBE practices is ensured by data-driven assessment and feedback mechanisms. The expansion of access to high-quality education across the nation is made possible by technological integration, which opens up chances for online learning, digital tools, and personalized teaching. Education institutions, educators, students, businesses, decision-makers, and society must actively work together and make the necessary reforms to reach its full potential for the OBE initiative by NEP-2020 in India. This entails supplying faculties with training, improving the physical environment, changing the evaluation procedures, encouraging business and academic collaborations, and putting supportive laws into place. By doing this, India can create a system of education that fosters talented and adaptable people, promotes economic progress, and meets the demands of a world that is changing quickly.

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Dynamic Role of Cognitive, Emotional and Behavioral Engagement during Student-Faculty Interaction in Higher Education: Novel SEM Approach

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***Abstract*—Student satisfaction, self-perceived employability, career decision, and self-efficacy in higher education are all influenced by student-faculty interaction. The empirical data of this study examined the relationship between interactions between students and teachers of business students from developing countries. This study demonstrates how interactions between students and professors affect their graduation chances. The study also proves that behavioral, emotional, and cognitive engagement mediate students' graduate outcomes. Smart-PLS is used in this study to analyze survey responses from 320 undergraduate and PG business students from Rajasthan's four private and NAAC-accredited universities. The findings show that interactions between students and faculty considerably increase students' contentment, employability, and life skills. Engagement on behavioral, emotional, and cognitive levels mediates student-faculty interactions and graduate outcomes. The research model outlines that HEIs in developing nations like India should use career-related interventions, market orientation, and instructor development to enhance student learning and graduate outcomes.**

Keywords— Student-Faculty Interaction, PLS-SEM, Career decision self-efficacy.

I. INTRODUCTION

Interaction between students and professors may motivate them to study and improve their perceptions of their employability, professional self-efficacy, and school happiness [1-2]. The environment of higher education institutions in industrialized nations is primarily where research on the interaction between students and faculty that fosters student engagement and its effects on academic achievements is conducted. Through national-level research, they continuously collect student data on their involvement, engagement, satisfaction, and learning results to study many aspects of teaching quality. Nevertheless, these tests only directly and superficially gauge interactions between teachers and students [3]. A lack of attention to the learning needs of the students causes a lack of engagement among management students. Additionally, there isn't much research specifically looking at student-faculty interactions and how these affect graduate results for business students in industrialized nations. STEM students make up the majority of research on student-faculty interaction [4]. As business-trained persons are required in all organizations' local, international, governmental, and developmental sectors and may provide employment for others, business education plays a crucial role in society in transitional and emerging nations. HEIs must also produce capable corporate leaders in developing countries. Higher education institutions in developing nations have unique difficulties; the influence of relationships between students and faculty on student results may differ from HEIs in affluent nations. The lack of educated faculty members at HEIs in developing countries affects the teacher-student ratio, increasing class size, the passive style of instruction, and the emphasis on material delivery [5]. Additionally, many instructors have part-time jobs, are not acquainted with newly created student-centered teaching strategies, and use passive teaching techniques that result in passive learning among pupils. The paper discusses the realistic inquiry into the impact of SFI on graduate outcomes, such as career choice, employability, and life skills. In a previously unstudied setting, we looked at the mediating effects of student involvement measures. This technique can deal with difficult modeling difficulties, such as unusual data features (for example, no normal data) and very complicated models [6]. The degrees are well-known and widespread in the global setting. The idea that SFI is a construct that requires research was promoted even in the developing market by the rising need for employable business students. Few studies look at the impact of scholar-faculty contacts and how they affect graduate outcomes in developing nations. Like developed nations, there is passive instruction and a lack of participation among management students. The most sought-after degree in these countries is in management education. Yet, there is a shortage of literature that explains how HEIs might improve the learning environment by encouraging student-faculty collaboration. These circumstances inspired us to carry out this investigation as a result. We put our attention on reaching the following research goals based on the literature review:

a. To investigate the impact of faculty-student contact on graduate results and student involvement.

b. To investigate how student-faculty contact and graduation outcomes relate and how behavioral, cognitive, and emotional involvement can mediate.

II. REVIEW OF LITERATURE

A. Student-faculty interaction

Teacher-student interaction is an important part of the seven principles of special education reform. The student working with the teacher during or after the lesson is an important study related to the study's success [7]. Likewise, regular discussion about the problem provides higher learning

and participation [8]. Teaching clarity and other classroom interactions are two areas in this study that attempts to demonstrate SFI. Transparency clarifies the teacher's approach and students' learning goals. It helps students connect with teachers and understand course expectations and teaching methods [9].

B. Student Engagement

The impact of student participation on learning and achievement has been recognized in higher education [10]. It has been suggested that many research papers defined "student participation." However, this concept is derived from [11], which broadens the definition to include four elements: behavior, thought, culture, and eating leadership. We call student engagement based on meta-terms that include attitudes, skills, and interventions [12]. Students who participate in good behavior, hard work, and other activities at school are considered to have good behavior [13]. Behavior engagement refers to individuals' active and participatory involvement in various actions, activities, or tasks. It is a term often used in educational, psychological, and organizational contexts to assess individuals' level of interest, attention, and commitment toward specific behaviors or learning experiences [14]. The lack of research on student engagement among business undergraduate students in India highlights the need for research. Participating students create resources that give them confidence in their work [15]. Therefore, teachers should be aware of and use specific strategies to promote participation inside and outside the classroom. This is why research established the following hypotheses:

H1: There is a connotation between SFI and BE, EE, and CE

C. Student Engagement

[16] Described that faculty members who engage with students personally can serve as mentors and provide valuable career guidance. They can offer insights into various career paths, share their experiences, and advise on pursuing specific career goals. This mentorship can be instrumental in helping students make informed career decisions and gain clarity about their interests and strengths. [17] studied that interacting with faculty can open doors to networking opportunities within the academic and professional community. Student-faculty interaction and behavior engagement go beyond the classroom and are crucial in shaping students' career decisions [18]. Positive interactions with faculty can give students valuable guidance, support, and opportunities that influence their career choices and contribute to their overall career development and success. Based on the literature, this study has the following hypothesis:

H2: Behavior engagement positively affects students' career decisions, employability, and life skills.

D. Impact of emotional engagement on employability, career decision and life skill

According to [19], building relationships with faculty can expand students' professional networks. Faculty members often connect with professionals in various industries and can facilitate introductions or recommend students for relevant opportunities. A robust network can enhance students' access to job openings and increase their chances of landing interviews. Meaningful interactions with faculty can contribute to developing essential employability skills such as critical thinking, communication, problem-solving, and teamwork [4], [14]. Faculty-led discussions, projects, and assignments can foster these skills, which employers across various industries highly seek. [11] concluded that emotional engagement can influence career decisions by motivating individuals to pursue paths that bring them joy, fulfillment, and a sense of purpose. It can lead people to prioritize job satisfaction over merely pursuing positions for financial gain or societal expectations. Thus, we posit:

H3: Emotional engagement positively affects students' career decisions, employability, and life skills.

E. Impact of emotional engagement on employability, career decision and life skill

Cognitive engagement refers to mental involvement and active thinking in various activities and tasks. It profoundly impacts employability, career decision-making, and life skills development. In the words of [16], Cognitive engagement enhances critical thinking and problem-solving skills, making individuals more valuable to employers. Employers often seek employees who can analyze complex situations, think creatively, and find innovative solutions. [18] confirmed that cognitive engagement is closely tied to learning and acquiring new life skills. Engaged learners are more likely to develop critical thinking, problem-solving, information processing, and decision-making skills. Engaged individuals are better equipped tolearn from experiences and mistakes, leading to continuous personal growth and development. Cognitive engagementfosters curiosity and a thirst for knowledge, encouragingindividuals to explore new topics and engage in lifelong learning, which is essential for personal and professional growth.

H4: Cognitive engagement positively affects students' career decisions, employability, and life skills.

F. Student Engagement as a Mediator

Behavior, emotional, and cognitive engagement are essential in promoting employability, career decision-making, and life skill exposure [19]. Active participation in various activities fosters practical skills and demonstrates initiative to employers, enhancing employability. Engaging in different experiences helps individuals explore career options, leading to informed decisions. Additionally, it develops essential life skills like time management and teamwork. A high level of enthusiasm and commitment at work leads to increased job satisfaction and performance, making individuals more valuable to employers. Many past pieces of literature [20-21] emphasize that these forms of engagement create well-rounded individuals, desirable to employers, with informed career trajectories and exposure to valuable life skills. Being actively engaged in various aspects of life contributes to success and satisfaction in both professional and personal realms. Therefore, it is posited:

H5: BE acts as a mediator between Student Engagement andcareer decision, employability, and life skill ability of highereducation students.

H6: EE acts as a mediator between Student Engagement andcareer decision, employability, and life skill ability of highereducation students.

H7: CE acts as a mediator between Student Engagement andcareer decision, employability, and life skill ability of highereducation students.

III. RESEARCH METHODOLOGY

This research focused on undergraduate management students who were employed for three years in management school, preparing for the job souk at prominent institutions in Rajasthan. The sample comprised 320 management students pursuing management courses. We have concentrated exclusively on management students since they are the most in-demand nationwide and have more job placements than other governmental management program students. Likewise, the degree is semester-based; the curricula were created according to the methods used by other international institutions, and worldwide management settings were included in the material [20]. Undergraduate management students replied to self-reported surveys in a cross-sectional research design. The four illustrious universities make up the study's clusters, and we gathered data from each cluster to reflect the population during April- June 2023. The connected colleges of these universities in the capital served as the source of convenient samples. By explaining the purpose of the research to the students and assuring them that the data would be kept confidential, the study upheld informed consent and voluntariness.

IV. DATA ANALYSIS AND INTERPRETATION

Examining existing theories, hypotheses, and methods revealed that we could consistently measure SFI, BE, EE, CE, CD, ES, and LS using measures that were adopted fromrecent literature. [25] created many SFI assessment items for the national survey on engagement. From [1], [17], [18], [20], certain items were evaluated for student engagement and emotional, behavioral, and cognitive engagement. The students were further asked about their career decision, employability, and life skills. Out of 400 respondents, the majority were male, 66.60%, and 33.40% were female. Most of the students were in the age group of 20-25 (55.00), 20-30 (40.00), and above 30 (05.00). 48.50% from first-year graduate programs, 25.80% from second-year, and the rest from final-year management students.

TABLE I. RELIABILITY AND VALIDITY CRITERION

Scale	Ch. α	rho_A	CR	AVE	MSV
Behavior engagement	0.521	0.432	0.560	0.552	0.565
Emotional engagement	0.871	0.521	0.625	0.420	0.506
Cognitive engagement	0.782	0.788	0.857	0.600	0.425
Career decision	0.714	0.508	0.506	0.450	0.659
Employment skills	0.779	0.521	0.662	0.511	0.458
Life skill	0.561	0.514	0.402	0.478	0.608
Student-faculty interaction	0.788	0.520	0.504	0.425	0.422

Reliability and validity are critical criteria for assessing the quality of research measures and instruments. Reliability refers to the consistency and stability of a measurement, ensuring that it produces dependable results when used repeatedly or in different conditions. There are different types of reliability, such as test-retest, internal consistency, and inter-rater reliability [15]. On the other hand, validity examines the accuracy and appropriateness of measurement in assessing the specific construct or variable it intends to measure. There are different types of validity, including content validity, criterion validity (concurrent and predictive), and construct validity. A measurement instrument must demonstrate high reliability and validity to make meaningful inferences and informed decisions based on research outcomes [18-20].

TABLE II. DISCRIMINANT VALIDITY

Scale	BE	EE	CE	CD	ES	LS	SFI
Behavior engagement	0.669						
Emotional engagement	0.548	0.521					
Cognitive engagement	0.543	0.408	0.326				
Career decision	0.659	0.621	0.405	0.490			
Employment skills	0.742	0.812	0.814	0.568	0.625		
Life skill	0.625	0.748	0.725	0.628	0.525	0.677	
Student-faculty interaction	0.658	0.587	0.621	0.405	0.490	0.415	0.623

Discriminant validity is a concept used in research to assess whether different constructs or variables are distinct. It is a type of construct validity that examines whether measures of other constructs truly measure separate concepts, not overlapping or measuring the same underlying construct [16]. The primary goal of establishing discriminant validity is to ensure that the measures used in a study are not confounded or influenced by other related constructs. If measures show high correlations with other measures of different constructs, it suggests that they are not distinct and may be measuring the same underlying construct or concept. Researchers can demonstrate discriminant validity by showing that the correlations between measures of different constructs are lower than those between measures of the same construct [12], [18].

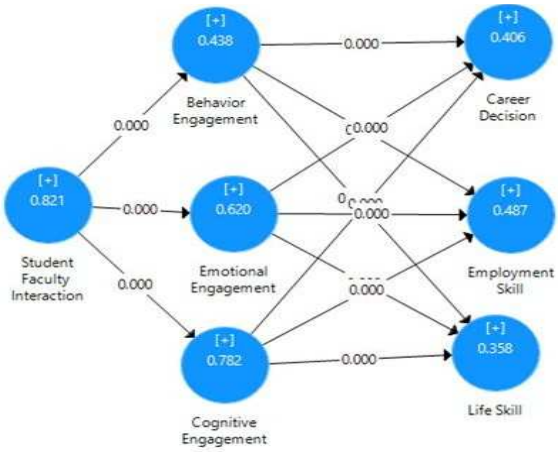

Fig. 1. SEM SFI Framework

TABLE III. HYPOTHESES TESTING

Scale	Sam. X	T-stat	Sig
BE→ CD	0.474	4.461	0.001
BE → ES	0.206	3.721	0.000
BD→ LS	0.229	4.215	0.015

EE → CD	0.169	1.498	0.001
EE → ES	0.145	3.214	0.003
EE → LS	0.215	4.250	0.002
CE → CD	0.125	0.258	0.042
CE → ES	0.514	0.458	0.000
CE → LS	0.158	0.231	0.001
SFI → BE	0.089	1.258	0.000
SFI → EE	0.250	03.25	0.002
SFI → CE	0.425	0.625	0.001

Table IV delineated hypotheses testing and model goodness-of-fit assessment, and hypothesis testing determines the significance of relationships between variables. Model fit evaluation ensures the appropriateness of the chosen model in representing the observed data. There is notable relationship between BE→CD (t.stat=4.461, p-value=0.001), BE→ES (t.stat=3.721, p-value=0.00), BE→LS (t.stat=4.215, p-value=0.015), EE→CD (t.stat=1.498, p-value=0.00), EE→ES (t.stat=3.214, p-value=0.00), EE→LS (t.stat=4.250, p-value=0.00), CE → CD (t.stat=0.258, p-value=0.04), CE → ES (t.stat=0.458, p-value=0.00), CE → LS (t.stat=0.231, p-value=0.001), SFI → BE (t.stat=1.258, p-value=0.00), SFI → EE (t.stat=3.25, p-value=0.002), SFI → CE (t.stat=0.625, p-value=0.001). The path coefficient of SEM conceptual framework for SFL was also deemed fit to the model (see Figure 1). This result has collaborated with earlier work [19-21].

V. CONCLUSION

The connection between students and professors and their beneficial effects on graduate outcomes are distinctive contributions made by this scientific study. In a scenario involving an emerging country, it also emphasizes the mediating function of student engagement characteristics. Examining student-facultyinteraction at business schools in emerging nations and graduate outcomes, including career decision self-efficacy, self-perceived employability, and student engagement characteristics, is crucial. Universities in industrialized nations are increasingly assisting students in making contactsin the business world, inviting companies into the classroom, and creating courses tailored to employers' demands.Business undergraduate students are more confident about their futures and employability thanks to universities' emphasis on the market. This study contributes to understanding the significance of student-faculty interaction in business education, given issues like poor student involvement, little student interaction, and universities' lack of market orientation in emerging nations. Similar to this, the context of the HEIs affects the mediating function of student involvement characteristics.

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StarQuestAR: A mobile-based augmented reality application to learn concepts in astronomy

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***Abstract*—Immersive technologies are making their presence felt in various fields, including the education domain. Among the immersive technologies, Augmented Reality (AR) stands out as a powerful tool that seamlessly integrates virtual objects (3D) into the physical world, providing users with an interactive and engaging learning experience. AR-based contents can be accessed using mobile phones, which are widely available to the majority of the population. Due to its various advantages, AR has gained traction in the field of education. Recognizing the potential of immersive technologies, the Government of India, in its newly released National Education Policy (NEP) 2020, has proposed the integration of these technologies into educational institutions. However, despite this push, there is a scarcity of studies exploring the impact of AR technology specifically in the Indian educational context. To address this gap, we have developed AR-based learning content focused on the topic of the solar system, drawing from the textbook for class 6 issued by the National Council of Educational Research and Training (NCERT), an autonomous organization of the Government of India. To gauge the effectiveness of AR-based learning content, we conducted a pilot study utilizing Keller's ARCS model, comparing the learning experience with that of traditional paper-based 3D models. The results of the study revealed that learners using AR-aided learning content exhibited higher levels of attention, relevance, confidence, and satisfaction. These findings demonstrate the potential of AR to enhance the educational experience for students. Additional research is necessary as it can provide valuable guidelines and recommendations for the successful adoption of AR technology within the Indian education context.**

***Index Terms*—Augmented reality, Paper Based 3D- Model, Indian Education, Astronomy Education**

I. Introduction

Dynamic learning environments using augmented reality (AR) and virtual reality (VR) can motivate students to actively construct knowledge. AR enhances the real world by overlaying digital content like text, graphics, and multimedia, providing an authentic learning experience. Studies have shown that AR technology positively impacts cognitive, motivational, and social processes in education, improving problem-solving, critical thinking, and student motivation [3].

Integrating AR into the curriculum can create immersive and interactive learning environments, making learning more engaging and effective. However, designing and implementing AR learning activities require considering pedagogical aspects, user interaction, and content updates for teachers. While AR is gaining popularity, its application in educational research, especially in subjects like astronomy, remains limited.

The Government of India's National Education Policy 2020 proposes integrating immersive technologies into educational institutions, but there is limited research on AR's impact in the Indian context. To address this, the current study focuses on developing an AR application to teach astronomy concepts to high school students based on the NCERT textbook for class 6. The goal is to encourage discussion and creative expression to enhance student's understanding and in-depth knowledge in the field of astronomy.

The current study compares the effectiveness of AR-based learning and the effectiveness of learning with paper-based 3D models using Keller's ARCS model. This research also aims to explore the potential of AR in the Indian education system while learning abstract astronomical content by making the concepts easier and clearer to students through 3D visualization. The paper's structure includes sections on related research, AR application design, methodology, pilot study results, and conclusions, acknowledging study limitations.

II. Literature Review

Studies have shown that the school curriculum has many subjects that require an understanding of abstract concepts and spatial representations and AR has the potential to provide valuable support to such subjects [6]. Further, in contrast to technologies like virtual reality, AR overlays computer-generated virtual imagery onto the real world, whether directly or indirectly, in real time [6]. Further, AR interfaces also maintain the same delivery of instructional content and only alter the way the content is comprehended by leveraging a distinctive combination of visual and sensory information [7].

Many studies have been conducted to understand the impact of AR in the teaching-learning process of different concepts. One of the studies focused on the development and use of an application named Augmented Reality Tracing (ART) aimed to engage children in the process of learning language writing by tracing over alphabets [8]. The results showed that the application provided a more engaging and interactive learning experience compared to traditional methods.

Salazar et al. [9] studied the effectiveness of an AR mobile application designed to educate fifth-grade students about the solar system. An experiment involving 27 students was conducted to study the impact of the AR application on the students. The results showed notable improvements in learning outcomes, user satisfaction, and overall interest in the subject. Xiao et al. [10] developed and analyzed the use of an AR based application to familiarize students with the planets in the solar system. The study involved 36 students, and the results indicated that the use of the AR application, combined with experiential learning, led to significant improvements in learning effectiveness, satisfaction, motivation, and overall interest in this learning approach.

The effectiveness of augmented books on students' learning and motivation was explored by Vahldick et al. [11]. A mobile AR application that presented interactive maps and other features related to the African continent was developed. The results of the study conducted among 28 ninth-grade students indicated a significant improvement in their average scores and increased motivation when using the AR application alongside the printed materials. Further, a study conducted by Turan et al.[12] indicated that the use of AR technology resulted in a decrease in students' cognitive load levels, while simultaneously improving their academic achievements and motivation. The results were based on a study involving the use of 15 AR applications among first-year university students to learn concepts in Geography.

To summarize, incorporating mobile-based AR technology in education offers several advantages, such as enhancing students' learning experience, increasing motivation, and promoting better knowledge retention. In addition, introducing new learning styles, especially in the fields of Geography and astronomy, allows students to visualize and comprehend abstract concepts and phenomena more effectively. However, despite the benefits observed, further research is needed to thoroughly assess the specific impact of mobile-based AR in Geography/Astronomy education and its overall effectiveness, especially in the context of the Indian Education system. Also, very little work has been done on comparing AR with non-AR methods. Hence, in this paper, we tried to cover these gaps through our research work by comparing the AR method with the non-AR (paper-based 3D models) method in Indian education.

III. Design Of The AR Application

To incorporate the learning content on the topic 'The Earth in the Solar System' found in the class 6 NCERT textbook issued by the Government of India, we created an AR-based

Fig. 1. Screenshot of the homepage of StarQuestAR application.

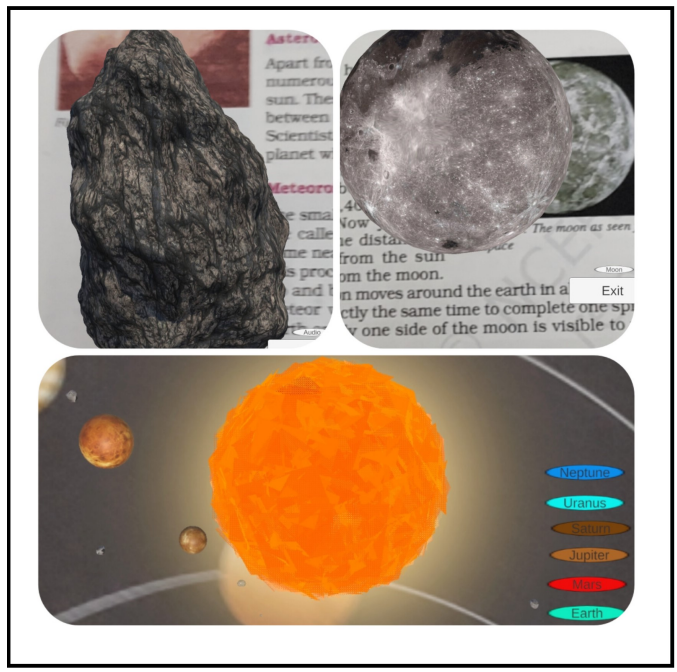

Fig. 2. Shows the 3D virtual images of the different celestial bodies

application 'StarQuestAR' using Unity 3D game engine and Vuforia SDK (a software development kit for smartphones). Computer vision is used by Vuforia to quickly and accurately identify three-dimensional objects. StarQuestAR is an android-based mobile augmented reality application. The app is designed as an active learning platform and a self-guided learning tool that allows the students to do self-study. In this app, the audio channel is also integrated along with the 3D models. StarQuestAR, which was developed as a marker-based AR application (Fig.1), uses the pictures present in the textbook as markers. The students use the app to detect the different images present in the textbook to display the corresponding 3D virtual image. They can interact with these virtual images and listen to the corresponding audio description about the celestial bodies.

The initial version of StarQuestAR has three main elements. The elements corresponding to an asteroid and the Moon allow the users to understand their shape and texture and provide options to rotate, drag, magnify, and shrink through the gesture

TABLE I
PARTICIPANT DETAILS

Group	*Male*	*Female*	*Total*
Paper Base 3D-Model	01	02	03
MAR	00	03	03
Total	01	05	06

TABLE II
MEAN VALUE FOR ARCS FACTOR

Factors	*Paper Based*	*MAR*	*Percentage Difference*
Attention	16.3	18.6	13.18 increase
Relevance	16.6	18.6	11.36 increase
Confidence	16.6	19	13.48 increase
Satisfaction	17.3	18.3	5.61 increase
Overall	66.3	74.6	11.78 increase

of touch (Fig.2). Through the audio option, the students can listen to the different features of each planet. Before conducting the pilot study with end-users, it was ensured that the application was stable and followed the required functional requirements as per the curriculum.

IV. METHODOLOGY

A. Participants

In this pilot study, six students of grade 6, around 11 years voluntarily participated. All the students used NCERT textbooks as part of their curriculum. Before conducting the study, the participants were detailed about the objectives of the study. The participants were randomly divided into two groups: the traditional Paper based -3D Model group and the Mobile Augmented Reality (M-AR) - based group as mentioned in Table I.

B. Data collection and instrument

The effectiveness of both methods was compared using Keller's ARCS Model. A questionnaire comprising 16 questions was prepared related to Attention, Relevance, Confidence, and Satisfaction on a Likert scale of 1-5. Here, "1" corresponds to "Strongly Disagree," and "5" corresponds to "Strongly Agree".

C. Experimental procedure

Before initiating the study, an introductory lecture on the solar system was given to all the participants. The participants were then randomly assigned to two groups. One group interacted with traditional paper-based 3D models of the celestial objects and the other group interacted through the developed StarQuestAR application. The details of the AR app were explained to the students and they used the application installed on an Android-based mobile phone. Using the prepared questionnaires, both groups were compared on the basis of Attention, Relevance, Confidence, and Satisfaction using Keller's ARCS model (Fig.3.). Qualitative feedback on the AR app was also sought from teachers who teach these topics in their regular classes.

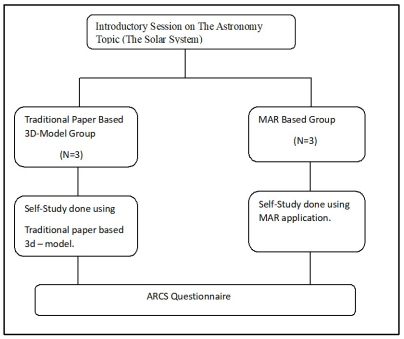

Fig. 3. Experimental Procedure

V. RESULTS AND DISCUSSION

The empirical data were analyzed by the method followed by Khan et.al [5]. The Cronbach's alpha of the survey questionnaire was determined to be 0.82, showing good internal consistency of the questionnaire. The mean values were calculated for both the questionnaires for the four factors that measured student motivation based on the ARCS model [13]. The mean value for each ARCS factor was calculated as shown in Table II. The percentage differences indicate that the mean values for attention, relevance, confidence, and satisfaction increased.

The data collected through the questionnaire based on Keller's ARCS model showed that the students were found to be more confident and satisfied in interacting with AR-based content as compared to traditional paper-based 3D models. However, more statistical analysis is required to determine the significance of the change in the mean value for each ARCS factor.

Based on the interaction with students, it was found that even though the participants were using AR for the first time, the application appeared to be easy to use. They interacted with the virtual images of the celestial bodies and listened to the respective audio descriptions. The students' fascination was evident as they interacted with the real-time 3D model, particularly when exploring the asteroid. Their feedback emphasized that the AR application significantly improved their visualization of the asteroid's shape. The captivating nature of the 3D model and its ability to provide a more comprehensive understanding of the asteroid's characteristics showcased the potential of AR technology as an effective tool for enhancing students' comprehension and engagement in the study of celestial objects. These observations shed light on the positive impact of AR applications in astronomy education, promoting a deeper connection with complex concepts and fostering a sense of excitement and curiosity among learners.

In the course of our study, we observed a notable level of enthusiasm and interest among the students when engaging with the educational app. In fact, one student went as far as inquiring about the source to download the app, expressing a strong desire to continue learning through this medium.

The incorporation of AR into their textbooks further fueled their excitement, as they eagerly embraced the interactive and immersive learning environment. These findings highlight the potential benefits of using AR technology in education.

Apart from gathering data from the students, we also presented the AR application to teachers who were responsible for teaching these topics using traditional methods in their regular classes. While many teachers appreciated the concept of augmented reality, they also expressed apprehensions regarding its implementation in classrooms. One teacher even appealed to still use paper-based 3D models, as they offer a more tangible and interactive experience for students. However, the teacher also acknowledged the challenges of creating physical models for every topic, as it requires significant time and effort from educators. Additionally, the teachers, who were already utilizing 2D animation videos in their teaching, were uncertain about how to effectively incorporate AR into their lessons, and the potential for distraction in the classroom was also a point of consideration. These insights highlight the need for further research and support in addressing the practical concerns and exploring the best practices for integrating AR technology in educational settings effectively.

VI. Conclusion

The aim of this study was to examine how an AR-based mobile application enhances the student's attention and confidence in learning certain topics in astronomy in the context of the Indian Education System as compared to the non-AR paper-based model. Existing literature highlights the lack of sufficient research on the use of mobile AR in education, presenting an opportunity to explore the potential benefits of AR in enhancing students' learning through visualization and ultimately contributing to improved academic performance. Our study demonstrated that students' attention, relevance, confidence, and satisfaction levels were higher when using AR than the paper-based model, indicating the effectiveness of introducing AR in Indian school education, aligning with the objectives of NEP2020. Looking ahead, integrating other technologies such as the Internet of Things (IoT), machine learning, and artificial intelligence (AI) with AR-based learning systems and more elements of gamification could further enhance the development of effective and futuristic learning platforms. However, more research is needed to address the practical challenges and explore optimal strategies to effectively integrate AR technology in educational settings, catering to the diverse needs of students and educators alike.

VII. Limitations And Future Research

The present study focused on only sixth-grade students and a specific topic, restricting the generalizability of the findings. The AR application's functionality is limited to the images (markers) provided in the NCERT textbook, which may affect its broader applicability. Additionally, statistical analysis to determine the significance of changes in mean values for each ARCS factor could not be conducted. Future research should aim to include a more diverse student population to ensure broader applicability. Due to limited resources, the experiment's duration was short, suggesting the potential for longer-term follow-up studies.

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Additive Manufacturing for Inclusive Games: How can Additive Manufacturing technology assist in the learning of the Visually Impaired

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***Abstract*—Game-based learning is an important aspect of education. However, when it comes to games, visually impaired children suffer. There are very few games developed for the visually impaired, and lesser so, to serve for educational purposes. In this paper, we discuss the role of additive manufacturing technology in creating inclusive games. Specifically, we focus on the design and development of a digitally-fabricated board game for the visually impaired. At the start of our study, we conducted a semi-structured interview with visually impaired children to understand our user group. Then, we developed a geography-based educational game focused on teaching the physical and political features of India. One of the key focus areas while developing the game was the design of the tactile nature of the game artefacts — the board and the pegs. Finally, we conducted a user testing of the game with visually impaired children. We found that the game enhanced the children's understanding about the map of India.**

Index Terms*—Inclusive design, universal design, educational game, additive manufacturing, accessibility, 3D printing, visually impaired

I. Introduction

Play and games have always been key elements of culture and have played a vital role in the development of civilization [1]. A reason for this is that games allow people to socially interact and share a collective experience. In addition to entertainment, playing board games is essential for psychological, cognitive and social development of children [2]. Educators are also discovering the cognitive potential of games in classrooms [3]. They have done this by applying principles of video games to K-12 classrooms, which significantly enhanced the learning of children.

Sadly, some children are excluded from playing most games, not because of lack of access to games, but because of a physical or a mental disability, which renders their access impossible. For instance, a lot of games rely heavily on visual cues, so they are inaccessible to the visually disabled.

It has been shown that students with visual disability need assistive technology for a wide range of activities, one of which is academic learning [4]. Studies in literature show the possible benefits provided by games to support education for people with disabilities [5]–[7]. For instance, enhancement of memory, development of logical reasoning skills, training in Braille, etc. As per the latest census data, there are 26 million disabled persons in India, out of which 5 million are visually impaired (VI). 1.5 million visually impaired are under the age of 20 [8].

II. Background

A. Additive Manufacturing for inclusive design

Additive manufacturing offers several advantages over traditional manufacturing methods; it allows for fabrication of complex geometry [9], mass-customisation of a product [10], and manufacture at a small scale without significantly increasing costs [11]. All these advantages make additive manufacturing well-suited for designing inclusive products. Inclusive products are products that can be used by people of all background and capabilities.

B. Games for Visually Impaired

Most games are designed for sighted people, hence, they face accessibility challenge for the visually impaired. Accessibility problems may include the following: unable to receive feedback; unable to determine in-game responses; unable to provide input using conventional input devices [12]. Visually impaired players may be unable to perceive primary stimuli, without which, it is impossible to determine what input to provide, even if players are cognitively and physically able to do so. We present a brief outline of the previous works done in the development of digital and non-digital games for the visually impaired.

In case of digital games, a significant amount of research has been focused on the accessibility aspect of games, but not on a blind player's mental representation of game or process related to storing of game state [13]. Since visually impaired subjects are unable to recognize information on screen, they have to rely on auditory and haptic feedback. And sometimes, on touch-based interaction mechanisms. Touch-based interaction

adds up to the cognitive load of the visually impaired user and decreases usability, as they have to remember the interactions as well as the gameplay, in addition to the current game state. User studies of digital games have revealed visually impaired having problems in proceeding with the game without moderator intervention, forgetting interaction mechanisms and requirements of game [14], accidentally undertaking wrong interaction mechanisms [15], etc.

When given a choice between playing online/via phone and offline, visually impaired participants choose to play face to face as they fell they have better control on the moves, and they can make better use of their abilities when they have control [16]. Since different input and output mechanisms present in digital games to make it accessible adds to the cognitive load of a visually impaired player, they might not be able to focus on enjoying the game, thus killing the very purpose of the game.

One advantage provided by board and tangible games over digital ones is tactile stimulation, which has a major impact on concept formation of visually impaired students. This is why the practice of explanation through models is used in education [17]. Using a physical model of a game has been shown to help the visually impaired in forming the mental model [7]. Visually impaired participants have reported experiencing autonomy while playing board games as they have the freedom to engage with cards/board by touch to properly develop strategies [16], [18]. Board games also create spaces for social interaction among visually impaired players [16].

We did not find much research on the use and impact of educational board games for the visually impaired. In one relevant research, a survey conducted in ten Blind Schools of Delhi compared the awareness and utilization of assistive technology among 250 visually impaired students [4]. The data reveals an overall higher usage of games (Tactile dice, Braille Chess, Print Play cards, Audible games balls) than assistive technology for education (Braille compass, Braille Ruler, Braille Protractor, Raised Line Graph, Tactile Geometric kit, Tactile map, etc.). It is striking to note that among Visually Impaired students, non-digital games are more common and more utilized than assistive technology for education in India.

III. Interaction with Visually Impaired Children

An interaction session was carried out with seven, 10 to 15 year-old visually impaired children enrolled in a Blind School in Guwahati. This included partially sighted, totally blind and congenitally blind children. Verbal consent was taken from the children before we started a discussion with them. We asked them about their interests, the games they played, the assistive technology they used, and their favourite and least favourite courses. The most popular games among children was audible cricket balls, chess, and a few offline computer games. Most of the children did not use any assistive technology except Voice-recorder, which was the most common assistive technology used in classrooms. All the children had different opinions on favourite and least favourite courses. However, We found that the students faced difficulties in topics where significant visual cues were essential to the understanding of the topic.

Based on the interaction, we decided to design an inclusive board game to teach the map of India to the visually impaired students. We first discuss the game mechanics, and then the prototyping.

IV. Game Mechanics

The game is played on a star-shaped board made up of hexagonal grid as shown in fig. 1. A tactile map of India is present on the board. The game can be played by a minimum of two players and a maximum of six players. Each players starts at one corner of the star.

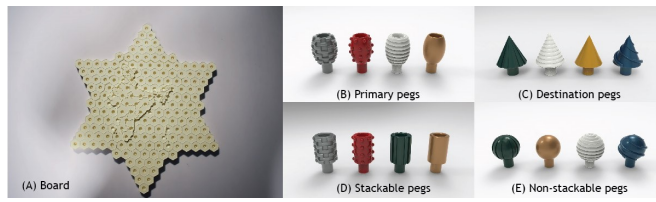

Fig. 1. 3D printed board and CAD model of pegs

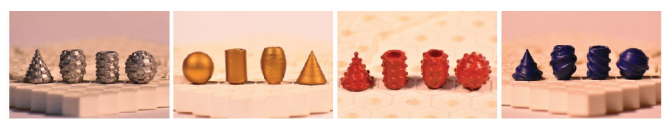

Fig. 2. A set of pegs belonging to one player has uniform texture and colour

Each player is allotted a location in India by their co-player. The aim of the game is to undertake a journey from the starting corner of the star to the opposite corner of the star, while passing through specified destination. The player who come backs to their starting corner at the earliest, wins.

Each player gets a set of pegs that can be used to make way for oneself while blocking the paths of other players. The pegs are as follows: one Primary peg, one Destination peg, three Stackable pegs, and three Non-stackable pegs. Players use Primary pegs to 'travel' through India starting from one corner of the star. A Primary peg can move exactly one space adjacent at one go. Players are supposed to place their Destination pegs on one of the spaces lying on, or nearest to, the destination. Incorrect placement of Destination peg invites a penalty. Stackable pegs are used to block paths of other players, but make way for oneself. Non-stackable pegs are used to block paths of all the players including oneself.

V. Prototyping

The first prototype of the game was a printed Indian map to test the gameplay. Several games were played with seven sighted adult players. Players used coloured pen and unique symbols for donating different pegs. Two possible sets of rules were tested through the games. After each game, qualitative feedback was taken, and the game-play was analyzed. Based on the feedback and analysis, the game was refined. The board was changed from hexagon to star. In a hexagonal

board, the minimum length of path a player needs to traverse is destination dependent, whereas, in a star-shaped board, irrespective of destination, the minimum length required to return to starting point is same. One of the two sets of rules was chosen. The number and type of pegs given to the player at the start of the game was changed.

A second iteration of the game aimed at testing the refinements was printed and user-tested in the same manner as that of the first prototype. Since feedback was mostly positive, we went ahead and 3D printed the board and the other game artefacts.

Since the game is designed primarily for visually impaired players, due attention was given to its tactile nature. The final prototype of the game consists of 3D printed board and pegs. The game artefats were modelled on a CAD software. Before the final printing, a few pegs of the game were printed to see if their dimensions were good enough to grab and play with. We also wanted to see if the 3D printed items had a texture as we desired. The board and the pegs were additively manufactured on Ultimaker-3 3D printer. ABS filament was used to 3D print the game.

We took care of the following points while designing and 3D printing the game:

1) **Form of pegs:** There are five different types of pegs - Primary peg, Destination peg, Stackable peg, Non-stackable peg, and a Bomb peg. Each type of peg has a unique overall form. For instance, the pyramid shaped peg is the destination peg. Each peg has a *leg* that can be inserted into the holes of the board.
2) **Tactile nature of the pegs:** A set of pegs for one player has a uniform texture and colour (fig. 2). The height of texture on pegs is 0.6 mm or more. We believe that a texture height of this value will be easily perceived by the visually impaired players as this value is greater than the minimum recommended height for Braille letters, which is 0.48 mm [19].
3) **Tactile nature of the board:** The star-shaped board has a tactile map of India at the centre. The political map of India has been represented. We also tried to represent a physical map of India (Using different textures to denote various physical features of India - the mountain range, the desert, etc.). However, the physical representation did not come out so well in the 3D print. The board has holes for inserting pegs.
4) **Additional features in game artefacts:** We made the best use of additive manufacturing technology by integrating additional physical features in the board and the pegs in order to prevent a violation of rules either by mistake or intentionally. The physical features afford certain actions (that are allowed as per rules) while they block other actions (that are not allowed as per rules). For example, one of the rules is that a Primary pegs can be stacked on top of a Stackable peg of the *same set* only. An extrusion on Stackable pegs and a corresponding extruded cut on the bottom of the Primary peg as shown in fig. 3 affords this. Similarly, only the Primary peg is allowed to enter the 'wing area' of the star. Physical features as shown in fig 4 facilitates this. These additional physical features ensure that rules are followed. This is especially important while designing games for the Visually impaired as they might not know/perceive the change in game-state after every action. By the time other players realise that a rule has been violated, it may be too late.
5) **Inclusive design:** The game artefacts have been spray-painted after their fabrication to make the game visually appealing to sighted players. If inclusive games are appealing to sighted people as well, it will can be played by a group of people with varying abilities.
6) **Game state can be perceived tactually:** Since all actions are carried out on the board, and involve physical manipulation of pegs, the game board can be perceived by touch after every action. This might reduce the cognitive load on the player as they do not have to put in efforts to remember the game state.

After prototyping the game, we took it to visually impaired children. The following section describes the user-testing in detail.

Fig. 3. Extrusions and corresponding extruded cut

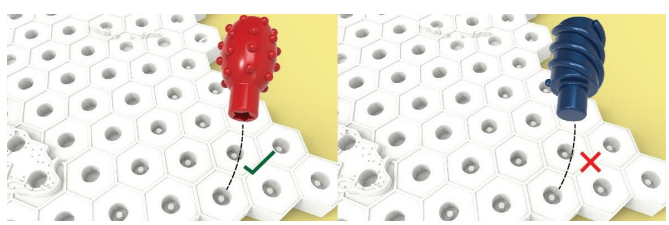

Fig. 4. Extrusions on board

VI. User Testing

The game was played by 7 Visually Impaired Children, four boys and three girls, between the age of 13 and 19 years. All the children were students of a Blind School. Six of the players were totally blind. The game was first played among boys, and then among girls.

Rules of the game were explained to the participants step by step. First, the participants were given a set of pegs with

uniform texture so that they could familiarize themselves with that texture. Then, the pegs were mixed, and the participants were asked to identify and sort their pieces. All the boys and two of the three girls successfully identified their pegs. All the players could differentiate between the pegs on the basis of their forms. Thus, the textures and forms were dissimilar enough to enable a visually impaired person to differentiate between them easily.

Before starting the game, the participants were given the board and asked to locate certain geographical features of India. Except for one participant who identified one place correctly, none of the participants could identify any feature of India. Next, the players were taught to move their primary peg to reach a given destination on the board. Initially, instead of moving their pegs to the adjacent hexagon, some of the players moved their pegs to next-to-next hexagon. However, they soon learnt the correct method. Once they learnt this, the players were introduced to the roles of other pegs, and then to the rules of the game. Finally, the game was played with the players. All the players understood the rules of the game well and applied them while playing the game.

Most of the participants had one or both of their hands on the board throughout the game. The board is perhaps too small to accommodate six to twelve human hands. While locating pegs, the players would accidentally move a few pegs such that they came out of the holes of the board. During the initial game sessions, we found that the participants were more focused on reaching their destinations instead of blocking another player's path.

We think that the participants were able to form a spatial image of the Indian map through the game. Even when the board was rotated, they were able to locate places correctly and move their primary peg in the desired direction. At the end of the game, the participants were asked to locate certain geographical features of India, once again. Most of the participants could locate most of the features accurately.

After the game, we asked the participants for a feedback. All the participants unanimously said that the game helped them enhance their knowledge about India. Five of the seven participants said that they found the game engaging and interesting.

VII. Discussion

Through the design, development and user-testing of a game, we show how the advantages of additive manufacturing can be used to make inclusive games. With the help of this game, we were able to give a general idea about the map of India to the participating players in an engaging manner. The various textures and forms were distinguishable from each other. The game helped the players form a mental image of the Indian map. While the game had its own set of advantages, it had its limitations too. A bigger sized board may allow the visually impaired players to place their hands comfortably onto it while playing the game. Usage of magnets will facilitate adhesion of pegs to the board to prevent it from falling and dislocating. An additional map and rule-book, both in Braille, can be provided with the game to make the visually impaired self-sufficient while playing. The designed game can be expanded where the map of India can be replaced by a different map, or by a different tactile diagram such as digestive system, etc. to teach visually impaired children different topics and concepts.

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Academic Self-efficacy and Motivation of Students Using Tablets in Afterschool Centres in Rural India

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***Abstract*—This manuscript describes a pilot study that investigates the use of tablet-assisted teaching in four afterschool centers in rural India. Students received 20 minutes of tablet learning for at least three days per week. For the first two weeks, students are given tablets to use randomly without following any particular curriculum so that they can learn how to use the applications, i.e., ReadAlong, Chimple, and mathematics game, and from the third to the sixth week, they follow a set curriculum. In total, 68 students from 1st to 5th grade participated in the program. The main objective of the pilot study was to evaluate the feasibility of the approach before introducing the program to 53 centers located in 21 states. Another important objective was to evaluate ways to measure the effectiveness of the program. The pilot study evaluated two instruments to measure the improvement in academic self-efficacy a nd a cademic m otivation i n t erms of their feasibility and internal consistency. For self-efficacy, the questionnaire by Liang (2000) was evaluated, and for academic motivation, the Instructional Material Motivational Survey (IMMS). The program shows promise, with good progress in weekly assessments in the intervention centers. Both assessment tools for academic self-efficacy a nd m otivation o f s tudents were found to have reasonable internal consistency. The study also finds t hat p erceived s ocial s upport i n e ducational p rograms is important in implementing educational programs in rural India. Overall, the results suggest that using tablets might be a cost-effective tool for bringing sustainable education to rural areas, motivating students, and improving their academic self-efficacy.**

***Index Terms*—rural education, rural development, technology for monitoring and coordination, education technology, sustainable development goals**

I. Introduction

The education system in rural India faces several challenges such as a lack of infrastructure and facilities, teacher shortages, a lack of educational resources, high dropout rates and low student attendance, language and cultural barriers with students from diverse linguistic backgrounds, gender disparities, and socioeconomic inequalities with the need for children in some rural areas to contribute to household incomes [1]. Addressing these challenges requires a comprehensive approach, including improving infrastructure, enhancing teacher training and support, providing adequate resources, addressing language barriers, promoting gender equality, and implementing targeted policies and interventions that cater to the specific needs of rural communities [2].

Amrita RITE is an initiative by Amrita Vishwa Vidyapeetham, a multi-campus university in India [3]. It aims to provide remote education in rural and remote areas [4]. Amrita RITE offers a range of programs designed to empower educators with knowledge and strategies to effectively utilize technology in their teaching practices [5]. The initiative focuses on various aspects of remote instruction, including online teaching methodologies, learning management systems, digital content creation, and pedagogical approaches for virtual classrooms. Through Amrita RITE, educators can gain insights into innovative teaching techniques, explore emerging technologies in education, and enhance their understanding of effective pedagogy.

In 53 remote villages in 21 states, Amrita RITE operates afterschool education centers where local teachers provide school subject training and awareness sessions to students [6]. The program runs for 2.5 hours every day, allowing village students to attend after their regular school hours [7]. Additionally, on weekends, the program offers value education classes and engaging activities focused on raising awareness [8].

The current report describes a pilot study for a planned, large-scale program by Amrita RITE to integrate tablets in the afterschool centers. The use of tablets in education has the potential to increase student academic self-efficacy and motivation because they can provide an interactive and engaging learning experience [9], they enable personalized learning [10], they give immediate feedback and track progress [11], they provide access to a vast array of educational resources, including e-books, videos, simulations, and online educational

platforms, and they are perceived as modern and appealing tools among students, particularly in the digital age [9].

However, it's important to note that the impact of tablet use on motivation may vary depending on factors such as the quality of educational apps, teacher facilitation, and students' prior experiences with technology. The effectiveness of tablets in increasing motivation also depends on how tablets are integrated into the overall instructional design and the alignment with pedagogical approaches [12]. A literature review by Pakdaman et al. [13] reveals that there exists a lot of variation in the effects of integrating tablets into a curriculum.

The situation is further complicated by the fact that measures of students' motivation and academic self-efficacy can only be assumed to be reliable when the instruments are culturally appropriate and relevant to the Indian context. This includes considering language, cultural norms, and the specific educational system in India. Adapting existing scales or developing new scales should involve validation procedures, including assessing internal consistency. This is particularly true for measures of self-efficacy, since cultural and contextual factors may influence self-efficacy beliefs. Therefore, it is recommended to validate self-efficacy measurement instruments specifically in the specific context that they are used [14].

This paper describes the implementation of pilot program and reports on the internal consistency of the academic motivation and self-efficacy The outline of this paper is a following. Section II gives an outline of the pilot study, describes the software that is used on the tablets, and the instruments that are used to assess academic motivation and self-efficacy. Section III describes the results and Section IV ends with a discussion and conclusion.

II. Methodology

A. Study Overview

A total of 68 students in grades 1 to 5 participated in a 6-week pilot program conducted in three afterschool centers in Tamil Nadu and one center in Uttar Pradesh. In the program, students used 20 minutes of tablet learning for at least three days per week. During the initial two weeks, students were given tablets to use without a specific curriculum, allowing them to familiarize themselves with applications. Starting from the third week, students followed a structured curriculum. Throughout the study, students were asked a set of questions on self-efficacy and motivation each week.

The outline of the study was as follows:

1) First, the content on the tablet was uploaded, and applications were installed.
2) The survey questionnaires were translated into the local languages, and the organisational workflow was established before the collection of the baseline survey data, which included basic information about students such as the name of the student, class, age, gender, parent's name, and occupation, caste.
3) The questions were broken up into 6 sets, since it was deemed infeasible to conduct a prolong set of questionnaires with the young students.
4) Based on the baseline survey, the total number of students in the afterschool centers was determined, and the deployment of tablets was be done accordingly.
5) After that, the initial setup of monitoring and fieldwork was initiated where the teacher training took place. The teachers were trained on all the applications being used for the study.
6) After completing the training, the interviews with the children in the afterschool center started, where a set of questions was asked each week.
7) At the end of the study, regular attendance, log files from the application, weekly assessments, and quarterly assessments were collected from the centers.

B. Main educational software used in this study

1) Google ReadAlong: ReadAlong is an educational app developed by Google that helps children improve their reading skills in a fun and interactive way. The app aims to assist young learners in developing their reading abilities through various engaging activities and exercises.

Google ReadAlong utilizes voice recognition technology to listen to children as they read aloud, providing real-time feedback and assistance. The app offers a collection of diverse stories and reading material that cater to different reading levels, ensuring a personalized learning experience. By combining technology, speech recognition, and educational content, the app provides a supportive platform for young readers to improve their reading abilities and build confidence in their learning journey.

2) Chimple: Chimple is an educational app designed to enhance children's reading skills and promote early literacy development. The app is specifically tailored for children in the early stages of literacy acquisition, providing age-appropriate content and learning experiences.

One of the primary features of Chimple is its extensive library of stories and reading material, encompassing a wide range of genres and topics. In addition to reading, Chimple offers various interactive activities and games that reinforce vocabulary, comprehension, and critical thinking skills. These activities engage children in meaningful interactions with the text and encourage them to think critically about the stories they read. Through interactive quizzes, puzzles, and word games, Chimple fosters active participation and ensures an enjoyable learning experience.

C. Psychometric instruments

1) Academic self-efficacy: Academic self-efficacy refers to an individual's belief in their own capabilities to succeed in academic tasks and challenges. It is a construct grounded in Bandura's social cognitive theory [15], highlighting the influence of one's self-perception on motivation, behavior, and academic achievement.

According to Bandura, self-efficacy beliefs play a vital role in determining the level of effort, persistence, and resilience individuals demonstrate when faced with academic demands. Students with high academic self-efficacy are more likely

to set ambitious goals, persist in the face of obstacles, and exert the necessary effort to attain desired academic outcomes. Conversely, those with low academic self-efficacy may doubt their abilities, experience reduced motivation, and may avoid challenging academic tasks [16].

Numerous studies have explored the significance of academic self-efficacy in educational contexts. Multon, Brown, and Lent [17] conducted a meta-analysis that revealed a positive correlation between academic self-efficacy and academic performance across various domains. Lent, Lopez, and Lopez [18] found that higher levels of mathematics self-efficacy were associated with increased interest in pursuing science-related careers.

The Academic Self-Efficacy Scale, developed by Liang [19], comprises two dimensions: academic competence efficacy and academic behavior efficacy. Academic self-efficacy pertains to students' beliefs and attitudes regarding their abilities to succeed academically, effectively complete academic tasks, and engage in successful learning. Self-efficacy refers to an individual's belief in their capacity to perform the behaviors required to achieve specific academic accomplishments. The instrument consists of 22 items that are evaluated on a 5-point Likert's scale.

2) Academic motivation: Academic motivation refers to the driving forces that influence individuals' attitudes, behaviors, and efforts in educational settings. It encompasses the desire to learn, engage in academic tasks, and achieve academic goals. Motivation plays a crucial role in shaping students' academic success, persistence, and overall educational outcomes.

The ARCS model for motivation, developed by John M. Keller, provides a framework for designing instruction that enhances learner motivation [20]. The model focuses on four components: Attention, Relevance, Confidence, and Satisfaction (ARCS). Attention aims to capture and sustain learners' interest and engagement. Relevance emphasizes the importance of connecting learning materials to learners' goals and interests. Confidence focuses on building learners' self-belief and self-efficacy. Satisfaction addresses learners' need for a positive and rewarding learning experience.

The Instructional Materials Motivation Survey (IMMS) is a psychometric tool that assesses students' motivation and engagement with instructional materials [21]. It examines dimensions such as attention, relevance, and confidence. The IMMS provides valuable insights into students' perceptions, attitudes, and preferences toward instructional materials, enabling educators to evaluate and improve the effectiveness of instructional materials in promoting student motivation and engagement.

The IMMS instrument consists of 32 items evaluated on a Likert's scale. Since it was not deemed practical to conduct all questions from the Academic motivation and from the pre and post Academic Self-Efficacy Scale (a combined 66 items) with young children, the questionairs were broken into 6 sets.

TABLE I
DESCRIPTIVE STATISTICS OF THE SCALES: MEAN, STANDARD DEVIATIONS, MEDIAN, MINIMUM, MAXIMUM, SKEWNESS, AND KURTOSIS

	mean	sd	median	min	max	skew	kurt
Attention	4.23	0.18	4.33	3.67	4.50	-1.21	0.46
Relevance	4.13	0.16	4.11	3.78	4.56	0.30	0.02
Confidence	3.95	0.56	3.44	2.33	5.00	0.87	0.07
Satisfaction	4.69	0.25	4.80	3.80	5.00	-1.73	0.03
Self efficacy (pre)	3.79	0.61	3.88	2.25	5,00	-0.99	0.07
Self efficacy (post)	3.90	0.46	3.88	2.50	5.00	-0.22	0.06

TABLE II
CONSISTENCY MEASURES

	α	λ_6	ω_h	ω_g	ω_t
Attention	0.68	0.64	0.52	0.73	0.71
Relevance	0.77	0.84	0.19	0.23	0.82
Confidence	0.88	0.93	0.75	0.78	0.96
Satisfaction	0.62	0.30	0.48	0.98	0.49
Self-efficacy	0.93	0.96	0.77	0.80	0.97

III. RESULTS

Six scales were evaluated in total: the subscales Attention (A), Relevance (R), Confidence (C), Satisfaction (S) from the IMMS academic motivation survey and a two versions of the self-efficacy scale, one from the beginning of the program (labeled Pre) and on from the end of the program (labeled Post). For each scale, the average of the Likert scale items were calculated giving a score between 1 and 5. The descriptive statistics of the six scales are shown in Tab. 1. Finally, Tab. 2 shows different measures of consistency for each scale: Cronbach's α, Guttman's λ_6, and three model based estimates (ω_h, ω_g, and ω_t); see the overview article by Revelle for a discussion on these measures [22].

IV. DISCUSSION AND CONCLUSION

The manuscript has described the implementation of a pilot study to integrate tablets in the teaching provided by after-school centers in rural India. The pilot study provides some encouraging results. The implementation was feasible and, while it required a lot of planning, was conducted smoothly. The overall feedback from the four centers was positive and both the teachers and the students are eager to continue to use tablets in the afterschool centers.

While the sample size of the pilot study is too small to provide any confident statements on the cost-effectiveness of the approach, the pilot study lays the foundation for the large-scale study in 53 afterschool centers with a study duration of 6 month. Most importantly, it was found that the instruments for measuring academic self-efficacy and motivation can be applied in the setting of rural India. A crucial part of applying these instruments seems to be to break the questionnaires into multiple sets and split them over multiple weeks. Initial testing strongly suggested that conducted a survey with 66 items with students from 1st to 5th grade is not feasible, since students will not be able to keep focus.

In terms of the selection of the software, one important consideration is that the applications must work in online mode, since it can not be assumed that stable internet is available at all times in remote areas. Both Google ReadAlong and Chimple are able to be used in a strictly offline mode, where all the data can be preinstalled on the tablets.

Additionally, the pilot study reveals that the perceived social support within educational programs plays a very important role in the successful implementation of such programs in rural India. From interviews, it seems that a large part of the benefit from using tablets may not come from the technology itself, but from the feeling of the students that they are provided with an effective method of studying.

Taken together, the findings indicate that utilizing tablets could serve as a cost-effective solution for delivering sustainable education to rural regions, while also fostering student motivation and enhancing their academic self-efficacy.

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Implementing AQAD (ASSET-Question-A-Day) for Creating Large Scale Impact through Continued Feedback & Learning Insights

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***Abstract*— The purpose of education is to ensure deeper learning and conceptual clarity that a student can apply in a multi-disciplinary environment. The way we test for the concepts can help us understand whether students have learnt through rote practices or have developed creative and critical thinking ability. Hence, exposing children to high-rigor questions in a low-stakes environment can help build curiosity, participation, and overall exposure to high standards assessments. With this intent, the AQAD offering (An ASSET- Question-A-Day) was provided freely. In the current paper, we discuss our work with the state of Gujarat where these questions were made available through the state-managed app, G-shala. G-Shala is an App designed for students and teachers as an open platform. Through the AQAD offering, each day, a question per class (3 to 10) for specific subjects like English, Mathematics, Science & Social Science was provided for children and teachers to attempt. The main objectives were to expose children to high-quality assessment questions to stimulate learning curiosity and understanding, offer teachers exposure to quality assessment questions, and provide data insights for classroom use. Monthly data analysis identified learning gaps, informed about the remedial activities, and tailored classroom strategies. Insights were shared through "Jeevan Shikshan," a state magazine for educators. This practice has continued for three years with some successes and challenges in scaling. The paper also discusses ways to scale solutions with the government, covering data trends, insights, dissemination, and current scaling and sustainability challenges.**

Keywords — AQAD, Asset-Question-A-Day, teacher professional development, innovative teaching strategies, learning insights, misconceptions, classroom strategies, educational solutions, educational research, student performance, G-shala, Gujarat.

I. INTRODUCTION

One of the essential aspects of education systems is to showcase their impact through participating in global assessments for learning outcomes & learning levels of students. In India, students across various grade levels often encounter significant challenges when it comes to answering questions that require deep thinking and a solid grasp of concepts. These challenges stem from a multifaceted problem that encompasses several key aspects. Firstly, the prevailing education system in the country tends to prioritize rote memorization over fostering genuine comprehension. **[1]** This overemphasis on memorization leaves students with a deficiency in critical thinking skills and hampers their ability to apply their knowledge effectively in real-world situations. Secondly, the assessment strategies employed in many Indian classrooms often fall short of promoting deeper understanding. **[2]** Teachers frequently lack the tools and techniques needed to identify and address areas where students are struggling to comprehend specific topics. In 2022, the Foundational Literacy Study conducted by the Ministry of Education and NCERT revealed that more than 50% of assessed class III children in Delhi possess either 'limited' foundational numeracy skills (37%) or 'lack the most basic knowledge and skills' (11% specifically) **[3]**. The similar observations in Gujarat under ASER 2022 report, suggests that the percentage of children in Gujarat who could read a Class 3 level text fell from 53.8% in 2018 to 34.2% in 2022.

[4] The NAS score for 2021, a national-level survey, further accentuated these educational challenges in India, highlighting significant gaps in students' understanding across subjects like Language, Maths, and Science. This gap is evident as the scores decline with increasing grade levels **[4]**. In the global context, India's educational performance faced challenges as well. In the 2009 PISA ranking, India was placed at the 72nd position out of a total of 73 participating countries **[5]**.

II. DESIGN AND DEVELOPMENT PRINCIPLES:

Ei ASSET evaluates a student's level of understanding by asking unfamiliar and thought- provoking questions that assess the student's basic understanding of concepts. ASSET questions have largely been praised for being high-quality questions that test higher-order skills. They require students to demonstrate reading and comprehension skills, and cannot be answered easily without understanding the concept. **[6]** While ASSET test is being administered twice a year for around 2 decades now, and is being taken by approximately 3,50,000 students of private schools across the India in English language, it came out as a challenge to make such quality- questions available on larger scale across different languages.

AQAD was conceived as a solution to provide their use to the larger audience without any paid subscriptions. From larger pool of ASSET, one question per subject per grade (3 to 10) have been published free on its website. Any student/teacher can access the platform and attempt the question that needs high-rigor regular classroom environment. All these questions on AQAD platform (https://www.aqad.in/?language=en) can also be seen in Hindi & Gujarati language as of now, with room for more languagesin the future as per the need.

Overall, the design and development of the AQAD initiative were grounded in research-based principles that promote effective learning and assessment practices. This section outlines the key principles and strategies employed in creating the question bank and integrating it into the G-Shala app.

III. IMPLEMENTATION DETAILS:

The successful implementation of the AQAD initiative required collaboration between educational authorities, technology developers, and teachers. Ei has been publishing AQAD questions every day on its website. **(Fig.1)** However, in Gujarat, Educational Initiatives provided questions in Gujarati context, testing the same objectives on the "G-shala" app."G-Shala" is an acronym for "Gujarat Students' Holistic Adaptive Learning" App, acting as an education and reference application. It has been created with the purpose ofhelping to nurture the students from Standard 1 to 12 of government and aided schools. The app is governed by Gujarat Council of School Education, Samagra Shiksha Education Department, Government of Gujarat based on Gujarat State Education Board (GSEB) syllabus. G-Shala is a platform-agnostic and device-independent app that provides digital interactives, 2D/3D augmented e-content mapped with textbooks for all the subjects and caters to grades 5-12. It is based on the Gujarat State Education Board (GSEB) syllabus. It was launched by Govt. in the wake of CoViD-19,to ensure that the learning does not stop for govt school children despite the lockdown extremities.

The process steps for the implementation of AQAD questions on G-shala are presented in the chart. **(fig.2)**

The questions were displayed on the G-shala app upon login. Whenever a child or a teacher logged in the app for the first time in the day, they received the AQAD question as a pop-up **(as seen in the fig. 3)**.

They were asked to select the correct option for the questions posed to them. They had the liberty not to attend the question by closing the pop-up. The questions were given specifically in the login IDs for classes 3 to 10; and for each

Fig. 1 AQAD website displaying the question daily

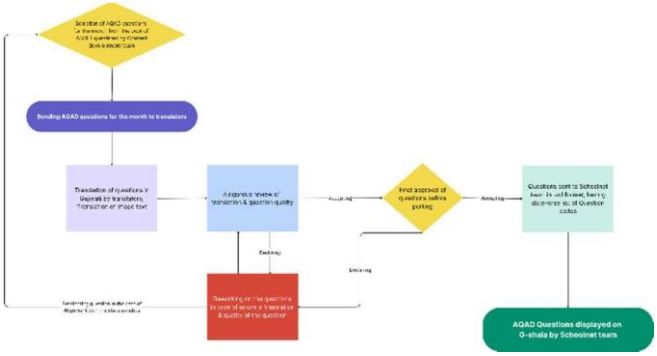


Fig. 2 Process flow of Question selection & sending AQAD questions to G-shala

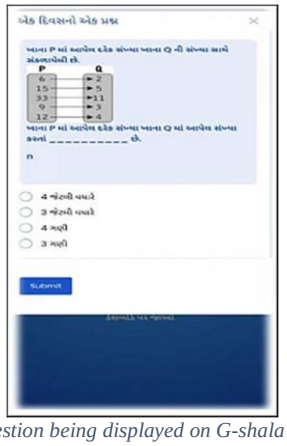


Fig. 3 AQAD question being displayed on G-shala app

day, a specific subject was decided for the question among Science, Mathematics, & Social science.

IV. EVALUATION OF EFFECTIVENESS:

The effectiveness of the AQAD initiative hinged on its organic scalability and its capacity to provide insights into students' learning levels. To ensure the achievement of the objectives, three specific parameters were given attention:

1. Total attempts of students on a particular question: This helped us to understand & maintain the uptake & scale. **2.** Assessing students' overall performance in the question: Thiswas essential as it highlighted how well they comprehended the underlying concept. **3.** Examining the option-wise percentage distribution of students' attempts : It is instrumental in observing the number of students trying alternative options and extracting insights into common misconceptions. Apart from underscoring the distribution of students' understanding across the various options, it also sheds light on the misconceptions associated with these choices.

V. INSIGHTS FROM AQAD STUDENTS' ATTEMPTS AND RECOMMENDATIONS

Upon analyzing the data and assessing the AQAD initiatives,the findings revealed substantial misconceptions that impedestudent learning. These findings have provided valuable insights and lessons about the factor responsible for such misconceptions. **[Table 1 at the end of paper]**

These misconceptions were highlighted along with the remedial activities for it through formal reports, as well as the

misconception posters **(Fig. 4 at the end of paper)**. Data on misconception was

made available to state in a format that can be used directly inside the classroom or can be disseminated through teachers' magazines (such as "Jeevan Shikshan" in Gujarat Education department). These posters were created in Gujarati language to cater to the teachers through all levels of demography within Gujarat.

The purpose of designing the poster was that "with this poster, an educator can simply walk in the classroom, and design the remedial activities on their own using the poster to clear out the misunderstandings in particular concepts that are challenging the learning in the children."

The poster includes elements as followed: specifying the subject's skill and sub-skill, showcasing a sample question with students' option-wise performance, probing students' thought processes, exploring the origins of misconceptions, and suggesting remedial activities for clarity. These components serve as a concise guide for educators and learners alike.

In Gujarat, these posters have been disseminated to educational authorities, demonstrating their pivotal role in fostering meaningful discussions. Notably, other state boards where Ei is supporting in establishing State Assessment Cells or undertaking board reforms have also received similar posters, leveraging students' attempt data for teacher training purposes. Encouragingly, their feedback highlights the substantial positive impact of these posters within their educational contexts.

VI. SCALING AND SUSTAINABILITY CHALLENGES:

While the AQAD initiative has demonstrated promising results, scaling and sustaining it on a statewide level pose several challenges:

- **Accessibility:** The foremost challenge revolves around ensuring proper platform accessibility. In Gujarat, AQAD operates through an app, significantly enhancing daily accessibility for students compared to the website. To illustrate this point, consider AQAD website engagement, where students must go to a browser, and add the website address, in order to answer the questions. As a result, the attempts received on the website have been observed to be significantly lower than the attempts received on the app platform. **[Fig. 5]**
- **Robust data infrastructure:** The second significant challenge involves the creation of a robust data infrastructure capable of receiving and organizing data from various clients through multiple client-specific sites and platforms. To overcome this internal obstacle at Ei, the key requirement is the formation of a dedicated team for the entire program. However, the success of this endeavor hinges on consistent support and sustained interest from the clients, primarily the state educational boards.
- **Scalability:** While The successful implementation of large-scale educational programs, such as AQAD, faces a significant challenge in the form of limited awareness within the educational community. This lack of awareness directly impacts the program's scalability, as widespread adoption relies on educators and students being informed and engaged. Integrating AQAD into their daily conversations and educational practices remains a formidable task essential for the program's success.
- **Classroom penetration & learning impact:** Currently, AQAD is not having its full penetration in the classroom where it is a part of regular classroom interactions and teaching planning. The maximum output of AQAD can be achieved when the students regularly attempt the questions, and the teachers discuss those questions in detail within the classroom setting. This can ensure the addressing of misconception and resolving them through different remedials used by the teachers.

In conclusion, it is evident that addressing these challenges necessitates a collaborative effort from all stakeholders within the educational ecosystem, underscoring the importance of a well-coordinated partnership between public and private entities. I have had the privilege of contributing to this endeavor through Ei, where our role involves maintaining open channels of communication with officials and providing requisite technical support as necessary. Upon careful examination of the annual data from G-shala, fluctuations in student engagement become apparent, particularly during examination periods, holidays, and vacations. Even during ordinary times, it becomes evident that the number of students actively participating in these activities each month falls short of the substantial potential that G-shala possesses. While significant progress has been made through initial implementation, it is evident that the path to even greater success lies in meticulously coordinated planning and the sustained execution of the program at all levels.

TABLE 2: MONTHLY-STATISTICS OF AQAD QUESTIONS FOR YEAR 2022-23

Subject	Sum values of parameters				
	#Question (s)	*Attempts*	*Highest attempts received on a question*	*Lowest attempts received on a question*	*Questions highlighting misconception*
Science	908	64,471	3934	10	353
Math	857	61,814	3969	12	357
Social Science	310	28,379	3410	7	111
Total	**2075**	**1,54,664**	**-**	**-**	**821**

TABLE 3: AVERAGE MONTHLY STATISTICS, HIGHLIGHTING THE REACH & IMPACT OF AQAD PROGRAM IN GUJARAT

Subject	Average values of parameters Per month			
	#Attempts received on a question	*#Highest Attempts received on a question*	*#Lowest Attempts received on a question*	*#Questions highlighting misconceptions*
Science	908	64,471	3934	25
Math	857	61,814	3969	26
Social Science	310	28,379	3410	8

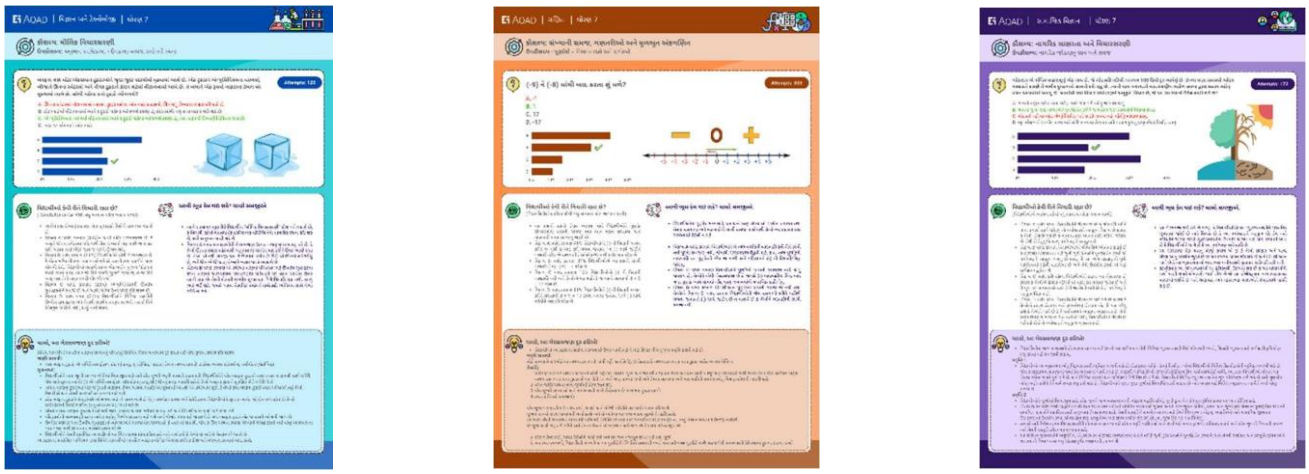
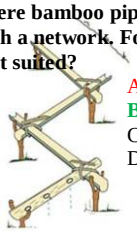


Fig. 5 Misconception posters for (a) Science (b) Math (c) Social Science

TABLE 3: EXAMPLES OF QUESTIONS WITH OPTION-WISE PERFORMANCE AND OBSERVATIONS BY EI

Fig. 5Jno,	Subject – Class	Question with Option-wise performance	Misconception observed
1	Science – 8	**The gas that is present in MAXIMUM quantity in the air we EXHALE is...** **A.** **Nitrogen (14%)** **B.** Oxygen (12%) **C.** Carbon dioxide (71%) **D.** Argon (3%)	Only 14% of students were able to choose the right option A. A common understanding is responsible for this, that humans emit "only CO_2" (carbon dioxide) in the form of exhalation. But, in reality, it only releases a mixture of gases, which contain a largeamount of CO_2. This understanding turns into "misunderstanding", and they choose option C. Exhaled air mixtures also contain the highest amount of nitrogen as outside air, and 14% of students who understand this concept prefer Option A.
2	Mathematics – 7	**What number will fit in the empty box to make the given number sentence true?** 4 - (-5) = -5 + [**?**] A. -4 (35%) B. 4 (21%) C. -6 (27%) **D.** **6 (17%)**	To answer the given question, students should understand whole numbers, and be able to add and subtract positive and negative integers. 35% of the students who chose option A might not have noticed the (-) sign appearing twice in the subtraction question. 21% of the studentswho chose option B might not know the difference between addition and subtraction of whole numbers. 27% and 17% of the students who chose options C and D have increased or decreased one unit by comparing the number to the left, irrespective of the sign.
3	Social Science – 9	**'Drip irrigation' is an irrigation system in which water is slowly applied to the roots of plants through a network of pipes. This is one of the traditional water-harvesting systems in Northeast India, where bamboo pipes are interconnected to form such a network. For what type of farming is this method best suited?**  A. Rice (42%) **B.** **Pepper (20%)** C. Coconut (8%) D. Bamboo (30%)	The question checks the knowledge of the crops grown especially in the northeast and other parts of India. Students choosing option A are using the recall of rice being one of the major crops of Northeast India, however, they failed to recall that rice or paddy saplings are planted in flooded soil making drip irrigation an incorrect answer. Students choosing option B have correctly connected pepper with Meghalaya where drip irrigation is used to grow this spice. Students choosing option C have not connected coconut being aplantation crop which cannot be easily grown in the hills. Students choosing option D have a gap in learning that bamboo, though a northeastern crop, requires a large amount of water in its initial period of growth.

VII. CONCLUSION

The AQAD initiative has proven to be a valuable tool for enhancing teacher professional development and promoting deeper learning among students. By providing regular accessto high-quality assessment questions, teachers and students alike benefit from improved instructional practices and enhanced academic outcomes. However, scaling and sustaining the initiative requires careful consideration of challenges and collaborative efforts. This research paper contributes to the body of knowledge in teacher professional development and provides insights for policymakers, educators, and researchers seeking to implement similar initiatives.

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Embedding Technology in Good Teaching Practice: A pilot

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***Abstract*—In this study we present an approach which uses tab-based technology enabled instruction modules to not only teach children but also to enhance the capacity of a teacher to make the complex job of classroom instruction easier and effective. Two modules – one for teaching fractions and one for introducing Devnagari script for Marathi to young children – were developed and tested as a part of this pilot study. Pre and post tests were used to assess the efficacy of the modules on the learning outcomes of children. Interviews were conducted with the teachers to understand the effectiveness of the modules in making teaching easier. Teacher interviews confirmed many of the criteria for selecting topics to develop as tech-enabled instructional modules and the effectiveness of the modules as teaching aids. However, the experience also showed that for some topics like script introduction, the tech-enabled instruction modules had to be a part of other non-tech based instructional practices to be effective.**

Keywords—Ed Tech, Pedagogy, Teachers, Meaningful technology, Tech-aided instruction

I. Introduction

Today, in every field, from medicine to engineering, digital technology is playing a huge role. Many of the tasks that were performed by humans are now being performed by programmed machines. Many educators and researchers have wondered about what the role of digital technology should be in the field of education [1][2][3][10]. Innovations like computer-aided instruction and intelligent agents have been designed with the implicit assumption that the role of the teacher can be performed by technology [6][7][8][9].

However, teaching is a highly complex skill performed in a dynamic environment and draws on knowledge bases such as pedagogical-content knowledge [5], along with a fair understanding of children's home language and their socio-emotional needs. Current trends like machine learning are bound to take time to test and apply in education and the application in regional languages seem highly unlikely.

However, we can develop classroom models which support the teacher in performing such a complex task. In this paper we present the findings of a pilot implementation of two such instructional design modules in which technology was used to support teachers in delivering a meaningful and effective classroom experience.

II. Instructional Design

The original concept of embedding technology in teaching included a classroom set-up with a tab for each child and a shared-surface like a screen on which teacher could share her or children's tabs. However, due to the pandemic and other constraints, the design had to be limited to tabs which could be used by children in a classroom or in a distant mode.

The goal of the instructional design was to create interactive digital technologies which enhanced children's learning and aided teachers in instructionally complex tasks. Many tech-based interventions with children involve either children solving tests or passively consuming content and the teacher's role is of tech-support. However, research has shown that certain practices of 'direct instruction' in a classroom are most effective, for example scaffolding, asking questions, chunking, and demonstrating [4]. Using these practices requires lesson plans which teachers must follow for children to attain competence and deep understanding of concepts.

Thus, we developed instructional design modules which took teachers step-by-step through carefully crafted lesson-plans along with hints and questions in each step for discussions with children. The modules were integrated into android applications which ran on tablets and phones which had two interfaces, one for the teacher's screen and one for the children. For example, while introducing the concept of fractions as 'a part of a whole' children would see the following slide.

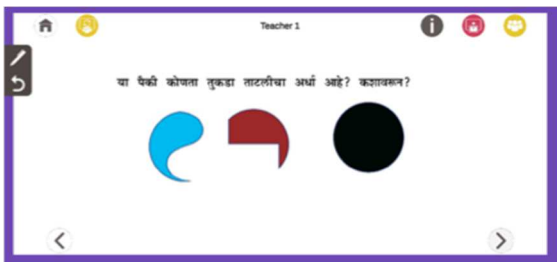

Fig.1 Slide that students see.

Development of this model was funded by Motivation for Excellence Foundation

The slide has a question 'Which of the pieces is half of the plate? Why?'. When children are working to solve it, they can copy any one of the pieces by simply dragging them and place two of them on the plate to test whether two such pieces fit on the plate. The teacher can view any child's screen on her tab and can also share her own screen to other children's tab to demonstrate. On each slide, the teacher could find prompts and hints with just a tap, as shown in the slide below.

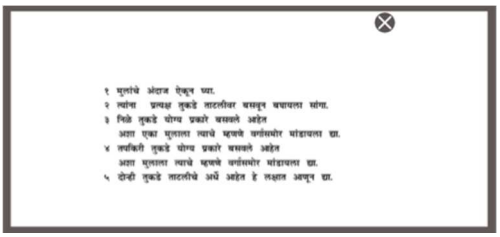

Fig.2 Slide that teacher see.

In the Introduction to Script module, activities like making words from letter cards on the slides were included along with prompts for teachers to ask questions like 'What does this word mean?'

We hypothesized that such instructional aid would help teachers in making concepts clearer to children and allow all children to handle the material and make their own arguments based on their own experiences.

III. PILOT

The Fractions module was piloted with 6 teachers and 31 students and the module on Script was piloted with 3 teachers and 30 students. All teachers were employees of QUEST who teach language and math and children were from tribal villages in Palghar district of Maharashtra.

In the Fractions module, 1 teacher taught a group of about 5 to 10 students in standard 1 to 4, either face to face or online via video-call and it took 2 weeks to complete it. None of the teachers had any noteworthy experience teaching using tech-enabled content in the past. Like the teachers, none of the children had much experience using this kind of technology for learning.

In the Script module, 3 teachers taught a group of 10 children each, face to face. We ran two iterations for the module. In the first, we used only the tab-based instructional design to teach. However, we soon realized that 'Script Introduction' needs a holistic approach and must be taught along with other language and literacy activities like read aloud, sound games, etc. In the second iteration, in each session, we used the tech-based instruction module for 20 minutes and 25 minutes were spent in other activities which did not use technology. It is important to note that some of the key activities of introduction to script like practicing drawing the aksharas were also not conducted on tab. This module was conducted over a period of one month.

We conducted a baseline and endline assessment of children for both the modules in order to determine if children learn through this process. The baseline and endline tests for fractions were of MCQ type and were solved individually by every child. The test for Introduction to Script also consisted of objective type questions but was conducted one on one with the children by teachers and researchers. After implementing the module, we also conducted interviews with all the teachers and the supervisors involved.

IV. RESULTS

The pre-test and post-test scores of children for each module are given below.

TABLE I. PRE-POST SCORES OF CHILDREN.

Module	Baseline	Endline
Fractions	24	66
Introduction to Script	17	67

Both the improvements are statistically significant ($p < 0.05$). The difference in scores on the tests shows that children do appear to learn through this tech-enabled mode. So, next we tried to understand through interviews if it fulfilled the aim of aiding teachers in their complex job. The following excerpts from the interviews conducted show the kind of response teachers had to the intervention. The first excerpt is from a supervisor who was in a unique position to observe many of the teachers during the sessions and has also been training the teachers in conducting normal classroom sessions.

Supervisor: Having prompts and questions in front of you will reduce the load on memory. It will be especially useful for novice teachers to have the lesson plan with all the prompts at the appropriate stages close at hand whenever they teach a topic like Fractions, which is complex but has a well-defined flow. This was not the case for the 'Introduction to Script' module as most of the instructions were simple and repetitive. It is also difficult to set a standard procedure for many of the topics in language as teachers have to respond to what children are saying on the fly.

The following excerpt from a teacher interview makes the points that many of the teachers in the intervention agreed with.

Teacher: I think one of the biggest advantages of using technology of this sort while teaching fractions, is that each child gets to handle the pieces and tries to fit them into each other and the whole. I don't have the time to do this in a normal classroom. It would be worth the while to explore what else can be taught using this technology. This was also true while teaching the language module. In an activity like making words from letters, each child could participate and make his or her own words and I could also discuss with other children about the words each child had made.

V. DISCUSSION

Use of digital technology for the purpose of learning is not a new phenomenon in India. Off-line computer aided instruction programs, internet based digital resource repositories, and digital audio-visual films are now commonly used. However, the role of digital technology in the process of learning is still under debate. There is a large group of educators who are skeptical about the meaningful

use of technology for learning especially for younger children. On the other hand some would consider the technology to be a game changer for mass education.

The digital divide between the different sections of society was starkly evident during the recent prolonged school closure due to the covid-19 pandemic. While a number of middle-class children especially from the English medium schools were receiving online classes, a large number of marginalized children were completely deprived of any formal educational experience. It is no wonder that the demand for the use of technology for learning has surged and there is a flood of quick-fix digital resources which are produced with low or no investment. Spreading these resources through social media & using them in the absence of the teacher has become a popular model of using digital technology for learning. In this type of model, the role of the significant adults (teachers or parents) is negligible. The assumption is that children can learn by interacting with the content directly. Although some learning will surely be possible through such an interaction, what and how much children can learn in this mode is yet largely unknown. Hence it would be necessary to design technologies which factor in the critical role of the teachers in the design itself. This was one of the central ideas of developing this model of a technology enabled classroom.

While creating the content for the tech-enabled classroom, we learnt that the development of such tech-enabled content has to be a collaborative effort between educators and software developers. At the stage of conceptualization, a lot of discussion and sharing of ideas needs to happen between the teams before actually coding. The educators need to understand the technical capabilities in order to use them best to evolve a suitable instructional design for the content at hand. The technology experts also need to understand the actual problem to be solved so that they can help the educators to build the design more efficiently. This may sound like common sense, but in reality, it is extremely difficult to build such a team especially if the content is being developed in a regional language. In our case we had an advantage of working with a team of software developers which was well versed with the pedagogy they were trying to digitize as they had spent enough time on observing these pedagogic practices in real classroom without the use of technology. Hence it is critical to think about the investments needed in this type of development.

The first question that one must answer in such a pilot is: do children really learn using such type of technology and how do we measure this learning? The results of the assessment show that, both in the 'Fractions' and the 'Introduction to Script' module, children showed significant improvement as compared to their baseline. When we asked teachers if they thought that children had learnt, all of them said that they did think so although they were divided on whether the children learnt better in this mode, or if the learning was comparable to a normal classroom scenario.

In a normal classroom whenever children handle any teaching learning material, what usually happens is that they either take turns and use it in front of the entire class or they share material in small groups. In our tech enabled mode, each child got the opportunity to handle all of the material for both modules. Further, all the children got to simultaneously interact with the teaching learning material. This reduced the organization and distribution time of teachers and the waiting time of students.

A teacher also mentioned that she found it useful to have prompts and questions embedded in the lesson which meant that she did not have to remember all the exact details of the lesson beforehand. Therefore, some time and memory were saved while planning and conducting a lesson. All of this contributed toward increasing the efficiency of teachers, which we think is a necessary criterion for any tech-enabled content. Although not particularly applicable for the pilot modules, we also think that tech-enabled classrooms will enormously increase the efficiency of teachers while grading tests and correcting assignments.

We think that the presence of prompts and questions which were accessible to the teachers at the correct places during the lesson also contributed to increasing the effectiveness of teachers while conducting the lesson. Lessons like fractions are instructionally complex and there are a lot of places where precise questions need to be asked of the children to facilitate their learning. Though the responsibility to judge the current level of understanding of the children rests with the teacher, tech-enabled content can provide teachers with support for conducting instruction effectively. As reported in the experience of a teacher, children asked more questions in the tech-enabled distant leaning mode, than they do in normal classrooms. She thinks that one of the reasons for this is that every child gets to handle the teaching learning material. While further research is necessary to establish if this is indeed the case, this experience illustrates the tremendous potential of thoughtfully designed and validated tech-enabled content in increasing the effectiveness of teachers.

One of the major learnings from this experience was that effectiveness of embedding technology in teaching-learning process also depends on the nature of the content to be taught. Our first attempt to teach script using technology didn't work well. The reason was that the script couldn't be taught in isolation, it requires inputs like shared reading, read-aloud & modeled writing along with it. In our case we had decided to digitize only a part (teaching of the script) of literacy instruction program because it is instructionally complex and demands a lot of repetitive work from the teachers. However, while implementing this part on the field we realized that teaching it in isolation is not possible, so we had to implement both the tech and non-tech component of the literacy instruction. This also points to the importance of looking at the learning process of children holistically. One needs to check if all the components of the learning process could be digitized meaningfully. If one has to embed technology partially in the process of learning, the non-tech parts must be given their due importance. Hence, while embedding technology in the process of instruction, answers to the questions like why technology should be embedded, where to embed it and where to avoid it need to be thought out carefully by the educators & technology experts. The possibility of using a blend of tech-based and non-tech-based pedagogy needs to be carefully explored before starting the development of the content.

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EdTech for Learning Outcomes and Impact: A Comprehensive Approach

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***Abstract*— A precise estimation of learners' abilities is the first and foremost step in personalized learning including EdTech solutions. Predictive analytic techniques such as Item Response Theory (IRT), Bayesian Knowledge Tracing (BKT), and Performance Factor Analysis (PFA) are established practices to achieve this purpose. However, the complexity, cost, and time involved in calibration, and the challenges in online implementation, have led to the adoption of simpler alternatives such as Elo, machine learning, and artificial intelligence. Nevertheless, the estimation of abilities is just one facet of personalized learning, and designing effective personalized learning experiences is equally essential to guide learners through their unique learning journeys and drive improvement in learning. The research body provides mixed evidence regarding the impact of EdTech on learning outcomes. Designing impactful learning experiences requires a foundation in scientific principles drawn from learning sciences and learning design and a sharp focus on learning progressions. A one-size-fits-all approach is quite unlikely to yield significant learning gains. The importance of robust implementation models cannot be underestimated, as even the best designs can falter if poorly executed. Learning science and design principles not only assist in developing effective EdTech products but also inform professional development programs to ensure the intended usage of the product and services. The objective of this paper is to understand different EdTech models and propose a coherent design and implementation framework to enhance their effectiveness and impact on learning.**

Keywords—Personalised learning, Measurement model, Learning science and design, Impact, Outcomes

I. Introduction

Unprecedented growth in technology and innovation in recent years has greatly transformed the landscape of education. There is widespread enthusiasm among governments, schools, and communities around the potential use of technology in various educational processes and substantial investments are being made accordingly. Evolving fields like machine learning, big data, and artificial intelligence have further intensified the integration and uses of technology in the education systems. There appears to be a general agreement among the public regarding the potential benefits of EdTech in enhancing the learning experience and improving outcomes, but what kind of technology and in what context - remains an area of discussion. As investments and available options continue to grow, students, parents, teachers, and decision-makers face a tough and genuine challenge – what to choose. On the other hand, there is mixed evidence regarding improvement in learning outcomes because of the use of technology [1], [2]. Severe concerns have been raised regarding the prevailing learning crisis, which has worsened further post-COVID, as revealed in the Learning Poverty Report [3]. In the Indian context, around one-fourth of grade 8 students were unable to read a paragraph, and half of grade 8 students were unable to do simple division sums even prior to COVID-19 [4], and as per the 2022 reports the downward slope has become steeper [5]. Students lacking basic reading and arithmetic abilities are less likely to achieve grade-level learning outcomes and that is evident from the National Achievement Survey [6]. In this scenario, one may ask – "Is the desire for improved learning driving the growth in technology, or is the technology driving the learning reforms?".

Researchers have identified a mismatch between how students learn and how the curriculum is delivered [7], [8]. Figure 1 shows that students' abilities within each grade level are highly heterogeneous suggesting that employing a one-size-fits-all approach to teaching and learning does not lead to optimal results. Learning systems need to cater to individual learners' readiness and needs. This fact hardly finds any consideration by curriculum designers and classroom teachers.

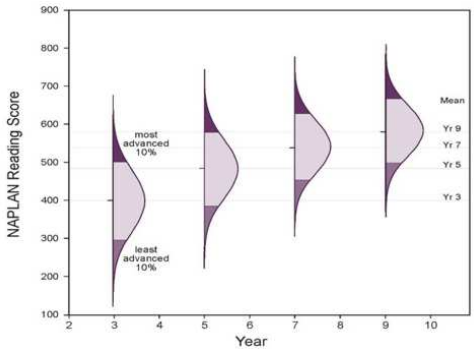

Figure 1: Performance of students in NAPLAN reading

However, designing a learning environment that caters to diverse needs is very challenging, as learners differ not only in their needs but also in their learning characteristics such as preferences, learning styles, objectives, expectations, and specific skill levels. The objective of this paper is to understand common models used in EdTech and propose a coherent design and implementation framework to enhance its effectiveness.

II. Modeling Learner and Cognition

Personalized learning solutions require a deeper understanding of learner behavior and learning domains.

A. Learner models

Learner models with diverse characteristics and modeling techniques have evolved over a period of time and have been successfully integrated into various personalized and adaptive systems. Initially, the focus was on learner's knowledge and cognitive attributes, but recent developments have expanded learner modeling to consider learning styles, behaviors, and

emotions to enhance learning efficiency and satisfaction [9], [10]. Learning styles, encompassing visual, auditory, or kinesthetic preferences, are considered to match content formats with individual needs. Behavioral aspects, such as engagement and motivation, are tracked to adapt task-difficulty and provide timely interventions, while emotions, like frustration or engagement, are leveraged to customize the learning experience. Learner modeling has helped education systems move from a one-size-fits-all approach to a personalized, student-centric paradigm, where education caters to each learner's uniqueness.

While these models help to identify learner traits, the next task is to design interventions based on the thoughtful application of theories and insights from various disciplines, enabling learners to move on their own learning paths.

B. Learning science and learning design principles

Relying solely on intuition or personal experiences is not sufficient for achieving intended learning outcomes. Learning science research suggests that clarity of learning outcomes is the pivot for enhancing students' learning abilities and the efficacy of learning tools. Principles of learning sciences guide through how design decisions impact learning outcomes by assessing the logic behind these decisions, aligning them with academic and socio-emotional goals, and identifying potential unintended consequences and riskiest assumptions [11]. Design research consists of not only learner profiling but also analyses the behaviors of educators and other stakeholders with the intent to enhance the overall learning experience, promote engagement, and improve learning outcomes through the strategic use of technology [12]. User-centered design is a critical approach in EdTech design research.

Research in learning design explores the incorporation of emerging technologies like artificial intelligence, virtual reality, augmented reality, and gamification in educational contexts. Researchers investigate how these technologies can support personalized learning, offer immersive experiences, and foster collaboration among learners, enhancing engagement and effectiveness [13]. The collaboration, creativity, and problem-solving aspects of EdTech design research, along with the integration of emerging technologies, hold the potential to create innovative and inclusive educational solutions. Applying learning science and design principles to design EdTech empowers both educators and learners with effective tools drawn upon the evidence-based practices, maximizing their impact on learning outcomes.

C. Theories of cognitive learning

Cognitive learning theories are rooted in the concepts of working memory (WM) and long-term memory (LTM), and emphasize the role of information processing in learning [14]. WM, with its limited capacity and short retention period, poses a challenge for instructional designers, who then employ techniques like rehearsal and chunking to enhance learning effectiveness by reducing cognitive overload when instructional materials exceed this capacity [11], [15]. Researchers have suggested multiple ways to reduce cognitive load, and one of them is the cognitive theory of multimedia learning. The overarching principle of multimedia learning is that we learn more effectively from words and pictures than from words alone.

The Zone of Proximal Development (ZPD) of Vygotsky serves as a guiding principle how to adjust content and difficulty based on student performance, ensuring a challenging yet attainable learning experience, allowing them to progress at their optimal pace, fostering critical thinking, and problem-solving skills through scaffolding [16].

III. Learner Models for Skill Estimation

Skill estimation is the most important aspect of adaptivity and learning personalization and a wide range of tools and techniques and learner measurement models are used to achieve this. These models follow Ausubel's proposition − the most important single factor influencing learning is what the learner already knows, ascertain this and teach [them] accordingly [17]. Models based on this proposition include traditional models such as the Item Response Theory (IRT) originally developed for adaptive testing [18], as well as specialized models such as Bayesian Knowledge Tracing (BKT) [19] and Performance Factor Analysis [20].

The use of IRT in personalized learning solutions has revolutionized the way educational content is delivered to students. IRT is a powerful psychometric framework, which enables the assessment of individual student abilities and the same framework has been used to tailor learning experiences that cater to each student's unique needs. Such learning solutions utilize IRT and intelligent tutoring systems (ITS) to dynamically adapt content and difficulty levels according to individual student performance [21]. This approach is versatile, and applicable to various subjects and educational levels. Teachers gain insights from IRT-based data analysis and make informed instructional decisions and targeted interventions while ITS provides real-time feedback and individualized support, enhancing the learning experience, deepening subject understanding, and increasing student engagement. The Rasch model is the simplest and most widely used IRT-based learner models.

BKT attempts to capture students' knowledge state indicating mastery, while IRT and PFA rely on a logistic regression model to estimate latent traits based on students' knowledge state and the difficulty of learning items. These approaches are complex to be integrated into online adaptive systems as they generally require extensive calibration of model parameters.

The Elo rating system commonly employed for rating contests and sports is being explored in educational systems to estimate student skills and item difficulty. It is characterized by its simplicity, speed, resilience, and sensitivity to order, which makes it suitable for integration into adaptive educational platforms, particularly for the purpose of updating students' skill levels. This model operates efficiently with a minimal number of parameters as compared to IRT, which makes it more adaptable to online learning environments. However, research suggests that Elo based learner model is suitable mainly for adaptive practice or low-stakes testing [22].

The Elo system interprets a student's response to an item as a match between the student and the item, calculating the probability of a correct answer through a logistic function based on the difference between the student's skill and the item's difficulty. While it offers practical estimates for guiding adaptive learning, it lacks the statistical assurances of well-calibrated IRT models used in computerized adaptive testing. The Elo rating system closely resembles the one-parameter

Rasch model in IRT, differing primarily in parameter estimation. IRT assumes constant student skill (common in testing scenarios), while Elo can track changing skill levels that can be easily adjusted.

Both the Elo rating system and the basic IRT models capture symmetric answers, while in many educational applications there may also be an asymmetry between correct and incorrect responses. As an answer to an item is not only evidence of students' knowledge but also an opportunity for learning, such situations demand different updates for correct and incorrect answers. PFA offers solutions in such situations. PFA can be viewed from two different perspectives − as an extension of Elo or IRT, which is a student modeling approach based on the logistic function, and, as a regression model which enables researchers to explore complex datasets and identify underlying latent factors that explain the observed variables. This approach has been extensively used to uncover the underlying structure of personality traits [23], [24]. PFA as a regression model provides researchers with deeper insights into the relationships between variables and enables data-driven decisions.

As stated earlier, ability estimation is one aspect of solutions, which must follow a personalized intervention. The next section proposes a comprehensive approach to designing effective EdTech tools.

IV. A COMPREHENSIVE APPROACH TO DESIGNING EDTECH TOOLS FOR IMPACT

Designing efficacious products needs to be guided by the findings from various disciplines of educational psychology, learning sciences, and instructional design principles supported by data and technology. Given below are key principles for designing effective EdTech tools.

Principle 1: Define the intended outcome

A clear articulation of what purpose a tool intends to serve in terms of learning outcomes is a prerequisite to designing an effective educational experience. It plays a pivotal role in enhancing self-regulation, student engagement, motivation, and overall learning. Research has shown that explicitly defined learning outcomes have a significant impact on student achievement [1]. Well-defined learning outcomes provide learners with direction and purpose. When students understand what is expected of them and what they are expected to achieve, they are more likely to be motivated and engaged in the learning process [25]. This clarity empowers them to set goals, track their progress, and take ownership of their learning journey.

In addition to this, they serve as a common thread among content creators, analysts, and users. While vague goals like "help students learn" lack specificity, outcomes such as "improving foundational reading ability" or "enhancing computational skills" provide a clear goal for all stakeholders including learners. These learning outcomes guide educators in designing instructional materials that align with specific objectives, promoting more effective teaching and learning experiences.

Principle 2: Model cognitive and affective domains

Domain modeling is another key consideration. Often, experience designers emphasize the cognitive domain, overlooking the significance of the affective domains, despite the fact that learning is an interconnected process. Motivation plays a vital role in cognitive processing. There is evidence that learners who are exceptionally motivated and persistent tend to tackle complex challenges and diligently pursue their learning objectives. Instructors and instructional technologies can foster motivation by creating opportunities for success and by framing errors and difficulties as integral components of the learning journey. Motivation and self-management can be fostered through learner autonomy, goal establishment, and constructive feedback that centers on the task, the learner's process, and self-regulation

Principle 3: Model learner and learning

To design effective systems and tools, it is crucial to consider students' needs throughout the process and actively involve them in the development process. Deep probing into how students learn is quite important as how students learn differently. Self-regulation capabilities play a predominant role in achieving learning goals and sustaining learning processes [26]. Fostering accurate metacognition and promoting effective self-regulation are essential aspects of educational technology design to optimize student learning outcomes.

Active learning models, such as project-based learning and problem-based learning, stimulate cognitive engagement, leading to improved complex reasoning skills, critical thinking processes, perceived learning, engagement, attitudes toward subjects, self-directed learning, and autonomy and therefore, deserve attention in the design and implementation of EdTech products.

Principle 4: Apply appropriate learning science and learning design principles

The development of EdTech tools requires a meticulous analysis of how each component influences and enhances the overall learning process, based on the principles of learning sciences drawn from diverse disciplines such as cognitive and educational psychology, neuroscience, behavioral economics, and computer science. Several best practices in EdTech design are discussed in the literature. Spaced practice, which involves spreading out learning activities over time rather than cramming, has been shown to strengthen information retention and counteract the "forgetting curve" [27].

A learning cycle approach supporting inquiry-based learning like the 5E instructional model offers good hope [28]. Additionally, the 5E model offers a structured approach to integrating instructional technology into teacher education programs, guiding educators through various stages of design and implementation [28] and its versatility is evident in its applicability to diverse educational settings, including early childhood education.

Principle 5: Build a robust learning metric and implementation framework

The critical question arises: how many educational technology products truly adhere to these principles? Furthermore, their implementation and product monitoring plans, along with evidence of their impact on intended outcomes, must be clear. Embedding relevant and valid impact measures within EdTech is crucial for real-time utilization, as external measures can be time-consuming and may cause learners to outpace the learning loop. External measures serve better for validation purposes.

However, the success of thoughtfully designed EdTech solutions hinges on the existence of a framework that fosters

student and teacher engagement. Implementing comprehensive professional development programs for educators, focusing on the potential benefits and effective integration of technology in the classroom, and tailoring learning experiences can be instrumental levers in this regard.

Educational institutions grapple with technological challenges, including limited access to infrastructure, outdated equipment and software, inadequate technical support, and insufficient funding for modern technology resources. Addressing these challenges requires substantial investments to ensure equitable access for all learners.

V. CONCLUSION

Designing impactful learning experiences hinges on integrating learning content and pedagogy rooted in the robust scientific principles of learning sciences and learning design. Crucially, these experiences should be guided by learning progressions that enable continuous growth in knowledge and skills. EdTech design should be evidence-based, firmly grounded in these principles and progressions, steering clear of one-size-fits-all approaches that often fall short of driving meaningful learning outcomes. Effective implementation models and collaborative efforts with technology experts and stakeholders are paramount to developing innovative solutions. Embracing change, addressing concerns, and advocating for the benefits of EdTech are essential for its successful integration in classrooms. To bridge achievement gaps and expand access to quality education, it's imperative to overcome resistance, offer adequate training, and support educators in technology integration. The ultimate goal is to ensure that every learner has the opportunity to achieve their full potential.

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A Temporal Model of Learner Behavior in an Immersive Virtual Reality Learning Environment Using Process Mining

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***Abstract*—The advancement of Information and Communication Technology (ICT) has paved the way for the integration of cutting-edge immersive Virtual Reality (VR) in education. Existing research studies in the field of education have explored the use of immersive VR technology and have examined its impact on learning outcomes, engagement, and the overall learning experience. These studies typically involve conducting experiments and collecting data through questionnaires, surveys, and interviews, as well as quantitative methods like pre-tests and post-tests, physiological sensors, eye trackers, and tracking the orientation of head-mounted display (HMD) and hand-held controllers (HHC). We collected interaction data of 14 undergraduate non-electrical students, while they interacted with MaroonVR, a Virtual Reality Learning Environment (VRLE) designed to teach the physics concept of electromagnetic induction. This paper aims to analyze the differences in interaction patterns between high performers and low performers and to identify the temporal sequence of actions that contribute to high performance using a process modeling approach. To achieve this, we employed a fuzzy mining algorithm to analyze the logged interaction trace data collected through our Interaction Behavior Data (IBD) collection mechanism. Unique interaction behavior models were developed for both high performers and low performers. These behavior models offer deeper insights into the differences in behavior exhibited by high and low performers. We propose that the findings of this study can be utilized to provide guidelines to VR learning content developers, enabling them to create immersive VRLEs that can offer adaptive personalized feedback, hints, and VR learning content based on learners' interaction behavior.**

***Index Terms*—Immersive Virtual Reality, Educational Data Mining, Interaction Tracking, Behavioral Data Logging, Process Modeling**

I. Introduction

The progress of Information and Communication Technology (ICT) has opened up new possibilities for incorporating cutting-edge immersive technologies into the field of education. These technologies include Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) [13]. VR involves creating 3D virtual worlds that mimic real or imaginary environments, allowing users to experience them firsthand. AR integrates virtual objects into the real world or vice versa, accessible even through mobile devices. MR, on the other hand, represents a continuum between reality and virtuality. In education, VR and AR have been widely utilized, while MR is also gaining popularity but not as extensively as VR and AR. The focus of this paper is to explore the learning processes that result from the application of state-of-the-art VR in education. VR can be divided into two categories: non-immersive VR and immersive VR [5], [13]. Non-immersive VR involves viewing a synthetic 3D virtual world on a computer screen and interacting with it using a mouse and keyboard. In immersive VR the users wear a head-mounted display (HMD) and use hand-held controllers (HHC) to interact with the 3D virtual world from a first-person perspective [2], [7]. The current study specifically concentrates on the educational applications of immersive VR.

In educational research, most studies experiment with immersive VR to gauge its impact on user experience. They analyze learning outcomes (knowledge and skill acquisition, retention, and transfer) [4] and affective states (engagement, confusion, frustration, boredom) [3]. Data collection methods for such analyses included:

- User experience: Data was gathered through self-reported questionnaires, interviews, and surveys [11].
- Affective states: Data collection for affective states involved both questionnaires and physiological sensors [4].
- Learning outcomes: Data was obtained through pre-test, post-test, and delayed post-test evaluations.

While existing tools effectively assess learning outcomes, they fall short in elucidating the learning process during VR intervention. Crucial questions about how learners acquire knowledge, which behaviors influence outcomes, and whether behavioral changes affect learning remain unanswered. Consequently, the VR intervention's learning process remains poorly understood. To bridge this gap, we developed a mechanism to log button clicks, virtual object interactions, and timestamps, akin to click stream data logs in computer-based learning environments (CBLE). This mechanism was applied in MaroonVR

[8], a VR learning environment for electromagnetic induction physics concepts.

In our study, we had 14 participants and collected their interaction trace data. We extracted action events from these traces and did correlation and regression analysis. However, this approach may not fully reveal the temporal action sequence or performance patterns. Therefore, in this paper, we explore a process mining approach to uncover significant differences in action sequences between high and low performers.

The paper's following sections address distinct research aspects. Section 2 reviews process mining in educational data. Section 3 outlines the methodology, study design, IBD logger data, and extracted action events for process mining. Section 4 presents process models and an in-depth analysis of high and low performers. Section 5 concludes, noting study limitations and suggesting future research directions.

II. Background and Literature Review

The IBD logging mechanism, which captures comprehensive information about interaction traces, virtual objects interactions, and timestamps, proves valuable in deriving essential behavioral artifacts like the duration of action events and their sequence of execution by learners in the VR Learning Environment (VRLE). Consequently, process mining can be applied to the sequential action events extracted from the logged IBD. This approach provides deeper insights into learners' behavior within the VRLE, aiding in understanding the learning process and discerning differences in the learning process between high performers and low performers. Since no prior studies on process mining in the context of VRLE are available, we conducted a search for research articles that discuss process mining in computer-based learning environments (CBLE). Below, we will discuss three articles that employed process mining techniques in CBLEs for various purposes.

In a prior study by Juhaňák et al. (2019) [6], process mining methods were applied to analyze students' behavior in online quizzes, categorizing actions such as "attempting all questions," "skipping questions," and "giving up." They observed that the frequency of these interaction sequences varied based on the quiz difficulty and the student's prior knowledge.

Similarly, Cerezo et al. (2020) [1] utilized process mining methods to evaluate students' self-regulated learning (SRL) skills in e-learning environments. They identified various behavioral patterns, such as "goal-setting," "planning," "monitoring," and "regulation," and found that the frequency of these patterns differed according to students' SRL skills.

In another study by Rajendran et al. (2018) [12], process mining was employed to construct temporal models of learners' behavior in Betty's Brain, an Open-Ended Learning Environment (OELE). Betty's Brain facilitates student learning of scientific processes through building causal models. The process mining approach was used to distinguish behavior patterns between high and low performers in the OELE.

Previous studies in CBLE revealed the use of process mining algorithms like alpha miner, heuristic miner, and fuzzy miner [12]. They developed distinct process models for high and low performers, offering insights into action sequence differences [6], [12]. This information is instrumental in identifying the specific sequence of interaction behaviors that correlates with high and low performance respectively.

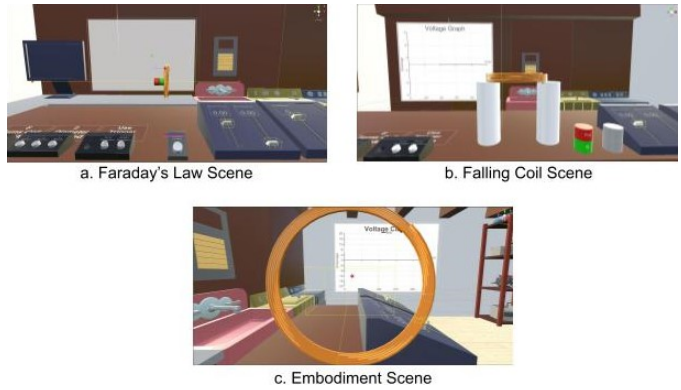
a. Faraday's Law Scene
b. Falling Coil Scene
c. Embodiment Scene

Fig. 1. Scenes in VRLE

From the knowledge gained in literature analysis, in our study, we applied a fuzzy mining algorithm to create process models. These models help us understand temporal differences in interaction behavior between high and low performers. With insights from these models, we can design VRLE with adaptive scaffolds to improve learning outcomes.

III. Methodology

In a previous study, we provided a detailed explanation of the IBD logging mechanism and the information it captures [9]. Additionally, we described MaroonVR [8], VRLE used to learn several physics concepts including electromagnetic induction, and in which we deployed the developed IBD logging mechanism [10]. Electromagnetic induction is a phenomenon where moving a magnet in close proximity to a coil induces an electromotive force (emf). For our study, we utilized three scenes from MaroonVR as shown in Fig 1 to explore this concept:

- Faraday's Law Experiment: In this scene, learners grabbed and dragged the magnet inside the coil to generate emf.
- Falling Coil Experiment: Learners observed emf by allowing the magnet and an iron bar to fall freely inside the coil.
- Perspective Scene: In this scene, learners assumed the perspective of the magnet and generated emf through their physical walking.

Throughout these scenes, learners could interact with virtual interfaces to vary the coil turns (2, 4, and 6 turns), coil diameter (2, 4, and 6 units), and magnetic field strength. The learners could also perform actions such as grabbing, dragging, dropping the magnet, and walking in the perspective scene. The learning follows embodied cognition as the learners tend to make meaning by interacting through their bodily actions. All the interactions were logged in the IBD logger. The IBD

logger is a .csv file that has column headers as 1) HHC used (right and left), 2) Buttons in the HHC used, 3) Actions performed with the HHC buttons (clicked, released, etc.), 4) Button pressure, 5) Thumbstick axes, 6) Thumbstick angle, 7) Virtual objects interacted with, and 8) Timestamp.

This comprehensive data allows us to analyze learners' interactions in the VRLE and gain valuable insights into their behavior during the learning process.

TABLE I
ACTION EVENTS EXTRACTED FROM THE IBD LOGGER AND THEIR DESCRIPTION

Action Events	**Description**
INFO	Reading instruction
NAVIGATE	Teleport, Scene switching
INTERACT_ REL	Handling virtual objects such as magnet and iron bar (interacted using Grip button)
PERS_ WALK	Walking in the perspective scene taking the perspective of magnet
SET_COIL_ REL	Setting the turns in the coil between 2 turns, 4 turns and 6 turns (interacted using Trigger button)
SET_MAG_ REL	Varying the magnetic field strength using VR slider interface (interacted using Trigger button)
SET_COIL_ IRREL	Setting the coil turns using HHC buttons other than Trigger button causing no interaction
SET_MAG_ IRREL	Setting the magnetic field strength using HHC buttons other than Trigger button causing no interaction
INTERACT_ IRREL	Handling magnet and iron bar using HHC buttons other than Grip button causing no interaction

We conducted a study involving 14 undergraduate students majoring in fields other than electrical engineering. The participants' demographic details were collected, and their prior knowledge of electromagnetic induction was assessed through a pre-test. Before experiencing the VRLE, the participants played a VR game called 'First Steps' to familiarize themselves with the Hand-Held Controller (HHC) buttons and VR interactions. During the VRLE experience, the interaction behavior of each participant was automatically logged in the IBD logger. Later, various action events were extracted from the IBD logger and are presented in Table I. Following the VR intervention, a post-test was administered to measure the learning gain. To analyze the action events mentioned in Table I, we employed process mining with a fuzzy mining algorithm.

IV. RESULTS AND DISCUSSION

The participants were divided into two groups: high performers and low performers, based on their post-test scores (M=7.64, SD=2.06) [10]. The 8 participants who scored above the mean score were categorized as high performers and the rest 6 were considered low performers. The resulting process models for high performers and low performers after applying process mining are shown in Fig 2.

The process models of both high and low performers exhibit similarities in certain behaviors. Specifically, cyclic execution of action events between 1) SET_MAGNET_REL and SET_MAGNET_IRREL, 2) SET_COIL_REL and SET_COIL_IRREL, and 3) INTERACT_REL and INTERACT_IRREL is evident in both groups' process models. The irrelevant actions (SET_COIL_IRREL, SET_MAGNET_IRREL, INTERACT_IRREL) are logged when participants press irrelevant buttons on the HHCs while trying to perform the interactive actions in the VRLE. However, no actual interaction occurs in the VRLE as a result of pressing these irrelevant HHC buttons. These common cyclic patterns found in the process models of both high and low performers suggest that both groups struggled and lacked experience in interacting with VR technology.

In the interaction behavior model of high performers, as shown in Fig 2 (left), we observed a repeated cyclic execution of action events, particularly "SET_COIL_REL" and "INTERACT_REL." Additionally, they exhibited a linear execution pattern, performing actions in the sequence of "SET_MAG_REL" followed by "SET_COIL_REL" and then "INTERACT_REL." This indicates that high performers first varied the magnetic strength and the number of turns of the coil before moving the magnet in and out of the coil. Moreover, they engaged in repeated cyclic interactions with the magnet and coil turns.

Conversely, such well-structured executions were not evident among the low performers as shown in Fig 2 (right). In their interaction behavior model, there was no node linked to the node representing "INTERACT_REL." This suggests that low performers did not perform any action events before interacting with the magnet to move it in and out of the coil. The absence of a preceding action event indicates a lack of meaningful planning or sequencing in their interactions compared to the high performers.

Both high performers and low performers start their interaction with the VRLE by reading the provided instructions, as indicated by the action event INFO. Afterward, the behaviors of both groups show similarities and differences. For high performers, their subsequent actions involve navigating or interacting with the coil to set its parameters. On the other hand, low performers navigate in the environment before setting either the coil parameters or the magnet parameters.

Further analysis reveals that high performers, after setting the coil parameters, proceed to set the magnet field strength and interact with the magnet to induce emf. They also navigate and enter the perspective scene. Moreover, high performers, after setting the magnet parameters or after interacting with the magnet to induce emf, go back to setting the coil parameters. This demonstrates a clear pattern of high performers repeatedly engaging in actions related to setting both coil and magnet parameters and interacting with the magnet to induce emf.

In contrast, low performers, after setting the coil parameter, mainly proceed to enter the perspective scene, similar to some high performers, and do not perform any other interactive actions. Additionally, low performers set the coil parameters after setting the magnet, following a pattern observed in high performers.

Overall, the process models for high performers reveal more deliberate and thoughtful interaction behavior, involving variations in magnetic strength, coil turns, and repeated inter-

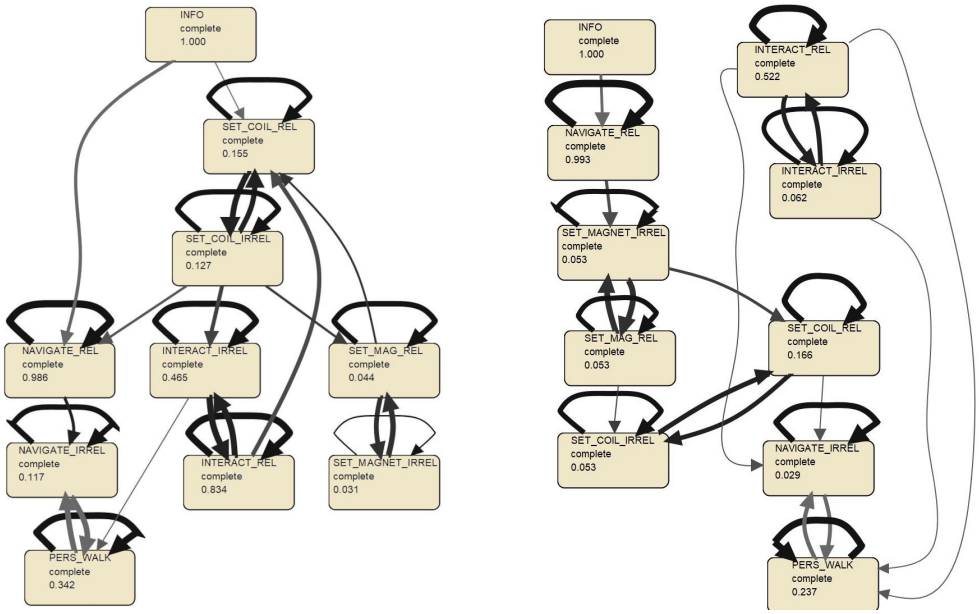

Fig. 2. Process Model of High Performers (left) and Low Performers (right)

actions with the magnet. In contrast, the process models for low performers indicate a more random and less organized approach to interactions, with a lack of meaningful actions before engaging with the magnet.

V. Conclusion

The lack of process modeling literature in VRLE, has made us adapt process modeling approaches used in CBLE and apply it to VRLE logs. We employed a fuzzy mining algorithm for analyzing VRLE log data's action events. The findings highlighted distinct interaction patterns: High performers repeatedly and cyclically executed actions of setting the parameters of coil and magnet, and interaction with magnet, contributing to their success. In contrast, low performers lacked these patterns in their interactions.

These key differences in learning behavior offer valuable information to design personalized feedback and scaffolding for learners in VRLE. However, the study has certain limitations. The small sample size of only 14 participants and the homogeneity of the learners, who were all computer science engineering undergraduate students from the same college and age group, may limit the generalizability of the findings. Additionally, using only the fuzzy mining algorithm as the process mining technique might affect the study's predictability and general applicability.

The study offers insights into action event frequency and duration in VRLE and its link to performance. The process models highlight interaction differences between high and low performers, revealing VRLE learning processes. Next, we propose the implementation of personalized feedback and scaffolding based on these patterns in future research.

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VR-based Scaffold Assembling Simulator for Construction Industry Training and Its Evaluation for Usefulness and Immersiveness with Experts

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***Abstract*—Scaffolding assembling in the construction industry is a critical and dangerous task. Accident rates in Scaffolding are high due to reasons such as insufficient training, less experience and unawareness about the assembling scenarios. Current training facilities and approach in Indian context does not meet to the demand of the industry. Technology-based training and tools have the potential to improve the skills of the trainee and meet the demand to some certain extent. In this paper, a Virtual Reality-based Scaffold assembling simulator is contributed. A mixed method approach is followed to collect opinions from five experts to understand the usefulness and immersiveness of the contribution. The results show the simulator to be a great aid to provide useful to the user and good engagement because of its immersiveness. These results would lead to conducting further study with more experts and then testing the simulator with novices.**

Keywords— Virtual reality simulator, Cup-lock Scaffolding, Skill training, Vocational education. Construction industry

I. INTRODUCTION

Scaffolds are temporary structures in construction that are assembled with metal pipes and panels. They are used by construction workers to perform various construction-related tasks like concreting, plastering, electrical, painting, etc. The Indian construction industry is the second largest after agriculture which is 16% of the contribution to India's GDP [1]. Out of the total workforce in this industry, approximately 65% of them work in Scaffolds [2] which states the need for a skilled workforce.

In the current training facilities only half of the requirement can be fulfilled [3]. Only small share of the Scaffolding workforce is coming out after formal training that offers civil engineering discipline and a major share of workforce enters into this sector through non-formal training [4]. Formal training infrastructure does not provide equivalent experience required in the workplace. For example, a maximum of three floor height Scaffold erecting and dismantling would be learned along with safety and other aspects. With this kind of limited formal training within limited infrastructure, they will enter into the workforce most likely as an apprentice [3].

There are very high threat and big risk to the new professionals and often prone to accidents at worksites [5]. Research on Scaffold accidents has received very little attention and according to the newspaper reports Scaffolding accidents and fatalities are high in India [6]. One of the major causes reported in such accidents are insufficient training, less experience, fear of height and performing tasks [7].

To deal with current situation, technology-based training solutions have been preliminary presented as a good approach to reduce accidents, enhance the learning and give proper training [15]. Advanced technologies like Haptics, Virtual Reality (VR), Augmented Reality (AR), and web-based applications have helped to upskill the workers [8]. Motivated by this, this paper contributes a VR-based simulator to explore a scenario for the Cuplock-type Scaffold assembling in VR. The study was followed after the development with experts for analysing the usefulness and immersiveness of the same. Mixed method approach was selected to conduct the study.

II. RELATED WORK

VR-based training solutions have been proposed and tested for industrial training which includes procedural knowledge, decision-making, and spatial skills. These studies are effective to learn the procedures and improving spatial skills in various field. For example, in [9], the speed and accuracy of nurses responding to emergency situation using immersive VR-based simulations is presented. Similarly, knowledge retention and learning outcomes improved in medical training due to VR/based interventions as they improved realism, engagement, and motivation [10]. These studies paves a path that VR training is capable to improve the skills of the novice in industrial experience.

A very few research works exist in the Scaffolding area of construction industry. Safety-based training solutions discussed the details of how novices can improve the skills of identifying hazardous situations and take early-safety precautions [11]. In [12], researchers developed a framework to understand the root causes of accidents in the construction industry - how to do the inspection, practicing the safety training, etc. The researchers discussed the immersive environments and how they affected the user psychologically with a comparison of simple VR modules. The results indicated a better user experience in the immersive environment [13].

III. METHODOLOGY

In order to assess the immersiveness and usefulness of VR-based simulator for Cuplock-type Scaffold assembling, 3

researchers did a detailed discussions with Subject Matter Experts (SMEs) and trainers, who have more than 20 years of experience to finalize the scenarios for the simulator development. Based on that discussion and analysis, researchers finalized the one-layer scaffold assembling in Cuplock type [16]. Moreover, they also decided to develop three simulation modules that include the parts identification, and Scaffold assembling on the ground and top floor modules. This whole modules could be a complete package for the trainees or learners. The development was based on the real case scenario in the actual work.

The overall methodology that the researchers follow in this study is based on mixed-methods research (please refer to Figure 1). Sutcliffe and Gault's heuristics model is used for analysing the collected quantitative data. The customizable interaction questionnaires and questions based on the simulation exercises are used for qualitative data [14]. Open-ended questions based on the customizable interactions questionnaire were prepared and for analysis planned the content and thematic analysis for qualitative data whereas descriptive statistics is used for the quantitative data.

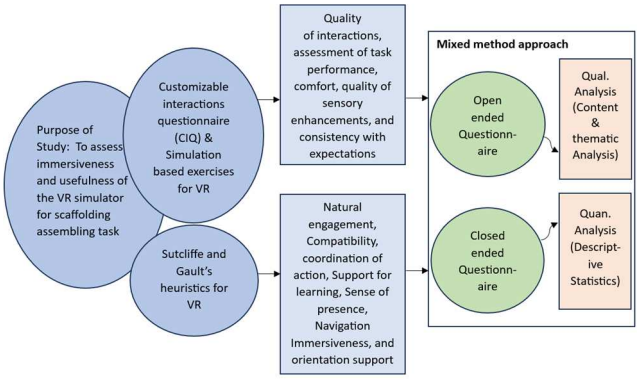

Fig. 1. Overall methodology followed in this paper

A. Cuplock Scaffold Assembling and Scaffold Exercises

The Cuplock is a widely used Scaffolding mechanism across the world. Figure 2 shows the assembling works of two experts. Its major components connected in a specific order and assembled the different layers of Scaffold [5]. Its key feature is unique circular node that allows up to four horizontal bars to be connected to a vertical bar in a single fastening action.

Fig. 2. Cuplock Scaffold Assembling

Researchers analysed the parameters including Scaffolding preparations, common tools and parts, the pre-training assembling module, and dangers in the Scaffolding environment and designed three exercise modules [5]. First module covers the identification exercise of the parts and tools involved in Cuplock Scaffolding. Second exercise is to do assembling tasks for the Scaffold in ground floor which gives the knowledge in assembling. Parameters like dangers and working at height factors were added with second exercise and designed for the top floor. Here exercise is made only for level one (single layer) and parts need to be used only for completing that task. In this level, one assembling exercise, four verticals are inserted using four base jacks and the same number of ledgers completed the square [5].

B. VR Scaffolding Simulator

The creation of the virtual environment was done using Unity 3D whereas The Samsung Odyssey VR of Samsung Electronics was used. The headset has a gear VR system that includes two controllers one for each arm which is wireless and can be used to provide inputs to the headset. The simulator consists of three learning modules, which are highlighted as follows.

1. ***Identifying the scaffolding parts:*** This module is aimed at familiarizing the user with the important parts and tools involved in a Scaffolding assembly. By the end of the study, the users should be able to differentiate the different parts and tools. The scenario is set inside a tool room environment with two tables and an instruction board. The instruction board will have the necessary safety guidelines to be followed. One table will have the nameplates for the different parts which will be placed on a different table. The user has to pick a name plate and place it near the corresponding part. This exercise is repeated until all the parts are identified correctly, which will trigger the message "*Congratulations Completed*".
2. ***Assembling on the Ground Floor:*** This module enables the user in understanding and familiarizes with the procedural aspects of building one-by-one meter single-layer Scaffold. The study environment is set on the ground floor of a half-built shed. The environment consists of important Scaffolding parts required to build the one layer which is called base player. The parts, tools and safety equipment need to be selected for the exercise. The user will initially be provided with the instructions for building a single-floor Scaffolding on a board present in the environment. The user can use the instructions to understand the Scaffolding procedure and this can be referred to anytime during the entire procedure. Figure 3 shows images of step by step process.

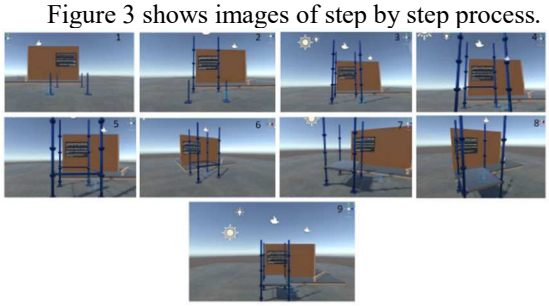

Fig. 3. Step wise Assembling in the ground floor

3. ***Assembling on the Top Floor:*** This module focuses to provide the users with an understanding of the real-life workplace environment. The user will be standing on top of a high-rise building in a city

environment. This module focuses on providing the users with a sense of work involving heights and thereby helps them in familiarizing the same. The task to be ccompleted in this module is the same as in the previous one (Please refer to Figure 4).

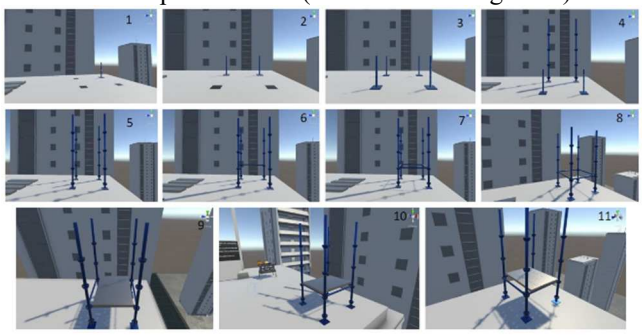

Fig. 4. Step wise Assembling in the top floor

IV. Evaluation

A. Participants

Five experts from the field of Scaffolding were invited to experience and review the VR-based Scaffolding simulator. The age of the population ranged from 25-30 years with a minimum of 3 years of experience (criterion according to National Skill Development Corporation guidelines to be an expert) in the construction industry. The Scaffolders were experienced in the construction of residential, commercial, and institutional buildings. They did not have any prior experience with VR.

B. Procedure

Initially, Informed Consent was obtained from each of the participants. Then a brief introduction regarding Scaffolding, VR headsets, and controllers were given to the user for 15 minutes. The conversations and the video of the participants doing the VR Scaffolding assembly were taken with the permission of the participants. Each subject was asked to do the three exercises explained in the session. An interval of 5 minutes was given after each exercise in order to avoid continuous engagement. After completing each exercise a set of questions were asked.

C. Questionnaire

There were three sets of questionnaires presented to the participants. First one was related to the demographic details, second and third focused on immersiveness and usefulness of the simulator. Each set of questions was asked after conducting each simulations modules and finally asked the overall usefulness and immersiveness like " How well would you think this VR-based training would be accepted by the users?"

V. Findings

A. Usefulness

For the first two questions focused on the initial simulation exercise, four of the participants reported usefulness positively. For the sub question of the second question, only Participant 2 reported moderately useful information and suggested improvement for better usefulness - "It could be further improved if there were some tutorial sessions in the VR world. Like giving demo classes regarding safety and all". Similarly, three participants mentioned that exercises focused on understanding procedure of assembling on the ground floor were really useful. Two of the participants recommended some suggestions - "The instructions in your study are easy. We just have to take the parts and keep it in marked positions. This makes it easier to learn but in the real world, there are some more steps involved like level-checking. If all the steps could be involved it could be really helpful for a new learner".

At the end, questions were asked based on the overall simulation. For the two questions, all participants positively reported on usefulness. For example, one participant quoted "All the users would love it. Individuals may not buy this but, construction industries will welcome this to train their new workers". Similarly, in response to the quantitative question "what about compatibility with the user's task and domain", four participants gave a score of 4 out of 5 (please refer to Table I).

TABLE I. Quantitative Usefulness Data

Participant	P1	P2	P3	P4	P5
Compatibility with the user's task and domain	4	3	4	4	4

B. Immersiveness

On the question ("What is the difference that you feel when you compare with the real world?") in the second exercise – three participants suggested good, and two recommended adding some features like "It was quite believable. Knew there was a difference from real world but my brain was tricked to be immersed in the virtual world ". In the third simulation module assembling on the top floor, four participants reported fear of height.

TABLE II. Quantitative Immersiveness Data

Participant-> / Parameter	P1	P2	P3	P4	P5
Natural engagement	3	4	2	4	4
Close coordination of action and representation	4	4	4	4	4
Support for learning	4	4	3	4	4
Sense of presence	3	3	3	3	4

For testing the immersiveness, four questions after the three simulations were asked. In a total of 20 responses (4 responses per five participants), nine of them suggested some additional questions are required to better report immersiveness. Four quantitative questions with a Likert scale of 5 were also asked to analyse the three simulations (please refer to Table II for the responses).

VI. Discussions

A total of 13 qualitative and 6 quantitative questions were asked to measure the immersiveness and usefulness of three VR-based scaffold assembling simulator. From the qualitative side, five questions focused on the usefulness. The researchers categorized the answer that includes keywords "helps, useful, support, good" as positive response. From the analysed

results, three modules are found useful for knowing and identifying the parts, and for sequential assembling procedure. Everyone suggested a good response for the overall use of three simulations for the construction companies and training institutes. Responses like “yes, I think” and “but, with these reasons” mapped to the improvement of the features of the simulator.

Feeling and experiences of participants regarding immersiveness were thematically extracted from their responses. Most of them felt, they are interacting with real objects and also reported height fear while assembling on top floor. They reported that the simulation would be positively taken by the trainee in real world training situations. Moreover, on the overall use of the three simulations, everyone agreed on their usability in authentic situations like construction companies and training institutes along with some recommendations and additional features.

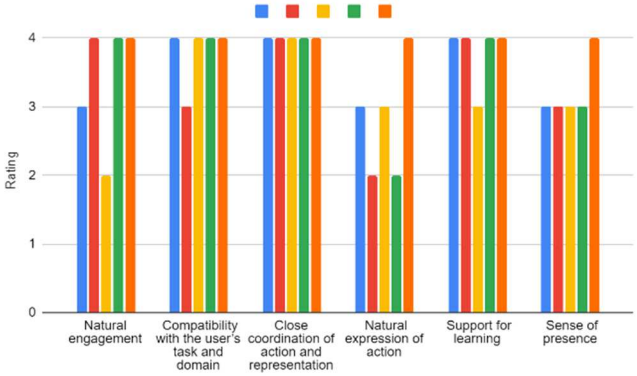

Fig. 5. Quantitaive data reperesentation from 5 participants

Figure 5 (Participants are color coded, P1 - Blue, P2 - Red, P3 - Yellow, P4 - Green and P5 -Orange) shows the graphical representation quantitative responses collected against six dimensions. On a Likert scale of 5, three responses score 2 on usefulness and immersiveness. The compatibility with the users' task and domain is coming under the usefulness and the average score is 3.8 which states the advantages of the training system. With respect to the immersiveness perspective, only the natural expression of the action scored 2.8, which provides information of the addition of the features to complete the task. Sense of presence scored 3.2 and natural engagement scored 3.4. Collected good scores for support for learning and the best score for close coordination of the action.

According to the information from experts, these simulations would be useful to the trainees in training institutes and even workers in non-formal sectors. Each of the users who would experience these exercises would be increase their knowledge in that specific area within safe and controlled environment. There would only the one-time investment and could be even covered by the NGOs and Government organizations. Then, such simulations might reach to most of the target audience. This might increase their motivation and productivity.

VII. Conclusions

This paper presented the design and development of a VR-based Cuplock Scaffold assembling simulator after the systematic approach that includes SME, types of Scaffolds assembling, and various levels of assembly. Qualitative and quantitative data were taken from five experts with respect to understand the immersiveness and usefulness of the three simulation modules. The results are reported here and demonstrated these VR based training simulations would improve the knowledge and experience of the trainee. The future works include incorporating adding the features like locking of cups while doing the assembly, addition of horizontal level checking, etc. The fear of height can be enhanced by simulating the assembly of multiple layers of Scaffold on top of a high-rise building. A greater number of experts need to be tested, collected and analyzed the data is one of the important things need to be done in future.

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ICT in Education: understanding Relationship between Student Attitudes and student Learning Readiness

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ABSTRACT: **ICT in education can deliver instruction, support collaboration, provide access to information, and assess learning. The use of ICT has increased due to the availability of technology. Research on its effectiveness and changes in learners' needs are in focus. However, to use ICT effectively, students must have the right attitude and willingness to learn. In creating effective ICT-based learning environments, it is important to understand the relationship between attitudes and skills. This study** on **students using ICT found a relationship between learning readiness and attitude influence the effective use of ICT in education.**

Keywords: ICT in education, learning styles, attitude, learning readiness, correlation.

I INTRODUCTION

The role of ICT in education is recurring and unavoidable. Rapid changes in technologies are indicating that the role of ICT in the future will grow tremendously in education [1]. Information and Communication Technology (ICT) has revolutionized various aspects of our lives, including education. In the field of education, ICT refers to the use of digital technology and communication tools to enhance the teaching and learning process. It encompasses a wide range of technologies, including computers, the internet, mobile devices, interactive whiteboards, and educational software. The integration of ICT in education has a profound impact on how students learn, teachers teach, and educational institutions operate. Information and communication technology (ICT) has transformed education by increasing access to learning resources and providing advanced ways to engage students. ICT tools can be used to fit instruction to individual requirements, enhance teaching strategies, address learning barriers, and promote self-awareness and metacognition among students. The integration of ICT in education has altered the learning atmosphere into a dynamic and interactive space.

[2]ICT tools provide innovative ways to engage students and enhance the learning experience. Interactive educational software, multimedia presentations, and simulations make complex concepts more understandable and enjoyable for students. Digital platforms and learning management systems facilitate communication and collaboration between teachers and students, enabling personalized and self-paced learning [3]The integration of ICT in education has transformed the traditional learning environment into a dynamic and interactive space. It has improved access to education, enhanced teaching and learning processes, and fostered collaboration and communication. By leveraging on ICT, educators can provide personalized instruction and support students' individual needs. As technology continues to advance, the role of ICT in education is likely to expand further, shaping the future of learning and teaching. ICT encompasses a wide range of technologies, including computers, internet connectivity, software applications, digital devices, and multimedia tools. Its integration into higher education has brought about significant advancements, enhancing the quality of education, expanding access to learning resources, and fostering interactive and collaborative learning environments

II LITERATURE REVIEW

Reference [4] stated that Students are more likely to have positive attitudes towards ICT in education when they perceive it as useful and relevant to their learning goals. If students see ICT tools as enhancing their understanding, engagement, and achievement, they are more likely to have favorable attitudes.

The ease with which students can use ICT tools and technologies can also affect their attitudes. If students find ICT tools user-friendly, intuitive, and accessible, they are more likely to have positive attitudes toward using them in their educational experiences [5]. Student characteristics such as prior experience and confidence in using technology can influence their attitudes towards ICT in education. Students who have had positive experiences with technology and feel competent in using it are more likely to have favorable attitudes toward ICT integration in the classroom [6].

Support and training provided by teachers in integrating ICT into the learning process can significantly impact student attitudes. When teachers are skilled, confident, and enthusiastic about using ICT, it can positively influence students' perceptions and engagement with technology [7]. The availability of reliable ICT infrastructure, including hardware, software, and internet connectivity, can influence student attitudes towards ICT in education. If students face barriers in accessing and using technology due to inadequate infrastructure, it can negatively impact their attitudes and engagement [8].

Learning readiness fosters higher levels of engagement in the classroom. Students who are ready to learn actively participate in class discussions, ask questions, and seek clarification. They are more likely to be attentive, motivated, and intrinsically interested in the subject matter, resulting in deeper learning experiences [9]. Learning readiness is associated with the development of self-regulation skills, such as goal setting, time management, and self-monitoring. Students who are ready to learn are better able to regulate their learning behaviors, set appropriate goals, and allocate sufficient time and effort to their studies, which positively

impacts their academic performance [10]. The study also found that there was a difference in attitude towards the use of VLE with respect to their technical background (i.e. technical/ non-technical) and no Readiness difference to adopt VLE in their learning. A significant relationship exists between readiness learning styles. this study emphasized more on learning styles [11].

III METHODOLOGY

A Objectives of the Study

i. To assess students' attitudes and readiness for ICT utilisation in their learning.
ii. To determine the gender difference in students' attitudes and readiness for ICT utilisation in their learning.
iii. To examine the difference between undergraduate and Post Graduate students' attitudes and readiness for ICT utilisation in their learning.
iv. To examine the difference between Technical and Non - Technical students' attitudes and readiness for ICT utilisation in their learning.
v. To examine the difference between Urban and Rural region students' attitudes and readiness for ICT utilisation in their learning.
vi. To find out the relationship between students' attitude and readiness for ICT utilisation in their learning.

B Hypothesis

H1: There is no significant difference in the mean attitude scores and learning readiness of male and female students on ICT utilisation in their learning.

H2: There is no significant difference in the mean attitude scores and learning readiness of PG and UG students on ICT utilisation in their learning.

H3: There is no significant difference in the mean attitude scores and learning readiness of Technical and Non-Technical students on ICT utilisation in their learning.

H4: There is no significant difference in the mean attitude scores and learning readiness of Urban and Rural Region students on ICT utilisation in their learning.

H5: There is no significant relationship between students' attitude to and readiness for ICT utilisation in their learning.

C Sample Selection

A convenience sampling method was employed to collect data. UG, PG Students of various colleges who were using/used any form of ICT in their education. A structured questionnaire was distributed through emails. 280 filled forms returned. After initial data screening only 243 responses were found to be suitable and usable. The respondents aged between 20 to 25 with an average age of 21 years.

D Tools used for the study

A questionnaire having two scales - attitude and learning readiness towards ICT usage for learning in addition to a few demographic questions is used. A modified version (Miller's 1995) of the attitude scale is used to assess the students' attitudes toward the use of ICT for their learning. The instrument has '11' statements. Five-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree), was used to collect the response options. The instrument's Cronbach's alpha was found to be 0.853. The Cronbach alpha is used as the reliability core of the scales [12] recommended that alpha should be at least 0.70 for all social sciences research. The internal reliability of the scales is found to be satisfactory for the collected data.

Student levels of learning readiness were measured using the modified scale developed by Hung et al (2010). The five factors of the scale are computer/internet self-efficacy, self-directed learning, learner control, learning motivation, and online communication self-efficacy. The five-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree), was used to collect the response options. The instrument's internal consistency in the form of Cronbach's alpha was found to be 0.962 [13]

E Data analysis

TABLE 1: MEAN AND STANDARD DEVIATION OF STUDENTS' ATTITUDE TOWARD ICT UTILISATION IN THEIR LEARNING

	TOTAL	MEAN	STDEV
Learning through ICT-based instruction is convenient	243	3.70	0.94
ICT-based courses allow me to control the pace of my learning	243	3.65	0.99
V LE-based courses should be utilized more often to deliver instruction	243	3.57	1.01
I will recommend ICT-based courses to my friends	243	3.68	1.03
ICT-enabled courses provide me with learning opportunities that I otherwise would not have had	243	3.43	1.02
I enjoy learning from the lessons using ICT	243	3.63	0.96
I will enroll in another course offered through ICT	243	3.63	0.97
I feel isolated as a student when I take courses via the web through ICT	243	3.16	1.12
I would not have taken ICT-based courses if I had some other means of acquiring course credit	243	2.95	0.98
I prefer Web-based courses to traditional classroom instruction	243	2.96	1.037
Learning using ICT-enabled courses is boring	243	2.49	1.107

The results of the above table reveal that 60 % of the students feel that Learning through ICT-based instruction is convenient. 63% of the students feel that ICT-based courses allow them to control the pace of their learning. 62% of the students support the statement V LE-based courses should be utilized more often to deliver instruction. 59% of the students are willing to recommend ICT-based courses to their friends. 51% of students feel that ICT-enabled courses provide them with learning opportunities that they otherwise would not have had. 61% of the students said that they enjoy learning from the lessons using ICT. 60% of the students wish to enroll in another course offered through ICT. 39% of the students feel isolated as a student when they take courses via ICT. 51% do not feel isolated. 27% of the students stated that they would not have taken ICT-based courses if they had some other means of acquiring course credit. Only 34% of the students prefer Web-based courses to traditional classroom instruction. 50% of the students feel that Learning using ICT-enabled courses is boring.

TABLE 2: MEAN AND STANDARD DEVIATION OF STUDENTS' READINESS FOR ICT USE FOR THEIR LEARNING.

Self-efficacy	TOTAL	MEAN	STDEV
I feel confident in performing the basic functions of ICT.	243	3.59	0.89
I feel confident in my knowledge and skills of how to manage software for learning through ICT.	243	3.62	0.92
I feel confident in using the Internet to find or gather information for learning using ICT	243	3.65	1.17
Self-directed Learning			

I carry out my own study plan using ICT based Instructions	243	3.49	0.98
I seek assistance when I face learning problems, while using ICT	243	3.46	1.049
I manage time well using ICT.	243	3.48	1.069
I set up my learning goals.	243	3.69	1.073
I have higher expectation	243	3.57	1.066
Learning Control			
I can direct my own learning progress.	243	3.46	1.060
I am not distracted by other online activities when learning online through ICT	243	3.03	1.257
I repeat the ICT based instructional materials on the basis of my needs.	243	3.58	0.960
Learning Motivation			
I am open to new ideas, while using ICT	243	3.72	1.05
I have motivation to learn through ICT	243	3.54	0.99
I improve from my mistakes, while using ICT	243	3.65	1.07
I like sharing my ideas with others through ICT	243	3.57	1.05
Online Communication Self-efficacy			
I feel confident in using ICT to effectively communicate with others	243	3.48	1.04
I feel confident in expressing myself (emotions and humor) through ICT	243	3.41	1.05
I feel confident in posting questions in online discussions through ICT	243	3.44	1.02

The results of the above table reveal the learning readiness among UG, PG students who use/use ICT for their learning. The mean score for the statements on self – selfefficiency states that the student feels confident while performing the basic functions of ICT, confident in their knowledge and skills on how to manage software for learning through ICT, confident while using the Internet to find or gather information for their learning using ICT is found to be 3.5 with a standard deviation of 0.97. indicates that most of the students have the ability to use ICT for their learning.

The mean score of 3.6 indicates that most of the students are self-directed for their learning using ICT the statements in the second dimension state that students can carry out their own study plan using ICT based Instructions, students manage their time well using ICT, set their own goals, 50% of the students are ready to seek assistance when they face learning problems while using ICT. Most of the students have higher expectations for their learning through ICT.

The statements that they can direct their own learning progress, not get distracted by other online activities when learning online through ICT, and repeatedly use the material for their learning needs have a mean score above 3 indicating that most of the students have the ability to take charge of their learning while using ICT.

For the statements that the student is open to new ideas, has the motivation to learn, tries to improve from mistakes, and also likes to share their ideas with others while using ICT for their education under the dimension learning motivation have a mean score of 3.73 indicating most of the students are interested in learning new things using ICT.

An average score of 3.4 indicates students agree that they are confident in using ICT to effectively communicate with others expressing themselves (emotions and humor) while posing questions in online discussions through ICT.

Overall, the results reveal that the students have a positive readiness to use ICT for their learning but also require additional support.

H1: There is no significant difference in the mean attitude scores and learning readiness of male and female students on ICT utilisation in their learning.

TABLE 3: MEAN DIFFERENCE BETWEEN MALE AND FEMALE STUDENTS' ATTITUDE AND LEARNING READINESS TO USE ICT FOR LEARNING.

Variable	Gender	N	Mean	Std. Deviation	T	Df	Sig
learning readiness	Male	115	3.5005	.79009	.510	241	.611
	Female	128	3.5538	.83536			
Attitude	Male	115	3.3684	.63085	.221	241	.826
	Female	128	3.3501	.65507			

The result reveal that [t(241)=0.51, p>0.05] the learning readiness of students in using ICT for their learning does not differ significantly with respect to their gender.

The result reveal that [t(241)=0.221, p>0.05] the attitude of students for using ICT for their learning does not differ significantly with respect to their gender.

H2: There is no significant difference in the mean attitude scores and learning readiness of PG and UG students on ICT utilisation in their learning.

TABLE 4: MEAN DIFFERENCE BETWEEN PG AND UG STUDENTS' ATTITUDE AND LEARNING READINESS TO USE ICT FOR LEARNING.

Variables	Studying in	N	Mean	Std. Deviation	t	df	Sig.
Attitude	PG	130	3.3685	.65402	.253	241	.800
	UG	113	3.3475	.63162			
learning readiness	PG	130	3.6179	.82254	1.847	241 .066	
	UG	113	3.4258	.79310			

The above table shows that there is no significant difference in the mean attitude scores and learning readiness of PG and UG students on ICT utilisation in their learning

The result reveals that [t(241)=0.253, p>0.05] the attitude of students in using ICT for their learning does not differ significantly with respect to different education levels with a mean value of 3.3 and a standard deviation of .64.

The result reveals that [t(241)=0.1.85, p>0.05] the learning readiness of students for using ICT for their learning does not differ significantly with respect to different education levels with a mean value of 3.56 and a standard deviation of .84.

H3: There is no significant difference in the mean attitude scores and learning readiness of Technical and Non-Technical students on ICT utilisation in their learning.

TABLE 5: MEAN DIFFERENCE BETWEEN TECHNICAL AND NON-TECHNICAL STUDENTS' ATTITUDE AND LEARNING READINESS TO USE ICT FOR LEARNING.

Variables	Academic Background	N	Mean	Std. Deviation	t	Df	Sig
Attitude	Technical	77	3.3743	.56523	.256	239	.799
	Non-Technical	164	3.3514	.68094			
learning readiness	Technical	77	3.5368	.75835	.134	239	.894
	Non-Technical	164	3.5217	.84401			

The result reveals that [p>0.05] the learning readiness and the attitude of students in using ICT for their learning does not differ significantly with respect to their Academic Background.

H4: There is no significant difference in the mean attitude scores and learning readiness of Urban and Rural Region students on ICT utilisation in their learning.

TABLE 6: MEAN DIFFERENCE BETWEEN URBAN AND RURAL REGION STUDENTS' ATTITUDE AND LEARNING READINESS TO USE ICT FOR LEARNING.

Variable	Belongs to R / U Region	N	Mean	Std. Deviation	t	Df	Sig
Attitude	U Region	186	3.2967	.69331	-2.575	237	.011
	R Region	53	3.5523	.37814			
learning readiness	U Region	186	3.4367	.85325	-3.561	237	.000
	R Region	53	3.8784	.54933			

Significant 0.05 level.

The above table shows that there is significant difference in the mean attitude scores and learning readiness of Urban and Rural Region students on ICT utilisation in their learning.

The result reveals that [t(237)= - 2.575, $p < 0.05$] the attitude of students in using ICT for their learning differ significantly with respect to the region they belong to with a mean score of 3.3for urban region and a 3.6 mean score for rural region and standard deviation of .7 for urban region and .4 for rural region.

The result reveals that [t(237)= - 3.575, $p < 0.05$] the learning readiness of students in using ICT for their learning differs significantly with respect to the region they belong to with a mean score of 3.4 for the urban region and 3.9 mean scores for rural region and standard deviation of .8 for the urban region and .5 for rural region. Rural region students have a more positive attitude and learning readiness for utilising ICT for their learning.

H5: There is no significant relationship between students' attitudes and readiness for using ICT for their learning.

TABLE 7: PEARSON PRODUCT MOMENT CORRELATION SHOWING RELATIONSHIP BETWEEN STUDENTS' ATTITUDE TO, AND READINESS FOR USING ICT FOR THEIR LEARNING.

Correlations			
Variables		Attitude	learning readiness
Attitude	Pearson Correlation	1	.795**
	Sig. (2-tailed)		.000
	N	243	243
learning readiness	Pearson Correlation	.795**	1
	Sig. (2-tailed)	.000	
	N	243	243
**. Correlation is significant at the 0.01 level (2-tailed).			

The above results show that there is a significant relationship between students' attitude to and readiness for using ICT in their learning (0.000; $p < 0.05$). The two variables are highly correlated with a value of 0.795. This means that the positive attitudes of students towards ICT usage will have an effect on their readiness for learning through ICT platforms.

IV FINDINGS AND DISCUSSION

The study assesses students' attitude and readiness for ICT utilisation in their learning and to determine the gender difference of students' attitude and readiness for ICT utilisation in their learning, and examine the difference between undergraduate and Post Graduate students' attitude and readiness for ICT utilisation in their learning, examine the difference between Technical and Non - Technical students' attitude and readiness for ICT utilisation in their learning, examine the difference between Urban and Rural region students' attitude and readiness for ICT utilisation in their learning, and to find out the relationship between students' attitude and readiness for ICT utilisation in their learning.

The study reveals that 60 % of the students feel that Learning through ICT-based instruction is convenient. 63% of the students feel that ICT-based courses allow them to control the pace of their learning. 62% of the students support the statement V LE-based courses should be utilized more often to deliver instruction and only 13% of the students are not in favor of usage. 59% of the students are willing to recommend ICT-based courses to their friends. 41% of the students does not wish to recommend ICT-based courses to their friends 51% of students feel that ICT-enabled courses provide them with learning opportunities that they otherwise would not have had. 61% of the students said that they enjoy learning from the lessons using ICT. 60% of the students wish to enroll in another course offered through ICT. Most of the students feel that Learning using ICT-enabled courses is boring. Students want interaction with their peers.

V CONCLUSION

Students' attitude and learning readiness to use ICT for learning is not influenced by the gender and academic levels of the student. Undergraduate students are not so inclined towards ICT usage. As PG students have more maturity they seem to have more inclination towards responsible usage of time and resources using ICT. Technology ease is not a barrier to using ICT for learning purposes as both technical and non-technical background students show no difference in their attitude and readiness.

Students from rural backgrounds are more inclined towards learning through ICT platforms we need to emphasize providing infrastructure to all.

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Analysis of In-Service Mathematics Teachers' Subject Knowledge and Misconceptions on Primary and Middle Grade Mathematics Concepts

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Abstract— This study examines in-service teachers' mathematical subject knowledge and their misconceptions in some of the essential math concepts that they teach in primary and middle grades. It also compares the extent of teachers and students' misconceptions on the same items. The paper reports the strengths and areas of difficulty of teachers on fundamental math concepts. The study contains data from 1,357 teachers who teach math to grades 3, 4, 5 and 6 on a math subject knowledge assessment. The teachers were from 152 schools from India, UAE, Oman and Saudi Arabia. The findings suggest that teachers have misconceptions in some of the fundamental math concepts which are similar to the misconceptions seen in students. The extent of teachers' misconceptions was as high as 58% in some concepts which was similar to the extent exhibited by middle grade students. Ratio, proportional reasoning, algebraic reasoning, estimation are some skills where almost 80% of the teachers were unable to answer items correctly. The implications of this study on informing curriculum and assessment designs and teacher training practices are also discussed.

Keywords: teachers' subject knowledge, mathematics, misconceptions, teacher assessments

I. INTRODUCTION

The Indian National Educational Policy 2020 (NEP 2020) lays down recommendations for aligning assessments to the holistic development of students. If implemented, the aim of assessment in the Indian schooling system will shift from one that is summative and primarily tests rote-memorization skills to one that is more regular and formative, is more competency-based, promotes learning and development for students, and tests higher-order skills, such as analysis, critical thinking, and conceptual clarity. The intention seems to be to improve conceptual and application skills of students. But are teachers, who are supposed to facilitate this holistic development, equipped with these skills themselves? Most teachers are themselves products of a system that focuses on rote-learning information rather than learning with understanding and how to use the information.

Teachers' subject knowledge plays an important role in student achievement. Past research has indicated that the teacher effects on student achievement are driven by teachers' ability to understand and use subject-matter knowledge to carry out the tasks of teaching [2] [5].

Research studies in the past have demonstrated that the teachers' mathematical knowledge was significantly related to the student achievement gains [2] [3] [6]. Another study by Hill claims that the teachers' mathematical knowledge plays an important role in their teaching of subject matter [4]. Knowing mathematics for teaching demands a kind of depth and detail that goes well beyond what is needed to carry out the algorithm reliably [2]. The tasks that teachers face such as error analysis, explaining the basis of algorithms, using mathematical representations etc. are deeply interwound with mathematics and mathematical reasoning [2]. Liping Ma's comparative study [5] of Chinese and US teachers' knowledge of elementary mathematics concluded that the knowledge of Chinese teachers seemed clearly coherent while that of the U.S teachers was clearly fragmented. The coherence of Chinese teachers' knowledge was because of the mathematical substance of their knowledge. In her book, Knowing and Teaching Elementary Mathematics, Ma concluded that "Having considered teachers' knowledge of school mathematics in depth, I suggest that to improve mathematics education for students, an important action that should be taken is improving the quality of their teachers' knowledge of school mathematics.". She also concluded that no amount of general pedagogical knowledge can make up for ignorance of particular math concepts [5]. Existing research has explored the correlation between students' achievement and teachers' mathematical knowledge and the fundamental mathematical knowledge that primary math teachers should possess. Most of the past research was on pre-service teacher candidates. However, there is a dearth of research on the mathematical content knowledge of in-service math teachers and the correlation between teachers' and students' misconceptions. In the Indian context, we do not have enough data to determine the quality of the teachers by way of how much they know and how much they need to be trained. This study, therefore, aims to address this very gap. The large scale student data collected and organized from a standardized Math benchmarking assessment across years and the data collected through an online teacher assessment were used for this analysis. To have such a huge data set is merely impossible or it involves huge costs with offline studies, without the use of technology.

With the above understanding, the current study analyses the math subject knowledge of in-service math teachers of grades 3 to 6.

II. METHOD

A. Sample

1357 teachers from 152 private schools took the TIPS - Math Subject Knowledge – Level 1assessment. These 152 schools were from India, UAE, Oman and Saudi Arabia. 80% of the teachers were from India, 18% from UAE, 1% each from Oman and Saudi Arabia. The data was collected over a period of two and a half years, starting from August 2017 to February 2020. While the duration was two and a half years, tests took place in specific months in each year. The schools that take ASSET test [1] had an option to participate in the TIPS programme. The decision to participate in the assessment was the school management's. While the exact class and subject taught by the teachers was not revealed, discussions with some schools indicated that the teachers who participated may be teaching a single class-subject or multiple classes and sometimes even multiple subjects. However, the tests they were assigned were based on the subjects they taught and hence the subjects where they were expected to deliver student learning outcomes. The option to decide which test/level should be taken by which teacher was given to the school academic head as well as the principal. The recommendation was to assign a test depending on the subject and grade the teacher was teaching. For example, a teacher teaching English Grade 5 should be allotted English Level 1 test; a teacher teaching Science Grade 9 should be allotted Science Level 2 test. However, in some cases, depending on factors like different subjects the teacher is teaching, the needs of the school and principal's discretion, some teachers were assigned either both the level tests for a given subject or multiple subject tests.

All the tests were administered online and the responsibility to proctor the tests or not lied with the school administration. Each teacher received their login credentials (a username and a password) and the tests were administered using an online test taking interface. Teachers were trained on how to take the test using training material in forms of documents as well as video tutorials. The test taking interface was also demonstrated in the video tutorial.

At the end of the test a detailed individual teacher report indicating the score of each teacher, the strong and weak areas, misconceptions demonstrated, and question-wise performance was shared with the teachers. The school also received a detailed school-level report highlighting the overall performance for each paper, strong and weak areas of the school, misconceptions seen in the teachers and individual teacher score and performance.

The data of all the teachers who participated in the TIPS - Math Subject Knowledge – Level 1 assessment was used in this analysis.

B. Measures

Educational Initiatives Pvt. Ltd. has designed the Teacher Impact Programmes (TIPS). One of the components of the programme is teacher assessments that measure teachers' subject knowledge and the pedagogical knowledge and shares detailed reports with the teachers and school principals. TIPS assessments are offered for six different subjects: English, Mathematics, Science, Physics, Chemistry, and Biology. There are two levels for each subject, Level 1 which caters to grades 3 to 6 teachers and Level 2 which caters to grades 7 to 10 teachers. Each test for a given subject has two sections – Section I, the Pedagogy Section and Section II, the Subject Knowledge Section. The Pedagogy Section has 30 multiple choice questions with a 50-minute time limit and the Subject Knowledge Section has 40 multiple choice questions with a 40-minute time limit. All the questions in the test are 4 option Multiple Choice Questions (MCQs). Each MCQ carries 1 mark and there is no negative marking for selecting incorrect option. This study uses the data collected from the Teacher Math Subject Knowledge-Level 1 test. It tests the understanding of mathematical knowledge on concepts that are taught in grades 4 to 7. The items were taken from the ASSET question bank to have the comparative student performance data. The questions had student responses ranging from minimum 9000 responses to maximum 22000 responses. Cronbach alpha values of the student assessment are reported to lie in the range 0.7 - 0.95.

The assessment items mainly test conceptual understanding and application skills. All the items are MCQs and the distractors were designed to capture specific misconceptions. The content paper contains 40 items covering the 4 math domains with 20 items from Numbers domain, 10 from Geometry and measurement, 5 from Algebra, and 5 from Statistics and Data analysis. As the elementary math content focuses more on numbers and geometry, more weightage was given to those domains.

III. RESULTS AND ANALYSIS

The reliability coefficient for the Teacher Math Subject Knowledge assessment was found to be 0.8389 which means that the test has high reliability.

A. Teachers' Math Subject Knowledge

The descriptive statistics like average accuracy and the accuracy at different percentiles is shown in Table I. Around 75% of the teachers who took the test could not answer around 50% of the questions correctly. 25% of the teachers could just answer around 25% of the questions correctly.

TABLE I. ACCURACY OF TEACHERS' MATH SUBJECT KNOWLEDGE

Number of questions answered correctly (out of 40) (N = 1357)				
Overall Average (SD)	***25th percentile***	***50th percentile***	***75th percentile***	***90th percentile***
16.6 (6.8)	11	16	21	26

We also analysed accuracy by the grade level at which the concept being tested was taught. Table II summarises the data. For example, 73.3% of the teachers have answered grade 4 items correctly. 36.7% of the teachers have answered the questions that are based on grade 7 concepts.

TABLE II. ACCURACY OF ITEMS BY GRADE LEVEL

Grade (in which the concept is taught)	**Number of Items**	**Teachers' Accuracy (%)**
4	2	73.3
5	3	49.1
6	21	40.7
7	14	36.7

B. Teachers' Misconceptions or Common Errors

In this section we report some of the misconceptions or the common errors that the teachers demonstrated based on their responses to specific items. The major misconceptions tested in the paper and the extent of misconceptions are shown in Table III.

TABLE III. EXTENT OF MISCONCEPTIONS

Misconception	Correct answer (%)	Extent of misconception (%)
M1: 'Thinking that the ratio a:b changes to a+k:b+k if 'k' is added to both the quantities'	15.9	58.9
M2: 'The perimeter of a shape formed by joining parts is the sum of the perimeter of the parts'	51.1	32.9
M3: 'Ordering decimals by comparing the decimal part of the numbers as whole numbers'	53.6	36.3
M4: 'If the common difference between the terms in a pattern is d, then the nth term is n+d'	21.1	46.5
M5 and 6: 'Probability of an event can't be a fraction or a decimal (OR) Probability of an event can't be 0 or 1'	31.1	16.4 (M5), 25.9 (M6)
M7: 'Applying some arithmetic operations on the given numbers when the answer can't be found with the given information'	12.1	46.2

The assessment item testing the ratio misconception(M1) is shown below.

Item: The ratio of the heights, in inches, of two plants was 6:8.

If each plant grew 3 inches more, what will be the ratio of their new heights?

A. 3:5

B. 6:8

C. 9:11

D. (cannot say - more information required)

As seen in the data, 15.9% teachers selected the correct answer D. They seem to be reasoning out that the given information is insufficient to answer the question. 58.9% teachers selected the incorrect option C. They seem to have a misconception that when the plants grow by 3 inches in height, the ratio of their heights will also increase by 3 inches correspondingly (from 6:8 to 9:11). 20.5% teachers also selected option B, indicating that they have a misconception that irrespective of the increase in heights of the plants, the ratio will remain unchanged.

The question below tests decimal comparison. 53.6% teachers selected the correct answer, option D. 36.3% teachers selected option B. They seem to have a misconception that the decimal numbers can be ordered by comparing the digits in the decimal part as whole numbers. As 2 lies between 1 and 3, they think that 0.002 lies between 0.03 and 0.1. They seem to relying on partially remembered rules without understanding the concept behind them or overgeneralizing the whole number thinking to solve the given problem instead of applying the place value concepts.

Item: Which of these numbers lies between 0.003 and 0.1?

A. 0.12

B. 0.002

C. 0.102

D. 0.012

C. Comparison of teachers' misconceptions/common errors with that of the students'

Each of the assessment items used in the teacher assessment test was also used earlier in a student assessment. 9000 to 21000 students had answered the items used in the teacher subject knowledge test. Student response data on these items was analysed to understand the extent of the misconceptions in students.

The extent of the misconceptions in teachers was found to be almost as high as that in students (ref Figure 1). On the concepts like decimals and perimeter which are introduced from grade 5 in many curricula, the teachers have better understanding of the concept with lesser extent of misconceptions compared to the students. In the middle grade concepts like ratio or general term of a pattern and probability which are introduced in grade 6 or above, the extent of teachers' misconceptions is almost same or slightly higher than that of students' misconceptions.

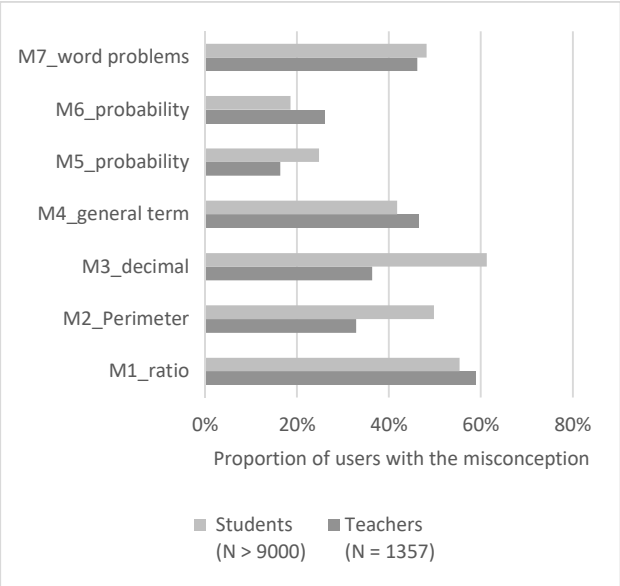

Figure 1 *The extent of misconceptions: Teachers' vs Students'*

D. *Strengths and areas of development of teachers' mathematical subject knowledge*

Only 2 out of the 40 questions were correctly answered by more than 80% of the teachers. These questions tested multiplication algorithm and reading a simple decimal fraction on a scale. Teachers seemed to be fluent with these procedures.

Around 80% of the teachers could not answer the questions testing the concepts like ratio, proportional reasoning, algebraic reasoning, estimation and logical reasoning. All these concepts are required to solving real life challenges.

One interesting observation is that in two of the assessment items the solution cannot be found with the given information. The average performance of the teachers who have answered both the questions correctly is slightly more than the performance of a teacher at the 90th percentile in the subject knowledge test (see Table 2). So, teachers or students with better understanding of the math concepts and good critical thinking skills are able to solve such questions correctly.

IV. CONCLUSIONS

The study aimed to measure the in-service teachers' math subject knowledge and the misconceptions they have in some of the fundamental math concepts that are taught in primary and middle grades. This analysis helped us to get some quantitative insights about the in-service teachers' math subject knowledge. Many past research studies have shown a strong correlation between teachers' subject knowledge vs student achievement as well as teachers' subject knowledge versus their quality of instruction. This analysis reported the in-service math teachers' low math subject knowledge with an average teacher just answering 16 questions correctly out of 40 questions that test deeper understanding of primary and middle grade math concepts.

The extent of misconceptions was almost similar to extent of the students' misconceptions in many concepts. If teachers have such misconceptions, it is very much possible that similar misconceptions have been taught to students as well. If teachers are unaware of these misconceptions, they may not be able to catch these errors in their students and remediate for the same.

The main takeaway from this analysis was that the in-service teachers' math subject knowledge needs major improvement. It may not be possible to recruit high-quality subject matter experts as teachers in all schools in developing countries like India where we need large number of teachers. Principals and school management, if aware of the teachers' gaps, can make continuous efforts to diagnose and improve their teachers' subject knowledge, which eventually helps in developing their pedagogical approaches. Technology-based online assessments are very useful to conduct these tests often, compare the data and provide specific feedback and remedial measures based on the needs of that teacher. Some rigorous measures can be explored, like making it compulsory for teachers to regularly take standard assessments that test teachers' subject knowledge as well as pedagogical knowledge and provide feedback on the strengths and areas of development for teachers. Specific and targeted workshops or online courses addressing the gaps might help in improving the teacher quality. The courses could also focus on making the teachers understand the issues with rote learning and the importance of learning with understanding. Policy changes that encourage diagnosis of teacher knowledge and make resources for teacher development accessible may be the need of the hour. Along with the pre-service teacher trainings, government should design short training programmes or refresher courses for in-service teachers to bridge their learning gaps as well as upscale their skill to face the new age challenges.

We plan to extend this analysis to study the teachers' pedagogical knowledge and the correlation between the subject knowledge and pedagogical knowledge. This paper analyses only the level 1 content paper which is mainly taken by the teachers of grades 3 to 6. Similar analysis on grade 7 to 10 teacher data of both subject and pedagogical knowledge will give us more rigorous insights on the quality of teachers.

One of the limitations of the study is that the teachers who participated in the study are mostly from the private schools in India. The sample may not be representative of the population. Even in India, considering the teachers from government schools may make the sample more representative. But that doesn't anyway lessen the importance of the current insights from the study. The misconceptions discussed in the paper were deduced by the authors based on the teachers' performance data and their past field experience in interacting with teachers and students. These misconceptions can be validated by collecting qualitative data from participants which we see as a limitation of the current analysis. The skip rate for the last 10 questions was found to be higher compared to the first 30 questions. This would need further investigation and insights from it can inform changes to be implemented for the next round of data collection.

Another limitation of the study is the fact that it considers data across multiple academic years. While the misconceptions are less likely to change without an active intervention, it might be worth investigating how the extent of the same misconceptions differ when checked in a single academic year.

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The Effect of Outcome-based Education on Academic Performance in Higher Education

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Abstract— **Education is the driving force in equipping learners with the knowledge, skills and attitude needed to create a peaceful, prosperous, sustainable and equitable world for all to thrive. The 21st education system should help learners acquire domain-dependent and domain-independent skills and contribute to sustainable development. Until the 20th century, the education system used the teacher-centric approach. The students were passive learners, and their level of learning was gauged through tests taken at the end of the course. In the 21st century, the students are the main focus, so learner-centric approaches are used. The students must develop the knowledge, skills and attributes to be globally acceptable. Flip learning, game-based learning, project-based learning, scientific argumentation, Outcome-based Education, and blended learning are mostly learner-centric teaching-learning processes. The first and foremost challenge in these learner-centric approaches is to define the outcome or target of the teaching. The curriculum must address what students can do upon completion of the course. The outcome-based curriculum, along with the learner-centric teaching-learning process, is described in this paper. The paper reported outcome-based education's efficacy in increasing students' academic achievement in higher education. It was observed that the student's academic performance significantly increased, the dropout rate was reduced by 13.42%, and the failure rate dropped by 5.49%. The paper also reported a positive correlation (between +0.156 and +0.378) between the effectiveness of the proposed outcome-based learner-centric TLP and students' academic performance. The result shows that self-learning and higher-order thinking contributed more towards the grades obtained by the students.**

Keywords— Academic performance, higher-order thinking, learner-centric, outcome-based Education, self-learning

I. Introduction

In the past two decades, the education system has changed from teacher-centric to learner-centric with the advancement of ICT facilities. The graduates, especially the engineering graduates, needed the skills required by the 21st century. To make the learners acquire skills like self-learning ability, active learning, communication skills, teamwork, etc., the teaching-learning process has shifted to learner-centric. The syllabus also needs to be modified so that the learners can learn in their learning styles at their convenient time[1]. To cater for these setbacks' the learner-centric approaches came into existence. The most common learner-centric approaches (LCA) are game-based learning, project-based learning, scientific argumentation, flipped teaching, outcome-based learning and blended learning. In flipped teaching or inverted classrooms, the study materials are provided to the learners before class. The learners need to learn in their own in their learning style before coming to the class. The class will be a discussion class, promoting self-learning and active and collaborative learning[2][3]. The materials provided to the learners should be easily accessible and adequate. A well-designed curriculum is needed so that learners can do their pre-classroom study in less time without any stress[4]. Game-based learning provides active learning where the learner learns by playing games. The learner can play single and also in groups, increasing collaborative learning. The games need to be designed for each course separately and carefully. The game-based learning (GBL) needs technical equipment and well-designed games to make it interesting. Again, learning should be the focus and not playing games[5]. Scientific argumentation (SA) is learning through scientific facts, evidence and reasoning. The learning process starts with a critical question each respondent tries to answer in the instructor's presence. In the end, a conclusion is drawn according to the arguments[6]. SA increases their communication skills, collaborative learning when they work in groups and critical thinking. The instructors need to mediate the process and guide the learners to stay on the topic for which they should have sufficient knowledge on the topic of discussion. Problem-based and project-based learning deal with real-world problems where learners use their previous knowledge to solve the given task. This promotes active learning, critical thinking, collaborative learning and communication skills. The process is very time-consuming, and not all learners in a group contribute equally[7]. The outcome-based education (OBE) stresses the outcomes learners will acquire upon course or program completion. OBE increases self-learning, active learning, lifelong learning and even collaborative learning. The accreditation body emphasises following OBE as it addresses domain-dependent and domain-independent learning[7]. OBE does not engage the learner throughout the course. Again, the outcome should be appropriately defined. Lastly, the assessment for all outcomes is not done[8][9]. Blended learning (BL) is another learner-centric approach that combines two or more teaching-learning processes. The most common example of BL is the mix of online learning with traditional learning. It promotes self-learning, active learning and engagement and increases the learner's performance. The learning activities should be properly blended else it will appear as two different courses raising unnecessary workload[10][11]. Thus, existing LCAs need to be modified to make the learners engaged throughout the course. The learners must acquire domain-dependent and domain-independent skills, knowledge and attitudes to meet

the demands of the 21st century. LCA should also be applied in large classrooms in the given time frame. The paper proposes the teaching-learning process where the detailed outcome-based curriculum is designed with the help of the instructor. This methodology aims to increase the learners' self-learning ability and active and collaborative learning, engaging them throughout the course[12]. It also increased their higher-order thinking skill and was implemented in a large classroom. Here, we studied the effect of the proposed methodology on academic performance and also which parameters have influenced more. The paper is organised in the following manner. Section II explains the methodology, Section III presents the result and discussion, and Section IV provides the study's conclusion.

II. METHODOLOGY

The stated methodology can be divided into two major parts, shown in Fig. 1. The detail of each part is explained below.

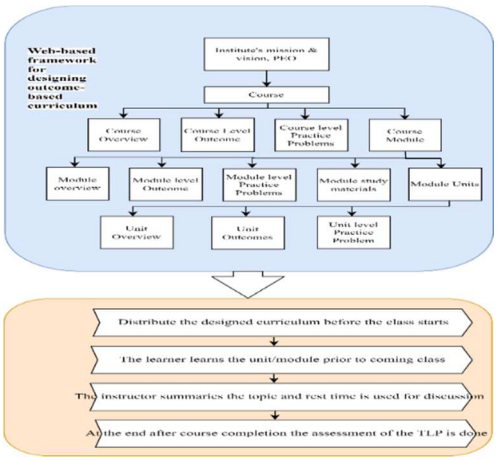

Fig. 1. The proposed methodology

A. The designed curriculum

The curriculum design starts with the course, and the course is divided into course overview, course outcomes and related course-level problems for self-assessment and course module. The course module is further divided into module overview, module-level outcomes and related to it module-level problem set, module learning strategy and module units. Each unit is further divided into the unit overview, unit objectives and the problem set aligned to it. The curriculum was designed for three courses using the open web-based framework [14]. Equation (1) represents the course structure

$$C = COV + \sum_{n=1}^{N} CO_n + \sum_{m=1}^{M} CP_m + \sum_{r=1}^{R} CM_r \quad (1)$$

Here C is the course, COV is the course overview, CO_n is the course outcome, CP_m are its related problems and CM_r are course modules.

$$\text{Again } CM_r = MOV + \sum_{a=1}^{A} MO_a + \sum_{b=1}^{B} MP_b + \sum_{c=1}^{C} MS_c + \sum_{d=1}^{D} MU_d \quad (2)$$

Here MOV is the module overview, MO_a means the module outcomes and MP_b are the related module-level practice problem set, MS_c represent the module study materials which can be texts, video lectures, animation etc. and MU_d are the module units. The course module is presented in (2).

$$MU_d = UOV + \sum_{x=1}^{X} UO_x + \sum_{y=1}^{Y} UP_y \quad (3)$$

Each MU_d again represented by (3), where UOV is the unit overview, UO_x are unit outcomes and UP_y are its related problem-set.

B. Teaching learning process

The learners were given the designed curriculum before the real class and they were advised to study in small groups. In class, the instructor summarises the whole concept and the important concept in 25% of class time and the rest time was used to discuss the given unit stated for the class. The learners too ask. their doubts and their peers clarify them. When the learners fail to answer the doubts of their peers then the instructor answers. This TLP increases self-learning, active learning, collaborative learning, communication skills and higher-order thinking skills.

C. Designing of the questionnaire

The questionnaire is designed to measure the effectiveness of the proposed outcome-based learner-centric TLP. The effectiveness of this TLP is measured by measuring the student's self-learning, active and collaborative learning, higher-order thinking ability, and satisfaction. There is another parameter known as "continuous Updating and promotion" which addresses the designed curriculum and how much further modification is needed. So, in total five parameters questionnaire are designed, table I shows the designed questionnaire. The data were collected on a 5-point MOS scale from the learners.

D. Participants

The research was conducted in the year 2019- 2020 and again in the year 2021-2022, the gap in between was due to the COVID-19 pandemic. The participants were undergraduate BTech learners of an engineering college named "Seemanta Engineering College" having Biju Patnaik University of Technology, Odisha, India affiliation. The methodology was applied to a total of 645 learners studying first year and second year, which is considered an experimental group. . The control group consists of 625 first-year and second-year learners who had traditional TLP. The control group and experimental group were divided arbitrarily. For the first year the TLP was used for the courses "RBL1B002" and "RBC1B002" in the first semester and (RBL2B002" and "RBC2B002" in the second semester. For the second-year learners subject "REE4D001" was designed. During the old semester of 2019, TLP was applied in the face-to-face room, for even semester 2020 more than half of the classes were in online mode. First semester of 2021, most of the classes were in online mode but the examination was offline. The designed questionnaire was given at the end of the

course to the learners. The learners who have agreed to participate and 100% filled questionnaire was only considered.

TABLE I. THE DESIGNED QUESTIONNAIRE

Item no	Item	Parameter
1	After reading the lecture materials, how many classes have you attended?	Self-learning and engagement
2	After reading the lecture materials, how many of the problems in the proposed curriculum were you able to solve by yourself?	Self-learning and engagement
3	Does the proposed course emphasize spending significant time studying and doing academic work?	Self-learning and engagement
4	Does this method of learning make you more engaged or understand the subject better?	Self-learning and engagement
5	How often have you asked questions in class or participated in class discussions?	Active and collaborative learning
6	How often did you discuss with your friends for solving the problem given in the course/subject?	Active and collaborative learning
7	How often you have worked with other students for completing the given assignment?	Active and collaborative learning
8	How many times you have worked with your classmates outside of the class to complete the given assignment?	Active and collaborative learning
9	How often you have tutored or taught other students during this course/subject learning?	Active and collaborative learning
10	How often you have referred to electronic mediums (Google, chats, blogs, open courses, etc.) to complete your given assignment?	Active and collaborative learning
11	How many course-level problems you have solved by yourself?	Active and collaborative learning
12	How often you have solved problems using the theory of your course?	Higher-order thinking
13	How often you have analysed a problem?	Higher-order thinking
14	Do the assignment problems relate to design and synthesis?	Higher-order thinking
15	Have you been familiar with any design tools/ software related to your course/subject?	Higher-order thinking
16	Is this way of teaching effectively clear your doubt?	Satisfaction
17	How would you rate this course/subject in terms of your overall educational experience?	Satisfaction
18	How do you rate your skill as desired from the subject?	Satisfaction
19	If you could start over again, would you go for the same method of learning?	Satisfaction
20	How well does the course provide reference materials for achieving the intended outcomes?	Continuous Updating and promotion
21	Are the reference materials provided in the course cover your learning strategy and learning approaches?	Continuous Updating and promotion
22	Does the curriculum include relevant reference materials in the context of the current requirement?	Continuous Updating and promotion

III. RESULT AND DISCUSSION

The semester results were collected and compared for both the control group which followed traditional teaching and the experimental group which followed the above methodology.

A. Semester Performance

The semester result was considered for comparing the result. The dropout rate in the experimental group was reduced by 13.42%, again the fail rate too dropped by 5.49%. The semester results were in grades. Fig. 2. Shows the trace of the grades obtained by the experimental group and control group. Considering these the Mean of the semester results was found to be 5.3(Standard deviation is 3.00) for the control group and the experimental group was found to be 6.76 (Standard deviation is 1.867).

B. Effects of the Parameters on Academic Performance

The detail items for each parameter is shown in Table I. Each grade is then correlated with each questionnaire of the five parameters as defined in Table I. Both Pearson correlation and Eta correlation are done and the result is shown in Table III. It was found all the questionnaires are positively correlated with the academic performance of the learners. All the items of the self-learning parameter are fairly correlated with the performance (r-value range from + 0.275 to +0.314) and item related to solving the self-assessed problem-set had the highest correlation with the performance. The second parameter, active and collaborative learning had a positive correlation but the correlation value was a bit low (+0.151 to +0.246). The highest correlation in this parameter is how much the learners solved problems by discussing with peers. The parameter higher-order thinking had the highest correlation values among the five parameters (+0.235 to +0.349). The questionnaire related to solving the problem related to the theory of the course is most correlated. The satisfaction parameter's item also had a positive correlation (+ 0.159 to +0.246) with the student's performance. Among the four items the item that states "the TLP, when applied in large classrooms can effectively clear their doubts" has the highest correlation. The continuous updating and promotion parameter was designed to measure the effect of the outcome-based curriculum. The result shows that it also had positive values (+ 0.134 to +0.201), and the item stating reference materials helped to achieve the stated outcomes had the highest correlation value. As stated by Pintrich, the correlation values below 0.01 are the least important, values in the range +0.01 to +0.02 have a small relationship, and the obtained values in the range + 0.01 to +0.02 are small, and from +.020 to +0.55 are statistically very meaningful[13].

IV. CONCLUSION

In these two decades due to evolution of ICT based tools, technology and resources demanding change in the education

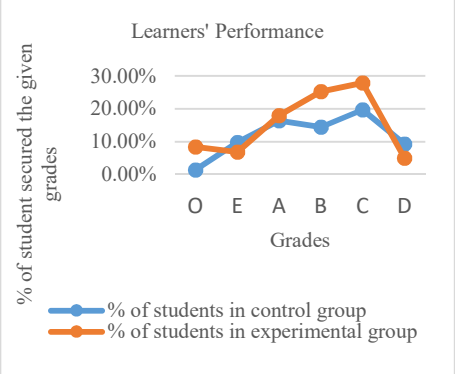

Fig. 2. The trace of the grades obtained by the experimental group and control group.

system. The main focus is the learner's taking responsibility for their learning and acquiring the skills needed. The result obtained shows improvement in academic performance, the fail rate also decreased by 5.49% and the dropout rate decreased by 13.42%. We also studied the effect of the different parameters: self-learning, active and collaborative learning, higher-order thinking, satisfaction and continuous updating and promotion on academic performance. All the items of the stated parameters had positive effects on academic performance. The self-learning parameter was found to have the highest effect on academic performance. Again, the semester questions for the corresponding course were not framed according to the course outcomes . In future, we will compare the performance on the questions framed according to the stated outcomes and compare the result which may show more difference. The TLP made the learners understand the skills they need to have as technical graduates.

TABLE III. CORRELATION OF PERFORMANCE WITH THE ITEMS OF DIFFERENT PARAMETERS

Correlations of Performance with:	**Pearson Correlation(p=0.001)**	**Eta Correlation**
SL01	r = 0.273	η =0.310
SL02	**r =0.314**	**η =0.352**
SL03	r =0.252	η =0.316
SL04	r =0.275	η =0.291
ACL01	**r =0.244**	**η =0.280**
ACL02	r =0.246	η =0.256
ACL03	r =0.180	η =0.208
ACL04	r =0.157	η =0.173
ACL05	r =0.176	η =0.180
ACL06	r =0.219	η =0.257
ACL07	r =0.151	η =0.173
HOT01	**r =0.349**	**η =0.378**
HOT02	r =0.236	η =0.254
HOT03	r =0.235	η =0.247
HOT04	r =0.248	η =0.251
SAT01	**r =0.246**	**η =0.269**
SAT02	r =0.203	η =0.225
SAT03	r =0.159	η =0.171
SAT04	r =0.186	η =0.190
CUP01	**r =0.201**	**η =0.270**
CUP02	r =0.134	η =0.156
CUP03	r =0.165	η =0.178

The TLP for two semesters: even semester 2020 and odd semester 2021 were in online mode. The result shows the appliance of the TLP in online mode. In future, we will study how to improve the TLP for applying efficiently in online mode.

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OTEACH: Empowering Teachers for Effective Technology Integration in Resource-Constrained Schools

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Abstract*— The integration of technology in the educational context has become an inevitable reality, especially after *Covid-19*. However, merely instructing teachers to use digital tools may not be sufficient for effective implementation of technology in classroom practices. Also in resource-constrained schools, teachers express a desire to use technology but often lack the necessary technological and pedagogical knowledge for effective integration. The *Digital Learning Solution* (DLS) project aimed to tackle the challenges of integrating technology into the pedagogical practices of teachers in resource-constrained schools in Mumbai. Also purpose was to tackle the challenge of integrating technology into teaching- learning practices for 8th-10th grade teachers. The teacher's capacity building program, OTEACH was designed based on the Technological Pedagogical Content Knowledge (TPACK) framework, emphasizing the importance of aligning technology with pedagogy and recognizes the importance of contextual relevance in technology integration. The *OTEACH* is a three-year progressive course with a tiered approach. The *OTEACH* program comprises two components: OTEACH workshop and Teacher Assistance (TA) Sessions. The workshop offers technical skills, hands on & TA assist in classroom application. In workshop, teachers learn TPACK framework with TPACK Cards(Kit). It facilitates teachers' exploration of content, pedagogy, and technology. The *OTEACH* helped in upgrading the digital and pedagogical skills of teachers. The result shows that teachers show significant improvement in their post-test as compared to the pre-test and 87% of teachers implemented *OTEACH* learning in classrooms. The key takeaway is, Effective teacher training necessitates engaging, context-specific workshops in regional languages, complemented by ongoing personalized support.

Keywords—TPACK, OTEACH, TPACK Kit, Resource Constraint, Technology, Pedagogy

I. Introduction

In today's educational landscape, technology integration has evolved from a novelty to an essential requirement. After *Covid-19*, the technological use and its adaptation are further accelerated and teachers were trained on conducting online sessions and using digital tools to facilitate participation, conduct online assessments, etc. Though it has supported in transition from face-to-face to online teaching during the pandemic, teachers simply using digital tools and resources might not be enough [1]. Emphasizing the integration of ICT into the teaching and learning process goes beyond mere technology adoption. It highlights the transformative potential of new technologies in fostering a deeper understanding among learners [2]. Hence there is a need for teachers to have content knowledge, pedagogy knowledge, and technology knowledge for using technology [3]. But most importantly for technology integration in their practice, they should be able to integrate all three types of knowledge [4]

Especially in impoverished schools, it is essential to put pedagogic strategies in place to improve the working conditions of teachers with technological developments [5]. The project work focuses on the capacity building of teachers in resource-constrained schools where resource-constrained refers to schools with limited. availability of learning resources, classroom space and digital devices. Also, students in these schools have limited availability of resources at their home. The resource constraint is of two levels in the education system, Material Resource Constraint (MRC) and Intellectual Resource Constraint (IRC). The MRC imply shortage of digital device and network facilities, while IRC refers to limited skill to use digital platform [6]. The project holistically focuses on supporting schools with material resources as well as teacher capacity building. The primary focus of this work is teacher capacity building.

The project works with a vision of creating a digital ecosystem in resource-constrained schools. To achieve the same, we aim to strengthen digital teaching-learning practices of teachers (teaching, assessment, etc.). The project started as a response to COVID-19 where the focus was on providing access to digital content and tools during pandemic. After *Covid19*, the project focused on teacher's capacity building on effective integration of technology in teaching-learning. The

project has a 3-year teacher capacity building program, out of which the second year's training is designed based on the TPACK framework. The teachers training program is known as OTEACH. In year 1, during *Basic* OTEACH, while interacting with the basic teachers or subsequently supporting the teachers through teacher assistance (TA) sessions, the facilitator observed that teachers had content knowledge, but they did not have either pedagogy or technological knowledge for using technology in their teaching process in the classroom. These finding is consistent with finding that in resource-constrained schools teachers wanted to use technology to support teaching and learning but they lacked technological and pedagogical knowledge for integrating technology [7].

II. Program Design

A. OTEACH Program Evolution

OTEACH is a training initiative by the *Digital Learning Solutions project* of *Kotak Education Foundation (KEF)* to upgrade the digital and pedagogical skills of the teachers of the KEF intervened resource-constrained schools. It is based on IIT Bombay's curriculum of Online Teaching (https://sites.google.com/view/iitb-teachonline). And content was adapted to the specific needs and context of KEF partner school teachers.

The OTEACH was designed as a three-level program, *Basic*, *Intermediate*, and *Advanced*. The *Basic* OTEACH is conducted with first-year teachers, and its content was designed based on Constructive Alignment, and technology is looked at as an augmentative tool at this level. The *Intermediate* OTEACH is conducted with teachers transitioning into the second level, Intermediate, and content was designed following TPACK framework. The *Advanced* OTEACH is conducted with teachers transitioned into the third level, *Advanced*. The content is designed so that teachers can sustain their learnings through research on their classroom practices, establish and sustain professional learning community (PLC) and create, curate and contribute to open education resources (OERs) as shown in figure-1

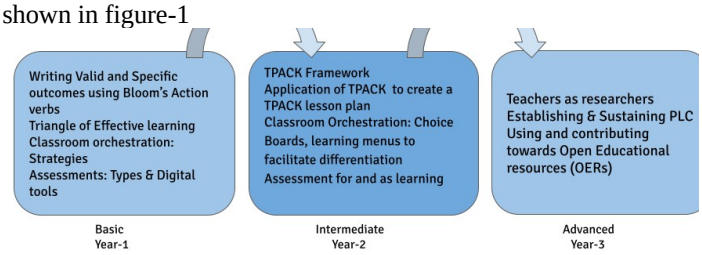


Figure-1 Details of Oteach program levels

B. OTEACH Design

As shown in Figure-2, the OTEACH program comprised two main elements: the OTEACH workshop and Teacher Assistance (TA) sessions. The workshop spanned 8 hours, encompassing a full day, to offer a conceptual understanding of crucial principles and frameworks, coupled with hands-on experience with various technological tools. Additionally, through TA sessions, teachers received personalized guidance to effectively integrate the insights gained from the OTEACH workshop into their classroom practices. The pre-test and post-test assessments were conducted before and after the workshop, whereas the End-line assessment took place at the end of the project.

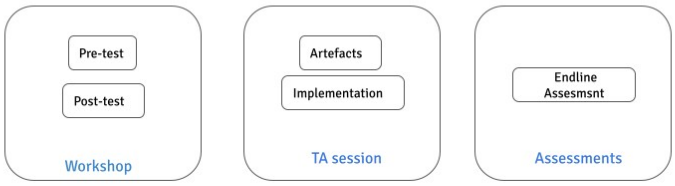


Figure-2 Stages within Oteach level

III. Implementation

The implementation focuses on second level, *Intermediate* teachers and schematic diagram of implementation session is shown below in figure-3

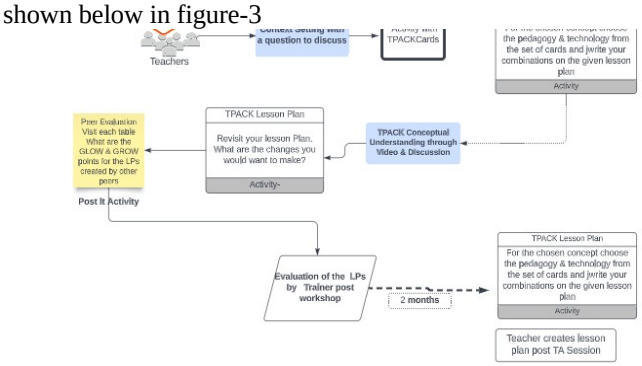


Figure-3 Oteach program implementation for intermediate level

Before commencing the *Intermediate* OTEACH workshop, the teachers were organized into groups based on their respective subjects. The OTEACH workshop was conducted in three sessions. The initial session, "*Unpacking TPACK*," involved teachers delving into the TPACK framework using *TPACK Cards* shown in figure-4. These instructional aids were created to assist teachers in effectively exploring combinations of content, pedagogy, and technology within the TPACK framework. Typically, these cards contained prompts related to technology and pedagogy, guiding teachers in their lesson planning process while considering the intersection of technology, pedagogy, and content knowledge. These played a key role in the exploration of the TPACK Framework. The design of TPACK cards aims to scaffold teachers' thinking, promote reflection, and stimulate discussions.

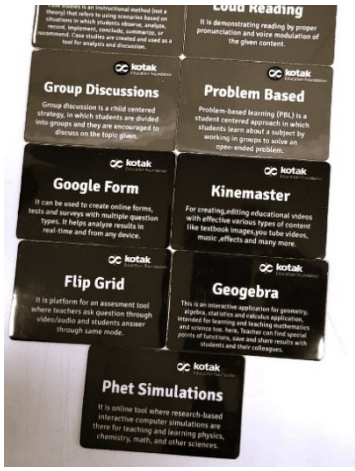
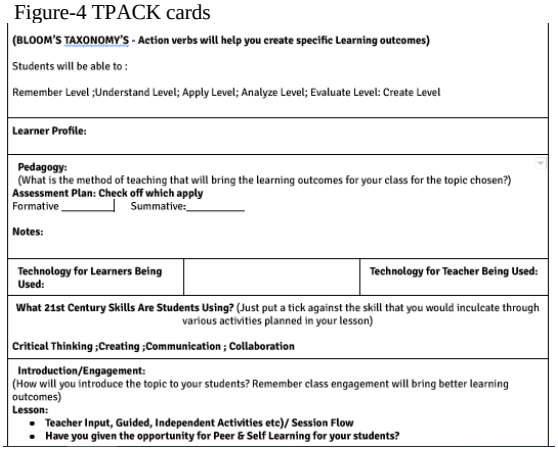


Figure-4 TPACK cards



(BLOOM'S TAXONOMY'S - Action verbs will help you create specific Learning outcomes)

Students will be able to :

Remember Level ;Understand Level; Apply Level; Analyze Level; Evaluate Level: Create Level

Learner Profile:

Pedagogy:
(What is the method of teaching that will bring the learning outcomes for your class for the topic chosen?)
Assessment Plan: Check off which apply
Formative _____ Summative:_____

Notes:

Technology for Learners Being Used:		**Technology for Teacher Being Used:**

What 21st Century Skills Are Students Using? (Just put a tick against the skill that you would inculcate through various activities planned in your lesson)

Critical Thinking ;Creating ;Communication ; Collaboration

Introduction/Engagement:
(How will you introduce the topic to your students? Remember class engagement will bring better learning outcomes)
Lesson:

- **Teacher Input, Guided, Independent Activities etc)/ Session Flow**
- **Have you given the opportunity for Peer & Self Learning for your students?**

Figure-5 TPACK template

During the session, the discussion for TPACK was facilitated by asking a contextual question: *What are the things that a teacher would require for a lesson with better student engagement and outcome?* The responses of the teachers were recorded on the whiteboard and later bucketed into three areas *Content*, *Pedagogy*, and *Technology* by teachers themselves through effective questioning by the trainer . In this activity, teachers were asked to collaborate on developing a lesson plan. They began by selecting a topic or concept they intended to teach. Each table was provided with a set of pedagogy and technology cards (TPACK Cards). During this process, teachers defined specific learning outcomes they wanted their students to achieve by the end of the lesson, using Bloom's taxonomy action verbs. Subsequently, teachers selected the appropriate teaching method (pedagogy) and technology tools from the provided cards. Through discussion, they arrived at a combination of content, pedagogy and technology tailored to their chosen topic. The teacher was given a TPACK template as shown in figure-5 where they recorded their first idea of Content, Pedagogy, and Technology. After this step, the teachers were given a conceptual understanding of the TPACK framework through a video along with discussion on the context and demographics of the learner for technology interaction. The video included the exploration of TPACK framework with relevant examples. It also included the croiterias to be included for technology integration. Following this, the teachers were asked to revisit their lesson plans and check their combination of content, pedagogy and technology for the topic chosen by them. The teachers were also prompted to consider their demographics and context of learner After that, a World Cafe activity (The World Café method is designed to connect participants over multiple ideas and perspectives on a topic by engaging them in small-group conversation) was conducted where teachers visited each table to share their Glow and Grow points on the TPACK lesson plans created by other teachers on other tables.

The second session was focused on the pedagogy element where teachers explored how affordable technology strategies like using choice boards and learning menus can be used in classroom orchestration and help them address students at different learning levels.

During the *third session*, the teachers engaged in a discussion about the role of assessments in the teaching and learning process. The trainer explored strategies for assessment for learning and introduced the concept of Assessment as Learning, which involves students self-assessing their own progress. The training session followed an iterative approach, prompting teachers to revisit their lesson plan templates and consider whether any updates were necessary to better align with their specific teaching contexts and the newly acquired insights about assessments. During the activity the teachers got an opportunity to go through a set of reflective questions like- *Is the combination for content, pedagogy and technology formed logical? Is this combination apt for my students and my context? Will this combination work for my class? Yes/ No *If No, what challenges may they face*

IV. ANALYSIS AND RECOMMENDATION

A. Participants

In this study, we discussed in detail about *OTEACH* training for intermediate teachers in the year 2022-23. These teachers were from resource-constrained schools teaching Maths, Science, English to grades 8-10. There were 241 teachers from 64 schools eligible to participate in the second year of training, with an almost equal distribution of males (116) and females (125). The average age of the teachers was 47 years with SD equal to 6.

B. Analysis

To understand the effectiveness of the *OTEACH* training, pre-test and post-test were conducted at the start and end of the workshop. The pre-test and post-test question papers were not identical but contained similar types of questions. The test paper contained questions about pedagogical

knowledge/strategies, technological tools, the implementation and knowledge of TPACK. It consisted of twenty questions with one mark each.

There were 207 (86%) of the teachers who attended the training session. Out of which 167 (81%) attempted the pre-test and 193 (93%) post-test. There were 161(78%) of the teachers who attempted both the pre-test and post-test. The average performance of the teachers in pre-test and post-test were 8.16 (SD=2.11) and 10.14 (SD=3.20). The performance of teachers in the post-test was higher than their performance in the pre-test. The paired *t-test* analysis with $p=0.05$ showed statistically significant improvement in post-test compared to pre-test. The analysis showed that there was a significant performance improvement.

C. Implementation of Pedagogical practices in classroom

To assess how teachers were applying what they learned from *Intermediate* OTEACH in their classrooms, various artifacts in the form of images, PDFs, and videos were gathered. These artifacts provided valuable insights into teachers' utilization of small group strategies such as Think Pair Share and game-based learning, as well as pedagogical approaches like orchestrating flipped classrooms, SWOT analysis, and choice boards. Additionally, the collection included evidence of technological implementation, with teachers using Edtech tools like PHET Simulations and OLabs. For analysis, teacher implementation was defined as the submission of artifacts at least once after participating in the workshop. Notably, 87% of the teachers, totaling 180 individuals, engaged in implementation following their attendance at the workshop.

A) *Learning:*

a. Teachers actively participate in trainings that engage them and seem important. The training material should be relevant to their needs and easy to understand for better learning.

b. The medium of instruction during the workshop does impact the engagement of the participants.

c. Attending a workshop about technology and pedagogy may provide knowledge, but if we want teachers to implement what they've learned, they may need personalized support and guidance.

d. The Teacher Assistance (TA) sessions assisted teachers in applying what they learned about technology and pedagogy in their classrooms. These sessions fostered a strong connection, allowing for the adjustment of their teaching plans to better suit their specific needs and situations.

B) *Recommendation:*

a. Teachers in resource-limited schools may find TPACK complex. TPACK cards with structured prompts reflective question and can aid their understanding of this framework.

ACKNOWLEDGMENT

The authors wish to extend their heartfelt appreciation to the dedicated members of the Digital Learning Solution Project team for their enthusiastic participation in this endeavor, without their continuous support project implementation would not have been possible. We are grateful for the support and resources provided by the leadership team at Kotak Education foundation which greatly facilitated our research efforts. The authors would like to express their sincere gratitude to Dr. T.G. Lakshmi for her invaluable guidance and mentorship throughout this research project. We also acknowledge the generous funding provided by the Kotak Mahindra Bank.

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Virtual Learning Community for an Online Undergraduate Writing Course to Promote Learners' Interactions and Self-learning

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***Abstract*—Computer-Assisted Language Learning has shown benefits for English Language Teaching (ELT) using Virtual Learning Communities (VLCs), a discussion platform fostering learners' self and peer earning. During the pandemic, many ELT practices incorporated a VLC for students to express their thoughts, feelings, and queries without fear of being judged by peers. This paper demonstrates a use of VLC in an online freshman writing course at the Indian Institute of Technology to complement limitations of online lectures such as one-directional communication and reduced student engagement. The explores how the activities such as group discussion in and beyond their own sections provided room for learner autonomy and self-regulated learning. The synchronous lectures were followed by a VLC activity, and the VLC activity was further discussed during the lecture. This circular practice has linked students' learning to actions organically. This paper emphasizes that the role of a teacher as a facilitator is pivotal in motivating learners to participate actively in the discussion. In a multilingual and heterogeneous classroom with varying levels of English language proficiency, the VLC proved a valuable tool for elementary and intermediate learners as it provides language samples of advanced-level peers. Despite some potential issues like unstable internet connectivity, inadequate power supply, abusive posts, and substandard quality of posted content, the VLC provided a ground for students to think and write without time constraints. VLC can be effectively applied in virtual classrooms, blended learning approaches, and Massive Open Online Courses as a way of achieving learner autonomy and self-regulated learning.**

Keywords—Academic writing, Online classroom, Computer-Assisted Language Learning (CALL), Virtual Learning Community (VLC), Self-regulated learning (SRL)

I. Introduction

Learners in the 21st century classroom are often "digital natives"', tech-savvy and comfortable with showing their ideas on various platforms in the Internet. Keeping up with them, the field of English Language Teaching has incorporated Computer-Assisted Language Learning (CALL) with visible positive effects [1]. Numerous platforms and tools have been utilized, including wikis, Padlet, Google Suite, Microsoft Teams, and Zoom, to facilitate and enhance learners' retention [2]. Furthermore, the need for online platform has increased since the COVID-19 pandemic.

Highly functioning video conference tools such as Zoom and Google Meet enabled many university courses to continue. However, their synchronous nature brought a few downsides for academic writing classrooms that require learners' active engagement: First, online live lectures were prone to be dominated by the instructor's speech, which resulted in limited pupil-pupil interaction. It consequently reduced peer-learning, essential for writing classroom. Second, the synchronous mode demanded learners' instant reaction, and it was often interrupted due to external circumstances (e.g., unstable internet) or students' inability to enact higher-level thinking on the spot. These called for a way to promote students' self-learning and learner autonomy in the virtual course.

This paper demonstrates a case of online academic writing course for first-year Engineering students that employed a student-centered discuss forum, or a *Virtual Learning Community (VLC)*, to complement online lectures in the way of facilitating pupil-pupil interactions and streamlining students' writing process. Section II illustrates the design and setup of the VLC for the writing classroom. Section III shows the role of asynchronous VLC activities, located between a live lecture and a live discussion session, to maximize students' engagement and performance. In section IV, we evaluate the course conducted with VLC activities in the Spring semester, 2022, and section V concludes this paper with implications and future projections.

II. Developing a VLC for a Writing Course

A. Conceptual Design

Our design and setup for Virtual Learning Community (VLC) was based on the recent approach [3, 4] of employing both synchronous and asynchronous modes for e-learning to receive better results in the classroom. The asynchronous mode was attractive to us, especially during the pandemic, because it provides students with room for pondering on given topics and sharing their thoughts, as pointed out by [4].

Moreover, in the academic year 2021-2022, around 250 first-year B.Tech. students were allotted to 8 individual sections for the two-semester academic writing courses. Most students took classes from home without enough exposure to academic environments, and naturally their socialization above the section was restricted. Even in the individual sections, student socialization was limited to small-group activities in the breakout rooms or use of the chat box with reactive remarks and emojis.

Under this backdrop, cross-sectional 3 VLCs were created by a collaboration with Yellowdig, an online learning platform with gamifying components for pupil-pupil interactions, and students were assigned to them VLCs (approximately. 77, 88, and 85, including repeating students) based on their proficiency levels of English. The level-based division was made under the assumptions that (i) interaction and peer-learning would be maximized when grouped in a

We thank the Maker Bhavan Foundation for supporting course development.

similar proficiency level and (ii) a VLC would operate well with a greater number of students than one section (i.e., around 30) for active online interactions. This cross-sectional mixing also aimed for additional socialization with cohorts.

Asynchronous VLC activities were streamlined between two synchronous modes: live lectures and the live discussion sessions, as illustrated in Fig. 1. At the end of the lecture, a topic for VLC activity was assigned, and students shared their posts and left their comments to their peers' posts. This activity was further connected to the live discussion session.

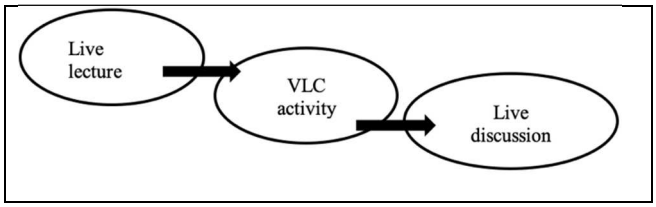

Fig. 1. Flow of writing course activities per week.

The course met three days a week, two lectures and one discussion session. In the academic year 2021-22, the discussion session was offered at the beginning of the week. Thus, students could use the weekend for VLC activities.

B. *Structure of VLC: Point, Post/Comment, and Tag*

To incentivize learners' active engagement, VLC participation takes 5% of the final grade. It is calculated based on the 'point' system, under which students collect points based on the number of created posts and comments. Tables 1 and 2 show the point assignment structure.

TABLE I. POINTS FOR CREATING A POST/COMMENTS

Points	Activity
280	Creating a new point (minimum words: 30)
210	Commenting on another user's post (minimum words: 15)
60	Receiving a comment from another user
45	Receiving a reaction from another user
	Weekly point goal is 750[a]

[a] Per week, students can take maximum 1050 points.

TABLE II. CONVERSION OF POINTS TO FINAL SCORES

Score	Criteria
5 / 5	Those who earned 11,250 or more
3-4 / 5	Those who earned 10,000-11,240 points
1-2 / 5	Those who earned 7,000-9,999 points
0 / 5	Those who earned less than 7,000 points

Posts and comments are two key items students create in the VLC. Using posts, they express their ideas directly; with comments, they interact with community members. When creating a post, users are supposed to use one or more tags that indicate the topic of the post. Tags include specific weekly topics (e.g., *Drafting Essay*, *Public Speech*) and general markers for reflection and pupil-pupil communications (e.g., *Weekly Reflection*, *Need Help*). For example, Fig. 2 is a students' post titled 'AI in Fraud detection', created as a VLC activity of choosing the topic for their end-of-the-module writing assignment. It is marked with two tags, 'My Favorite Topic' and 'Presentation Tips', and two classmates made supportive comments on the post.

Students were advised to make two posts, one for a week-specific activity and the other for weekly reflection, and three to four comments to get the full mark. As mentioned in Table 1, there is a weekly limit in collecting points (i.e. 1050), to keep students visiting the VLC on the regular basis. All course instructors and teaching assistants were nominated as VLC managers to regulate week-specific topics, violation of code of conduct, and various tasks.

III. SHOWCASING FLOW OF LECTURE-VLC-DISCUSSION

This subsection shows a VLC activity in week 10 as an example. Lessons of week 10 marked the beginning of the last learning module, *academic writing*. Live lectures introduced the genre of academic writing and features of a good topic for academic essays. At the end of the lecture, the week's VLC activity instruction was given, requesting them to choose their topic for their end-of-the-module writing project, as illustrated in Table III. Students were asked to make a relevant post before the next discussion session.

Fig. 3 is a screen-captured image of students' post and comments for week 10. The post writer shared a topic of his/her choice with the tag 'My Favorite Topic' with the link of a article related to the topic. Two classmates wrote comments positively assessing the choice of the topic. There are also options of emojis for expressing their feeling for both posts and comments: Comments can also receive 'like', as shown in the comment at the bottom.

TABLE III. EXAMPLE INSTRUCTION OF VLC ACTIVITY FOR WEEK 10.

For the next session, we will start working on writing an academic essay. Choose a topic you are interested in and use your research skills to find one article about the topic. Read the article and then post the topic as well as the article links on VLC.

When choosing a topic, consider the following areas:

- Science and Technology (e.g., genetic engineering)
- Culture and the Arts (e.g., art as activism)
- Entertainment and Sports (e.g., Hindi cinema)
- Politics (e.g., government corruption)
- Social Issues (e.g., illiteracy)

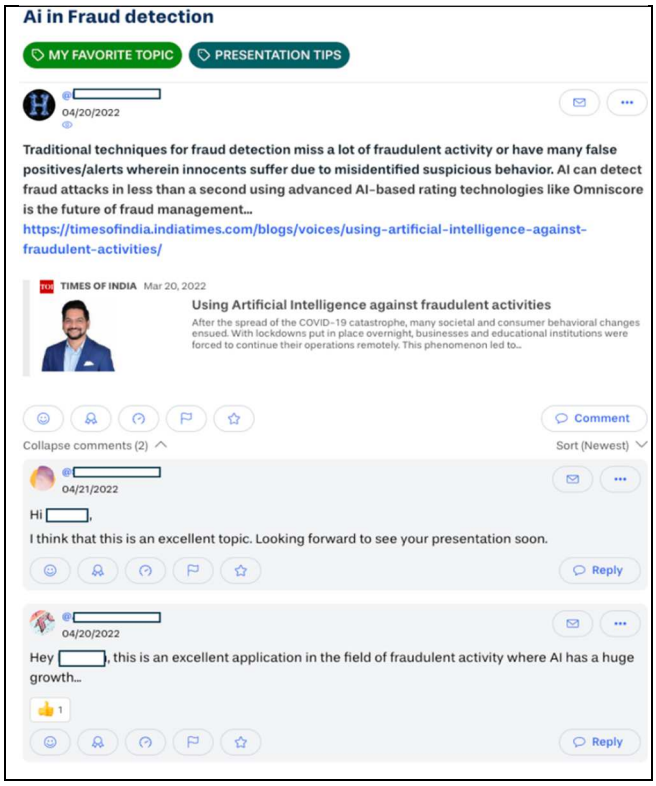

Fig. 2. Example post with tags and comments.

The live discussion session followed the VLC activity led by individual section instructors. They used students' posts and comments in the VLCs for students' self- and peer-assessment. Table IV contains part of the instructions made in the live discussion.

TABLE IV. EXAMPLE TASK OF DISCUSSION

Go to your VLC community and identify two posts you find the most impressive. What are they and why did you choose them? (10 minutes for identifying posts; 20 minutes for class discussion) Is there anything you wanted to post but did not or you want to add now? (15 minutes for class discussion)

In this way, VLC tasks facilitated students' expanding their practice in continuation with the lecture, and they were further strengthened by live discussion.

IV. OBSERVATION AND DISCUSSION

The VLC operated for 15 weeks, from January 13 to April 28, 2022, with a total of 18 tags. 52.7% of the students received the full mark; 64.5% received 3-5 points out of 5, as shown in Fig. 3.

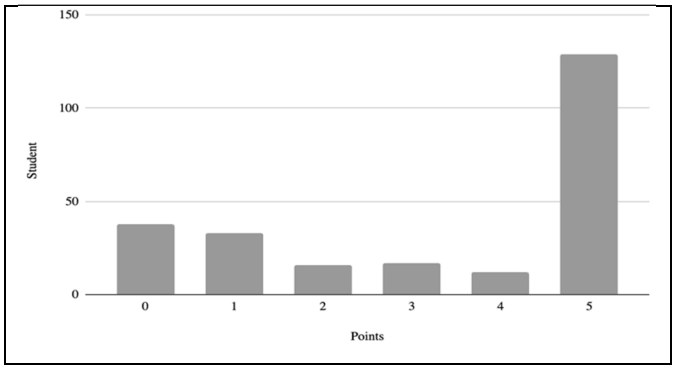

Fig. 3. Final VLC scores of students out of 5.

A. Self-regulated Learning

We observed self-regulated learning (SRL) and learner autonomy during the VLC activities. Learner autonomy, "the ability to take charge of one's own learning" [5], as well as SRL has been considered one of the crucial phenomena in the teaching and learning process, and researchers have shown the significant importance of SRL in online learning [6-9].

Our student population consists of people from various language backgrounds with varying degrees of English language proficiency. For their overall growth in academic writing, VLCs provided comfortable and solid learning environments especially for beginners and intermediate English speakers. They sought help using 'Need Help', and meaningful conversation occurred. Reading and responding to peers' work assisted them in navigating rich language samples and practicing their own styles. This implicit learning process is believed to be crucial in the online academic writing class.

In addition to contributing to students' implicit learning, the VLCs also worked as support groups. For example, a pupil-pupil interaction boosted their confidence level. In Table V, a student posted about his/her presentation topic, and two classmates provided their feedback with a positive and encouraging manner. In the first week of VCL activities, part of live lecture was devoted to online conversation etiquettes and positive and gentle attitude in the support group setting.

TABLE V. EXAMPLE OF PEER FEEDBACK IN THE COMMENT BOX

Post	I chose Time Management as my topic for the presentation. It is quite reletable in times like these. It is an ideal scenario for the audience as well because all of us are going through hectic days and will help me express my honest opinions.
Comment 1	Hey OOO, Your topic is quite fascinating and hoping that your presentation is going to reach everyone.
Comment 2	Hey OOO! Your topic is really interesting. And yaa it is very important to manage time in our coming days. Hope your presentation went well.

We also witnessed that pupil-pupil interaction fostered peer-assisted troubleshooting. Table VI shows an example of a student's post about a challenge in using a search engine and a peer's comment. The peer first showed empathy and then suggested a way to resolve the challenge. With many examples like this, our VLCs became a platform that helped reduce anxiety and frustration. This function complemented a hindsight of live Q&A sessions, especially when underconfident students hesitated to stand up and share their private challenges in the classroom setting. The digital platform created a place where students could resolve issues at their own pace without facing the live audience. The system of students inviting peers for troubleshooting [10] was sometimes also assisted by instructors and teaching assistants on VLC as well.

TABLE VI. EXAMPLE OF A SUPPORTIVE COMMENT

Post	Hi everyone In this week I learn innovative things like Google scholar, it helpful to find specific articles. But it is more difficult to find the information related to my topic. At the end I got some clarity to use the Google scholar but some thing is missing....
Comment	Hello, OOO even I too learned something new about this google scholar. You can find sources using proper keywords easily.

In addition, the use of emojis and reaction buttons in the post and comment boxes is believed to engage students even more. They enjoyed using them for their near-to-social-media vibes. The tools were frequently observed when students conveyed their feelings or added humor to the conversation. Table VII exemplifies the use of a smiley emoji and symbol +.

TABLE VII. EXAMPLE OF A FUN-PLAYFUL INTERACTION

Post	Hello Everyone, I hope you all are doing well. This week I learnt about how to give feedback. Start with positive feedback. Then do not give comparative feedback.Receiving a reaction from another user
Comment	Hi OOO ! I want to give you positive feedback for this post. +++ +++++++ +++ +++++++++ ++ ++++++++++++++++++++++++++++□

B. Instructor's Role

To ensure successful operations, instructors and teaching assistants took part as managers and facilitators inside and outside of VLCs. All activities were mediated at the live lecture, and we guided students' in-class activities so that

much of the contents was taken care of in the synchronous mode and students took the liberty of peer interactions and socialization at the VLC, except for one task. It was challenging to keep a fine line between promoting students' post/comment generation and suppressing over-generation that might interrupt the flow of discussion. The efforts were theoretically predicted by [11,12]: Both physical and virtual classroom teachings demand the instructor's active role in students' achievement learning objectives and enhancement of knowledge. Especially, during online discussions, the instructor had to choose wisely about when and how to communicate in the ongoing students' discussion.

The topmost mission of the instruction team in managing VLCs was to make students feel protected, inclusive, and unbiased. Despite the sessions on communication etiquettes, learners sometimes showed irregular behaviors that called for our intervention. There were a couple of incidents where the we intervened and controlled the discussion. For example, one student created a post containing a discriminatory remark against a group, and we flagged the post and made it invisible to other students. We learned how to lay low with an eagle eye on discussion, and it matches the perspective of [12], which states that instructors have to enact the role of sage, guide or sometimes ghost. What was surprising in the aforementioned case is that many peers responded to the post criticizing the discriminatory point of view. Thus, student's autonomy and self-regulation also played out in the case of managing discourses.

C. Advocacy of VLC

The study indicates that VLC have acted as an online platform where learners gather and interact for a better learning in general. Additionally, the government's policy supports the idea of including e-learning at the higher education level. For example, government institute like the National Informatics Center, University Grants Commission, All India Council of Technical Education, and Department of Science & Technology encourage e-learning processes throughout the country [13]. The studies in English language Teaching also support the potential advantage of VLC displaying the probabilities of various types of communication. Moore's theory of transactional distance enlists the three forms of communication/interaction in the online mode of learning: learner-teacher, learner-learner and learner-content [14]. In addition, many studies [15-19] advocate the use of VLC in language learning.

V. Conclusion and Projection

The practice and observation of current practice with VLCs reiterate [7], "online discussions provide an important training tool and foster collaborative and flexible group learning". Despite potential issues like unstable internet connectivity, inadequate power supply, abusive posts, and substandard quality of posted content, the VLC provided a ground for students to think and write without time constraints. This model can be effectively applied in virtual classrooms, blended learning approaches, and MOOCs (Massive Open Online Courses). All in all, utilizing CALL has enabled our writing course to overcome the limitation of virtual classrooms by boosting engagement and facilitating self-regulated learning. In the future task is to improve and apply the VLC format to other courses in various format.

Acknowledgment

We thank instructors and teaching assistants of the course *Introduction to Writing - II* in the academic year 2021-2022. We deeply appreciate that the freshmen writing courses at the Indian Institute of Technology Gandhinagar were generously supported by Maker Bhavan Foundation in 2021-2022. We also thank Yellowdig and Active Learning Sciences Teams for their excellent help when modeling the course.

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Teachers as Troubleshooters: Making ICT Lab in School an Active Space for Innovative Teaching and Learning

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***Abstract*—In India the Information and Communication Technologies (ICT) have been introduced in the school ecosystem by way of ICT lab or computer lab. However, numerous studies and reports have found that many ICT labs in schools do not function properly. Due to lack of funds and non-availability of technical personnel in the remote and rural areas even a smallest technical glitch renders devices dysfunctional. Even today, the government schools do not have any provision for a computer technician and most of the teachers are still catching up with basic digital literacy skills. Moreover, there is a culture of fear of breaking-down the devices and machines. Therefore, when encountered with an issue no one dares to try to troubleshoot the computing devices thereby rendering a large number of school ICT labs non-functional. With a view to address this challenge and to make the ICT lab in school an active space for innovative and technology enabled teaching-learning we experimented to develop teachers' technical capabilities and attempted to orient teachers as troubleshooters and maintainers of the school ICT lab. As part of a large scale technology integration project in government schools across India we developed and offered a teacher professional development course. Originally designed for a blended mode of instruction, due to covid-19 restrictions, the course was offered in online mode to three cohorts of total 191 in-service government school teachers in the states of Telangana, Chhattisgarh and Mizoram. The course was offered over six weeks and included synchronous online sessions and asynchronous activities of hands-on/practical nature which needed to be shared on a learning management system. Based on the assessment performance a substantially high number of course participants (77.45%) successfully completed the course and received the certificates. This paper outlines the design of the course and its implementation with the three cohorts. Analyzing the data generated by online course platform, feedback by course participants and experiences of course designers/instructors, the paper examines the viability of the model of 'teacher as a troubleshooter' to sustain ICT lab in schools and suggests recommendations for the future.**

Keywords—school ICT lab, ICT in education, teacher professional development, teachers as troubleshooters

I. Introduction

With the pervasive and inescapable use of computers and technology in education there appears a broad consensus on the need for teachers to develop capabilities and professional competence to teach with technology. In the technological, pedagogical, and content knowledge (TPACK) framework [1] Harris, Mishra and Koehler have argued that in addition to the essential pedagogical and content knowledge (PCK), teachers now need to cultivate technological knowledge too, in order to effectively integrate technology in everyday teaching. The National Education Policy - 2020 of India [2] recognizes the need for teachers' professional development in technology enabled teaching and learning as well as the need to create supportive infrastructure. Similarly it has been widely emphasized that teachers as drivers of educative process in the school ecosystem need to develop information and communication technology (ICT) literacy and digital competencies that could range from awareness to ability to effectively use and even create thoughtful content that could engender innovative pedagogical practices and better learning outcomes [3], [4], [5].

While there have been multifarious efforts to upskill teachers with ICT and digital literacy skills there is a burgeoning challenge that is creating hindrance to the efforts of technology integration in education - the lack of technical maintenance and malfunctioning of computer devices in the school ICT lab. This is a crucial issue. Because in India the Information and Communication Technologies (ICT) have been introduced in the school ecosystem by way of ICT lab or computer lab. An ICT lab is generally a dedicated room with 10 or more computers connected in a local area network (LAN). Sometimes the lab is equipped with a projecting device such as a projector or a digital display screen, and internet connectivity. Seldomely the classrooms are equiped with any technology. That means the technology use and integration in the teaching-learning process is dependent on the functioning of the ICT lab in school. Numerous studies and reports have found that many ICT labs in schools do not function properly [6], [7]. Because, the computers, the software applications installed in them and the peripheral devices in ICT labs frequently malfunction. These devices need regular maintenance and upkeep. And, due to lack of funds and non-availability of technical personnel in the remote and rural areas even a smallest technical glitch renders devices dysfunctional. Even today, the government schools do not have any provision for a computer technician and most of the teachers are still catching up with basic digital literacy skills. Moreover, there is a culture of fear of breaking-down (kharab hona in Hindi). Therefore, when encountered with an issue no one dares to try to troubleshoot the computing devices thereby rendering a large number of school ICT labs non-functional.

With a view to address this challenge and to make the ICT lab in school an active space for innovative and technology enabled teaching-learning we experimented to develop teachers' technical capabilities and attempted to orient teachers as troubleshooters and problem solvers of the school ICT lab. As part of a large scale technology integration project in government schools we developed and offered a teacher professional development course. Originally designed for a blended mode of instruction, due to covid-19 restrictions, the course was offered in online mode

to 191 in-service government school teachers in three different states in India over six weeks during 2021. This paper outlines the design of the course, its implementation with three cohorts and laments on the experiences of course designers/instructors (authors of this papers) and that of the participating teachers. Analyzing the data generated by online course platform, the paper examines the lessons learned and suggests recommendations for similar interventions which may be relatable for the technology enabled/integrated TPD in the global south context.

II. Approach and Design Principles

Following the TPACK framework and principles of constructivism and constructionism, the TPD course aimed to develop teachers' technical capabilities with a view to address the challenge of ICT lab maintenance and to make the ICT lab in school an active space for innovative and technology enabled teaching-learning. The course attempted to equip teachers with skill sets to troubleshoot and resolve the commonly encountered technical issues in the school ICT lab.

A. Design of TPD Course

The TPD course named "ICT Lab in school" carrying an academic weightage of 2 credits (corresponding to a total of 50 hours of engagement (15 synchronous + 35 asynchronous hours)) was originally designed for a blended mode of offering (few face-to-face sessions followed by online learning) to be offered over 6 weeks, with 3 days of in person hands-on workshop and subsequent online mode requiring a minimum of 6 hours of weekly engagement by learners.

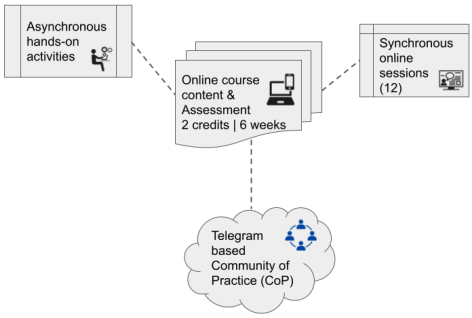

Fig. 1. Course design - ICT Lab in school a course for teachers.

However, due to COVID-19 pandemic, the course was offered in fully online mode. The course structure and content were revised. The hands-on activities were divided into small chunks and recorded as short video bytes. The assessments also had to be revised with the considerations of blended to online mode of the course. Nevertheless, principles of constructivism and constructionism remained embedded as the activities needed hands-on effort by participants.

With the assumption that the teachers taking the course may have absolutely no knowledge of technology the course content was design as low threshold high ceiling - i.e. the content started introduction to basic technology literacy and then gradually moved to cover more technical details of hardware, software, network and finally the setup of ICT lab in school. Table 1 below outlines the unit wise structuring and assessment components.

TABLE I. Course content and assessment structure

Topics	*Assessment Activities and Weightage*
Unit 1: Introduction to ICT	Peer Graded ORA (open response assessment) – 5%
Unit 2: Hardware	Three Peer Graded ORA and Three machine graded MCQ/Drag-Drop – 40%
Unit 3: Software	One Peer Graded ORA and Three machine graded MCQ/Drag-Drop – 40%
Unit 4: Maintaining ICT lab in school	One Peer Graded ORA – 15%

The topics ranged from basic introduction of ICT terminologies to functional aspects of netwroking and troubleshooting computer and netwrok devices in the school ICT lab. The assessment components were of two types: i) to gauge learning and understanding of concepts; and ii) application of understanding through hands-on and learners were to upload proof of their work as actual digital artefact or image/video which were then anonymiously peer graded by learners.

The course was offered on the in-house learning management system (LMS) – TISSx https://www.tissx.tiss.edu – a customized version of Open edX MOOC platform which could be accessed through a browser based web app (for laptop/desktop) or an android mobile app. As can be observed in Table 1, the course was designed to be hands-on and included many activity based assessments. In order to foster collaboration and peer learning the course thoughtfully leveraged the LMS platform features of discussion forum, peer graded assessment and Telegram based community of practice (CoP). The participants were supposed to achieve passing grades (70%) to receive the course completion certificate. In the next section details of implementation will be discussed.

B. Details of Implementation

The course was offered in online mode to three cohorts of total 191 in-service government school teachers in the states of Telangana (cohort-1), Chhattisgarh (cohort-2) and Mizoram (cohort-3) during the year 2021. For each cohort there was a different course run (instance) on the LMS platform which ran between 6 to 8 weeks. All of the course participants were in-service government school teachers, having different subject specialization, and were nominated by the state government's nodal agency - state council for education research and training (SCERT) as part of a large-scale collaborative EdTech intervention - connected learning initiative (CLIx) [8].

The course commenced with 12 synchronous sessions of one hour each for the initial two weeks. The online synchronous sessions covered conceptual aspects of the topics and allowed interaction and opportunities for exchange between course learners and instructors. Subsequently the course participants were engaged on the online course platform (LMS) and through Telegram app based CoP. At the end of the course participants were asked to undertake an online post-course survey (having 20 questions about the course content, structure, learning experience and feedback to instructors) which was strongly encouraged but was voluntary and not tagged to course completion. By making the post course survey voluntary independent of course completion it was hoped to gather genuine and honest responses ensuring reliability and validity of data.

III. Course performance data, discussion and findings

The course yielded some interesting insights. First, this was a unique first of its kind course which aimed to develop government school teachers as technical troubleshooters and

thereby sought to provide a sustainable model for the upkeep and functioning of ICT lab in schools. As shown in Fig 2, the course had a total passing percentage of 77.45% across three cohorts with cohort 1 having a passing percentage of 87.63%. This unusually high passing percentage as compared to general trends of MOOC passing percentage could be attributed to the fact that this course was offered not as a MOOC but as a Small Private Online Course (SPOC). Additionally, since it was mandated by the state government, the teachers had to take the course. There was no choice. Despite this, in view of the subject matter (which was technical in nature) that required teachers to put extra effort to learn and practice, and multiple peer graded assignments (which means the participating teachers had to review anonymous submissions of their peers) such a high passing percentage is a significant achievement.

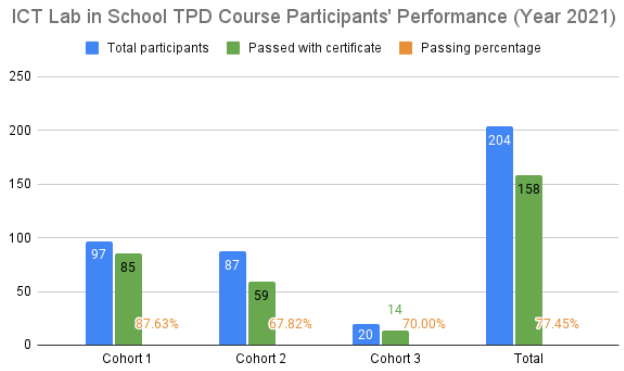

Fig. 2. Performance of course participants in ICT Lab in School TPD course (Year 2021)

Now, let's look at post course survey results. With the aim of gathering genuine and honest responses the survey was made as voluntary and independent of course completion. However, this had a somewhat adverse effect on the data sample. Only 60/158 of the participants i.e. 38% responded to the survey. The quest for reliability and validity of data seem to have skewed the overall data. Nonetheless, the post course survey results give some interesting insights on the experiences of course participants.

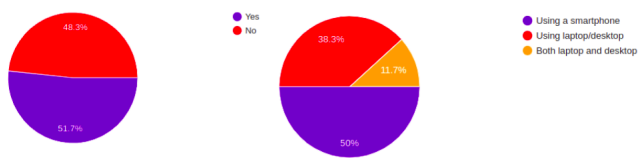

Fig. 3. Did the participants had prior experience of taking an online course and how did participants accessed the course

Out of 60 respondents 39 were from cohort-1, 9 from cohort-2 and 12 participants from cohort-3. 40 Male and 20 female participants responded to the post course survey. Interestingly, for almost half of the respondents (48.3%) this course was the first experience of online learning for professional development (see Fig. 3). And, in terms of devices, half of the respondents had taken the course completely on a smartphone device, while the rest 50% had accessed the course on a laptop or desktop. This is an interesting insight which goes against the popular perception that government school teachers do not have access to laptop or desktop devices.

With regard to the relevance of course content and learnings, a significant majority of respondents (56/60) found the course content very relevant or relevant; Moreover, 61.7% (37/60) respondents said that some of the content was new, whereas only 38.3% (23/60) found all of the content as new. Similarly, while 83.3% (50/60) respondents found the topics, examples and activities given in the course as adequate, 16.7% (10/60) felt the need for more topics and examples. Therefore, it can be inferred that the course content did resonate well with both novice and experienced teachers and teachers do like to understand technical aspects of educational technology.

Can teachers be able to troubleshoot common issues in the school ICT lab and keep it functional? Was the driving question that led to design development and implementation of this course. One possible way to answer this question is to look at the performance of participant teachers in the course (see Fig 2.) which indicates and affirmation. To further triangulate the survey responses on learning outcomes provide deeper insights of this primary objective of this course. An overwhelming majority (88%) of respondent teachers indicated that they felt confident or very confident about hardware and software components in a school ICT lab setup. Only 6.7% teachers did not feel confident in handling the hardware and software components.

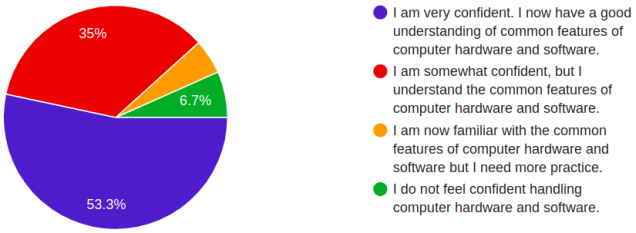

Fig. 4. How confident you are now with regard to the topics you have learned in the course E09-ICT Lab in School?

Similarly, as depicted in Fig 5. Most of the teachers expressed confidence and readiness to take steps which can keep the ICT lab functioning in their schools. That means the teachers were able to successfully don the hat of a troubleshooter! This is a significant finding. Perhaps this manifests TK (technological knowledge) of TPACK.

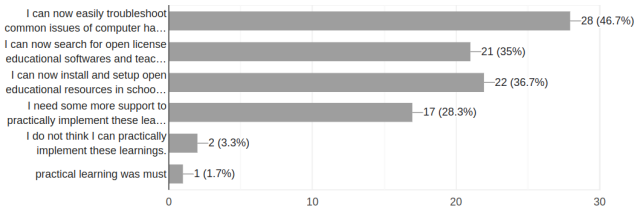

Fig. 5. How do you plan to practically implement the learnings in the course? (can choose multiple)

In regards with the quality of engagement on LMS discussion forum and CoP the observations have been of varied and mixed kinds. Further analysis is required to identify patterns and draw any conclusions.

Overall, 95% of respondents reported having a good or very experience while taking the course. The respondents also suggested some new topics to be included mostly catering to their subject domain teaching. Importantly, many respondents and participants strongly suggested to conduct few face-to-face hands-on sessions (as was envisaged while designing the course in the beginning).

A. *Effectiveness and limitations of the model*

The ICT Lab in School TPD course was not just a course for teachers professional development but a model for sustaining and maintaining essential EdTech infrastructure in schools. The findings from the above pilot implementation indicate that the model has found resonance with teachers. That is, teachers have found it useful to know the basic troubleshooting skills to maintain the ICT lab in their schools. However, since the course was offered during the COVID-19 pandemic when ICT labs in schools were still closed it could not be ascertained whether teachers were indeed able to activate lab and make them functional. However, the course performance of participating teachers and their responses in the survey positively indicate the effective potential of this model – teachers as troubleshooters. Needless to say, the argument of teachers as troubleshooters should not be misconstrued as an attempt to render teachers as technicians or overburden an already crammed schedule of teachers. Instead, the argument and experiment done in this TPD course should be viewed from a digital agency perspective [9]. Digital agency includes competence, confidence and accountability with respect to technology. Troubleshooting is an advanced and higher order skill. It goes beyond literacy. It is about critical understanding of technology. Therefore, by developing the ability to critically understand the available educational technology and ICT lab, teachers become empowered to not only keep the technology functional but also will become empowered to assess, evaluate, select as well as reject EdTech as per their relevance, affordance and pedagogical practices [10], [11].

IV. Conclusion

On the one hand the ICT Lab in School TPD course was an experiment to address the common challenge of dysfunctional school ICT labs. On the other hand, this was also a model to demonstrate ways to cultivate teachers' agency - to own, sustain and nurture school ICT lab as an active space for innovative teaching and learning. The simple, easy to understand low threshold high ceiling design and structure of course seemed to have resonated with the needs and requirements of teachers to keep up with the technological advancements. While a component to ascertain learning outcomes in terms of ground level realities i.e. status of ICT lab in the schools of participating teachers would have given a more reliable sense; nevertheless, the high passing percentage, participation in peer graded assessments for asynchronous activities/practicum and self reported data do indicate the need, relevance and effectiveness of such a TPD model to keep ICT and EdTech infrastructure in schools functional and thriving.

V. Recommendations for Future Practice and Research

- In order to make the teachers efficient and have the effective use of the ICT labs in the school for daily teaching and learning process, teachers should go through such TPD courses that upskill and empower them.
- Ability to troubleshoot and critically understand technology leads to empowerment of teachers and enables them to select, reject or adapt EdTech; this ability can also help to avoid water-tight dependencies on technology vendors and enhances usability.
- Teachers should be encouraged to create help materials and resources on troubleshooting and make those available to other fellow teachers for ready reference.
- Availability of such modular online courses will enable teachers to take advantage of such opportunities; a mix of self paced and open runs, possibly in multiple indian languages will provide more freedom and flexibility for teachers and educators to build their capacities to leverage ICTs and educational technology more meaningfully and confidently.
- Despite teachers' upskilling it is imperative on the government to allocate adequate funds to ensure upkeep, functioning and upgradation of ICT infrastructure in schools.

Acknowledgment

We recognize and thank the pivotal role played by colleagues Vighnesh Nair and Shivani Dixit in designing, developing and offering the course. We also acknowledge the efforts of all the colleagues at the connected learning initiative (CLIx) who helped in various ways to develop and rollout the course in the three states, concerned officials who supported this initiative and teachers who participated in the course.

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Evaluating Effectiveness of Training Students in Prompt Engineering for Generative AI Chatbots

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***Abstract*—Generative AI technology-based chatbots like ChatGPT, Bing AI, Google Bard, etc. are used for various tasks like generating ideas, creating content, writing code, and alike. The research studies have reported the ability of Generative AI tools to help learners develop reflective and critical thinking, creativity, and problem-solving skills. While using these tools, giving effective prompts is critical for obtaining accurate and precise results. Prompt engineering is used to create and develop prompts that are useful for engaging with AI-powered tools, ensuring that these tools deliver appropriate, logical, and exact responses. The majority of studies look at how Generative AI tools might enhance education by improving concept comprehension. Existing studies explore the notion that writing effective prompts is critical to fully utilizing these Generative AI capabilities. This study determines the effectiveness of training 25 students from a Digital Marketing course to provide specific prompts to Generative AI chatbots to obtain precise and pertinent content. A mixed-method approach was used to analyze the effectiveness of the training for writing effective prompts and its impact on students' ways of writing prompts. It was observed that before training, students were utilizing AI chatbots as an information tool, but after being trained in prompting, their use of these AI chatbots transformed into a creative tool. The student feedback collected through a post-training questionnaire indicates that a vast majority of participants, 92%, felt that the training on prompts improved their skills in generating effective prompts. Furthermore, the content analysis of prompts provided by the students before and after training led to the identification of two categories of students, namely active and passive learners. These analyses highlight the importance of ensuring that students do not just passively consume AI-generated information but instead cowrite the content. The research findings, thus, highlight the importance of training students in prompt engineering for enhancing their learning experience and improving their ability to use these AI technologies.**

Keywords—Artificial Intelligence, Chatbots, Generative AI, Prompt Engineering, Training

I. INTRODUCTION

Social media is becoming a key component of the Digital Marketing of a variety of products and services. The Digital Marketing content needs to be made creatively to draw audiences on social media. The format of the content should be such that it improves audience engagement[1]. However, creating engaging content, such as a blog post, educational article, or Google or Facebook advertisement, is a time-consuming activity involving brainstorming and creativity. In addition, content creation for social media platforms is a time-bound task that needs to be completed by the specified deadlines.

The Artificial Intelligence (AI) technique known as "Generative AI" can create a wide range of content, including text, images, and audio. Generative AI technologies are utilized in various tasks, such as writing codes, communicating, generating ideas, and creating content. These tools benefit social media content creators by generating fresh content based on inputs. They have shown effectiveness while training students in the field of Digital Marketing. It has been found that it fosters students' interest, improves creativity, promotes active learning, and cultivates critical thinking, concept comprehension, problem-solving, and customized learning experiences[2].

But students are not aware of how to give effective prompts to get the desired response from the chatbot. Our approach to overcoming this issue is to teach students how to craft compelling prompts for Generative AI chatbots, enabling them to use these chatbots not only as information tools but also as creative tools for effective writing. To successfully integrate these chatbots into education, educators must give students instruction and support to enable them to use these technologies efficiently and increase student engagement. We intend to achieve this through a technique known as "prompt engineering," which is becoming a specialized skill for obtaining intriguing and useful responses from Generative AI chatbots.

The effectiveness of Generative AI technology-based chatbots like ChatGPT, Bing, Bard, etc. is being improved increasingly through prompt engineering. Prompt engineering is the art of structuring text that is entered into the Large Language Model (LLM) to get the desired result. Prompt engineering tends to save time and effort for students, so they can focus more on learning and execution and spend less time on content ideation and writing.

This study explores the notion that writing effective instructional prompts for AI chatbots is important for augmenting learning and teaching practice. The research question addressed in this paper is: What is the effectiveness of training students in prompt engineering for Generative AI chatbots to generate precise and creative content? Based on student responses to the post-training questionnaire and evaluating their prompts before and after teaching them prompt engineering, this study establishes the effectiveness of training students in crafting prompts. The paper presents the findings of a short-term Digital Marketing course in which students used Generative AI chatbots for content creation so that they could focus on their project work.

II. Related Work

This review of literature investigates the significance of AI in education, including the importance of AI in Digital Marketing, the benefits of employing Generative AI chatbots for creating content, and the necessity for prompt engineering to fully exploit the potential of Generative AI chatbots.

AI is becoming a significant research topic in higher education. But in higher education, the use of AI-based solutions is still very limited. The institutions need to create focused adoption strategies for AI while updating the current technology infrastructure and enhancing the AI capabilities of academic instructors[3]. The research studies analyze the development of AI tools and highlight the potential ways that Generative AI chatbots might help students learn about digital writing and other topics, such as composition and writing guidance, as well as the potential for co-creation between humans and AI[4].

AI is transforming Digital Marketing by enabling more intelligent search engines, smarter ads, refined content delivery, relying on bots, continuous learning, preventing fraud and data breaches, image and voice recognition, sales forecasting, language recognition, predictive customer service, customer segmentation, and so on[5]. The significant area under which AI can have an important impact on Digital Marketing is professional content creation[6].

With the help of Generative AI chatbots, students can engage with complicated ideas, discover new information, evaluate their comprehension, pose questions, get immediate feedback, and consider other viewpoints[7]. The best practices for crafting prompts involve considering AI chatbots as intelligent entities, adding context awareness, personalizing prompts, defining roles and styles, and utilizing suitable forms and wording[8].

Artificial intelligence and prompt engineering are integrated into an innovative field, optimizing output quality by creating efficient prompts for Generative AI chatbots. There is a need for a framework that instructs prompt writers and incorporates the principles of clarity, consistency, explicitness, reflectiveness, and flexibility. Professionals must embrace this framework for expertise in prompting[9].

The review reveals that Generative AI tools are effective when integrated into higher education, but students must be trained to utilize them before these tools can become an integral part of mainstream higher education.

III. Methodology

This study aimed to measure the effectiveness of training students in prompt engineering for Generative AI chatbots. A ten-day Digital Marketing course was organized for 25 undergraduate female students of a degree college in India. The Digital Marketing course included training on designing a website and performing Search Engine Optimization (SEO) on the website using Google Analytics, making a personal or brand YouTube channel and posting a video, and creating an Instagram business account and a Facebook page. Students in this Digital Marketing course were required to create content such as blog entries, articles, and social media posts. Content writing is a crucial component of Digital Marketing. All Digital Marketing strategies, including Search Engine Optimization (SEO), Pay-Per-Click (PPC) advertising campaigns, and Social Media Marketing (SMM), rely on content.

Generative AI is commonly used in Digital Marketing to streamline customer interactions, automate data analysis, create personalized marketing campaigns, and create content. Participants in this course were instructed to use Generative AI chatbots for generating content such as blog articles and posts on social media, creating Google or Facebook advertisements, writing titles and descriptions for YouTube videos, and so on. The training program was designed to guide students in producing effective instructional prompts for Generative AI chatbots in order to save time and effort spent on content writing for Digital Marketing and allow them to focus more on learning and project work. Because this is an emerging field, the instructor referred to various courses available on MOOC platforms like Coursera, edX, Udemy, etc. to train students in crafting prompts. In addition, the instructor used resources on websites like Google Cloud, Analytics Vidhya, and several YouTube videos on prompt engineering. During the training, the instructor discussed many aspects of prompting, such as clarity, conciseness, context, and adaptability. Learning resources were shared with students on Learning Management System (LMS) to further enhance training. Some of the examples of useful prompts that were discussed during the training are as below:

- Suggest keywords for the SEO of the website for the [Topic].
- Generate a 5-minute video script for a YouTube video on the [Topic].

The data provided in this study was gathered using a post-training questionnaire. Multiple-choice questions were used to assess participants' opinions of the course's usefulness, familiarity with Generative AI chatbots, the instructor's explanation of prompt engineering, and Generative AI chatbot utility in social media content generation. Additionally, the chat data, including the prompts provided by students to the Generative AI chatbot and AI-generated responses, was submitted as a document. Each prompt was analyzed as a separate unit, and the focus was more on understanding the change in pattern or style of prompting.

IV. Results and Discussion

In this section, we report the results of the effectiveness of training students in prompt engineering as evaluated by a post-training questionnaire, as well as the sorts of prompts provided to AI chatbots. A total of 130 prompts were provided to Generative AI chatbots by 25 students, and this section also discusses the comparative analysis of these prompts.

A. Feedback Analysis from the post-training questionnaire

The data analysis of feedback gathered from students regarding the benefits of utilizing Generative AI chatbots in content writing for Digital Marketing on social media platforms and the effectiveness of prompts showed several significant findings.

1) Confidence in applying learnings from the course: The result showed that 68% of students were confident, and 24% were very confident in applying the skills and knowledge gained from the Digital Marketing course to their projects (Fig.1). This suggests that the Digital Marketing course was effective in helping the majority of students gain confidence in applying their newly acquired skills and knowledge to their work.

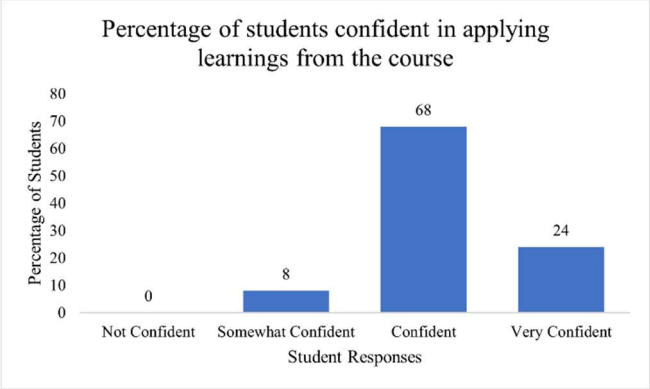

Fig.1. Percentage of students confident in applying learnings from the course

2) Familiarity with AI chatbots before taking the course: Based on the data provided, it seems that a majority of students were familiar with AI chatbots like ChatGPT and Bing before taking the course. Specifically, 40% were somewhat familiar, 32% were familiar, and 24% were very familiar. This indicates that many students had prior knowledge about AI chatbots before enrolling in the course.

3) Which AI chatbot is convenient to use: According to the feedback, 44% of students found both ChatGPT and Bing convenient for content development for Digital Marketing on social media platforms, with 32% finding Bing more convenient and 24% finding ChatGPT better. This implies that many students perceive ChatGPT and Bing to be convenient tools for content creation for Digital Marketing on social media platforms, with some students preferring one over the other.

4) Instructor's explanation of prompt engineering: The majority of participants, 92%, agreed that the course instructor was effective in explaining to the students how to use Generative AI chatbots to craft prompts for content generation.

5) Improvement in prompt generation: Combining the responses of strongly agree and agree, we find that a significant majority of participants,92% felt that the prompt training enhanced their skills in generating effective prompts using AI tools (Fig.2). This suggests that the training was effective in helping students develop their skills in this area.

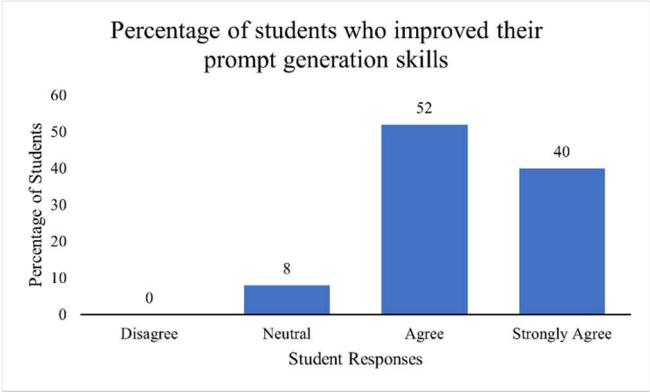

Fig.2. Percentage of students who improved their prompt generation skills

6) Usefulness of AI chatbots: Based on the feedback data, most students find AI chatbots for content creation for Digital Marketing on social media platforms useful. Specifically, 36% said they found it very useful, 44% said they found it useful, and 20% said they found it somewhat useful (Fig.3). This suggests that AI chatbots are a valuable tool for content creation in Digital Marketing on social media
platforms.

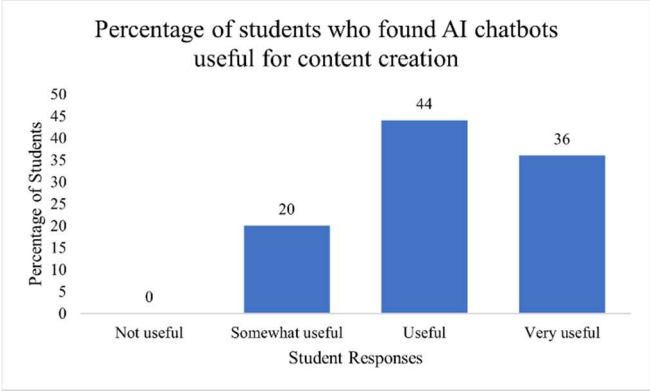

Fig.3. Percentage of students who found AI chatbots useful for content creation

7) Likely to use AI chatbots in the future: According to feedback data, the majority of students are likely to use AI chatbots for their own Digital Marketing projects or work in the future. Specifically, 36% said they were very likely to use AI chatbots, 56% said they were likely to use them, and 8% said they were somewhat likely to use them (Fig.4). This suggests that there is a high level of interest in using AI chatbots for Digital Marketing projects or works in the future.

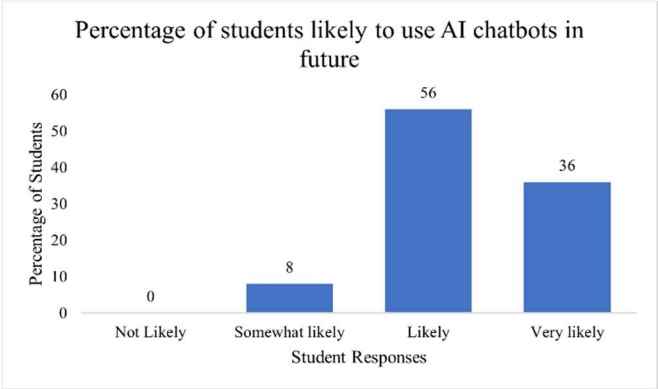

Fig.4. Percentage of students likely to use AI chatbots in future

B. *Comparative Analysis of Prompts*

The prompts used by students to produce the social media content enabled researchers to evaluate the effectiveness of teaching them prompt engineering. The comparative analysis of prompts (TABLE I) provided by students revealed that prior to being trained in prompt engineering, students used brief prompts of 3–4 words. However, after training, they started interacting with AI chatbots using longer, more descriptive prompts. Similarly, prior to training, students were not specific when giving prompts for obtaining information from AI chatbots. However, the students' prompts following training were more focused on the topic of their interest. The analysis further revealed that before training, students used Generative AI chatbots as an information tool, but after training, their use of these AI chatbots evolved into a creative tool.

TABLE I. COMPARATIVE ANALYSIS OF PROMPTS

Length of prompts before training (Short)
• Tips for perfect skin. • Lines on fast food. • About Kasol.
Length of prompts after training (Long)
• Suggest a description for the Facebook page on healthy lifestyles. • I am having a nail studio, and I want a poster for my Facebook page. • Create an article outline for canvas art. Make it concise, yet leave no information.
Prompts before training (General)
• Types of warm-up exercises. • Why is denim trending? • Any art quote.
Prompts after training (Specific)
• Description of a skincare routine with two wonderful and amazing lines. • Generate a Google Ad for yoga classes with 3 headlines and 2 descriptions. • Suitable Instagram captions and hashtags for a fashion brand.
Prompts before training (Informative)
• History of Indian classical dance forms. • Content for the Indian dance form. • Tell me more about the changing landscape of Indian classical dance forms.
Prompts after training (Creative)
• Give me a valid hashtag about Indian dance forms. • Suggest keywords for the SEO of the website for Indian dance forms. • Write a suitable title and description for a YouTube video on Indian classical dance.

In addition, two types of learners, active and passive, were identified through a comparative analysis of the prompts. The analysis of prompts provided by students to AI chatbots was done based on parameters such as prompt length, specificity, and creativity. This content analysis of prompts showed that 92% of students utilized Generative AI chatbots as creative tools, crafting effective prompts and enhancing creativity. The post-training feedback and comparative analysis of prompts used by the students prove that training students in prompt engineering helped them create goal-oriented content and gave scope for more creativity rather than struggling for content only.

V. CONCLUSION

Prompt engineering training was provided to the students to address difficulties discovered while developing content for Digital Marketing. The effectiveness study of our training was done in terms of prompts provided to Generative AI chatbots. The analysis of feedback and prompts reveals that the students' main takeaway was that they were able to craft effective prompts required to generate precise and relevant content. Thus, according to students' positive responses (92%), it can be claimed that training students in prompt engineering has been successful in addressing the challenge of developing effective prompts. This research highlights the importance of training students in crafting prompts to integrate Generative AI chatbots into education and various fields effectively. By doing so, students can learn to communicate with AI chatbots in a way that elicits accurate and relevant responses, thereby enhancing their learning experience and improving their ability to use AI technology in their future careers.

This study is limited to a single short-term course. As a result, in order for the study's findings to be generalized, this training could be implemented in a variety of educational contexts. Also, as part of our future work, we intend to design learning strategies for training students in prompt engineering who have been identified as passive learners so they can actively engage with the Generative AI tools in creating the content rather than just passively consuming AI-generated information.

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Investigating the Pedagogical Benefits of Augmented Reality in Facilitating Visual Communication Between Students and Professors in Architecture

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***Abstract*— The architectural landscape has undergone a profound metamorphosis as a result of remarkable advancements in Computer-Aided Design (CAD), computational design, and generative architecture techniques. One technology that has propelled this paradigm shift even further is Augmented Reality (AR). AR represents a groundbreaking innovation that empowers architects by offering an immersive experience that enhances spatial comprehension and visualization. The integration of AR into architectural education is still in its early stages of development. In architectural education, integrating mobile devices as a component of an AR-enabled learning environment confers flexibility and mobility for students to engage with their designs at their convenience, regardless of location. This research paper aims to delve comprehensively into the effective implementation of augmented reality with its role as a potent visualization aid for students pursuing architecture studies, particularly within design studios, to enrich the visualization of students' designs and facilitate effective visual communication between professors and students. The primary objective of the paper is to integrate an existing AR technology into the design process of architectural pedagogy and understand the benefits and problems that are associated with the same, through surveys. Overall, this research encapsulates an ardent exploration of integrating augmented reality within architectural education when confronted with comprehensive projects. Results distinctly affirm its transformative potential as a powerful tool augmenting visualization prowess amongst aspiring architects whilst seamlessly facilitating effective communication channels between students and faculty.**

Keywords—*Augmented Reality, Architectural Pedagogy, Visualisation, Communication, Design Representation*

I. Introduction

Architectural pedagogy has traditionally been a sharing space for educators and students. With the advancement of self-learning and distance education techniques, the role of professionals and teachers upgrades to solving crucial issues in the studio and generating ideas rather than a one-way flow of teaching and learning.

Augmented reality (AR) can be a torch bearer in this aspect, allowing students to experiment with their designs subjecting to various technical constraints and digital prototyping. User experience can also be evaluated easily when educators and students can experience the design.

A. Existing Developments in the Field of AR in Architecture, Engineering & Construction Education

AR remains an emerging tool that demands additional exploration in order to effectively, efficiently, and suitably integrate it into the curriculum.[1][2]

AR improves student engagement and interest, nurtures a collaborative environment, and is a faster and more practical learning method. Students and educators benefit from AR in all aspects of education.

The application of AR in architectural education has been through the development of software. These integrate existing architectural software such as Building Information Modelling (BIM) software with augmented reality. [3]–[10]

B. Need for Research

The development in architectural/ design education practices has been moderately slow considering allied fields. Integrating existing AR software into the design process and testing it to see the advantages and problems has been amiss in research.

II. Materials and Methodology

The research involved a combination of literary review and surveying to determine the efficacy of integrating AR into the design process, specifically in the visualization and representation stages. The steps involved in the research are seen in Fig.1.

A literature review was done to identify the research gap. A campus design project was introduced in the studio, with students choosing to use traditional modelling or AR modelling, implementing the same with BIM software.

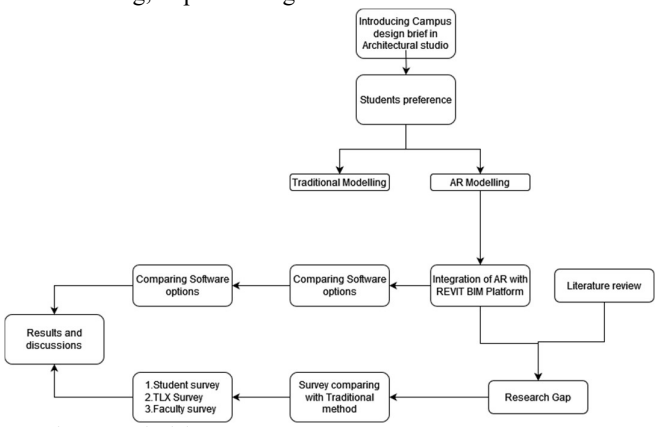

Fig. 1. Methodology

The feedback of the students and the faculty was taken through a set of surveys, which were analysed.

A. Augmented Reality Implemented in Pedagogy

A review of existing literature and literature review gives an insight into the current practice of integrating augmented reality into education, particularly architectural education. The common BIM software and its possible integration with AR is analysed and depicted in Fig.2.

1) Augmented Reality in Architecture Education

- In the field of architectural education, augmented reality is utilised as an interactive learning software.[11]
- Augmented reality is also used in mobile learning, where learning is more personalised.
- The technology is used for providing an annotated 3D model, tracking user movement, data analysis, and providing supplemental lessons.

Parameter of Analysis/Software	BIMserver.center	Unity	SketchUp Viewer	ARKit and ARCore
Integration with Modeling Software	Seamless integration with Autodesk Revit. Gives users the ability to upload to cloud. Explore material properties, orientations, sunlight and shadows.	Lacks native integration with Autodesk Revit. Users need to export models from Revit to Unity. Disrupts streamline workflow.	SketchUp Viewer requires users to convert Revit models into SketchUp-compatible formats. It lacks the depth of advanced functionalities that BIM-centric solutions offer.	These software do not provide model integration capabilities, while providing a space for creative AR applications.
Ease of Use	Direct integration with Revit simplifies workflow process, and enriches the learning process for students and educators.	Users need to undergo a learning curve about game development, as that is the primary basis for its interface.	Users with beginner-level proficiency find it easy to use, however, those who require advanced needs find it falling short.	These software require users to have programming skills and application development expertise.
Features and Functionality	It offers features that allow users to look at sectional views, material properties, analyse shadow effects, sun positioning and orientations. Users can get complex understanding about the design, free of cost.	Highly customisable AR experiences can be created, but it require extensive development skills and significant expenses.	It provides rudimentary AR visualisation but lacks advanced functionalities. It suffices for basic educational needs.	These software lack specialised features and ease of use that other solutions dedicated for architecture provide.

Fig. 2. Analysis of BIM Software

B. The IIM Sirmaur Project

1) Project Brief

- IIM Sirmaur, Himachal Pradesh is a fully residential Information and Communication Technology (ICT) enabled campus.
- Students are required to design a universally accessible campus with better connectivity between the different buildings.

2) Survey

- Students were given a choice between using the traditional modelling method and augmented reality.
- Later, the students and faculty completed a questionnaire with their feedback on ease and user satisfaction.
- The survey involved the participants answering questions on a Likert scale.

C. TLX Survey

- The NASA Task Load Index (NASA TLX) is a tool for measuring and conducting a subjective mental workload (MWL) assessment [12].
- The aim was to identify which tool has a more mental workload.

D. Assessment Parameters(Student Survey)

The parameters for evaluation were chosen through a critical analysis of the literature (Fig.3).

Pedagogical Benefits of Visualisation	Critical Skills	Self Learning (SE)
		Peer Learning (PE)
	Communication Skills	Engagement (EG)
		Ease of Communication (EC)
Architectural Skills	Design Representation (DR)	Accuracy to 2D Representation
		Materials and Textures
		Lighting
	Spatial Abilities (SA)	Spatial Perception
		Spatial Visualisation
		Mental Rotations
		Spatial Relations
		Spatial Orientation
		Scaling

Fig. 3. Parameters of Student Assessment[7], [13], [14]

E. Assessment Parameters (Faculty Survey)

The evaluation criteria were chosen through a critical analysis of the literature (Fig.4).

Adaptation	Navigation and Ease of Access (NV)	
	Effort (EF)	
	Accuracy (AC)	
Visual Communication	Design Representation (DR)	Accuracy to 2D Representation
		Depiction and Clarity
		Materials and Textures
		Lighting
	Spatial Perception (SP)	Spatial Perception
		Scaling
Evaluation	Functionality (FC)	
	Brief Requirements (BR)	
Communication and Collaboration	Engagement (EG)	
	Ease of Communication (EC)	

Fig. 4. Parameters of Faculty Assessment[7], [13], [14]

III. Results and Discussion

The survey was conducted with a sample size of 13 students, out of which 9 students opted for the traditional method while 4 opted for AR. The smaller number of students who opted for AR could be attributed to a lack of awareness about software, a requirement for high configuration workstations, and other reasons. The survey was conducted to understand the precise reason behind this difference.

AR was integrated with the design process through the BIMserver.center, which was selected through the analysis in Fig.2. BIMserver.center has better integration with modelling software, is easier to use and has better functions and features.

Students who used AR incorporated the same with BIM software [15], [16].

A. *The steps, process, and result of using AR with BIM software*

- Inside Revit, the BIM model can be converted into an AR-accessible model through plug-ins, such as Open BIMserver.centre. (Fig.5). The model can be visualised on mobile screen. (Fig.6.)

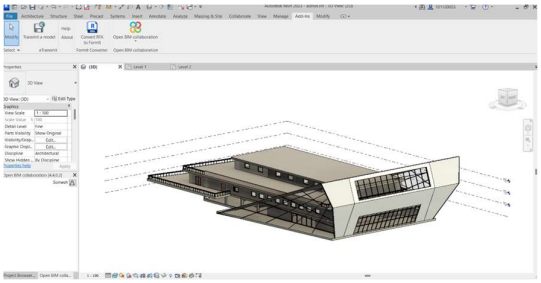

Fig. 5. Revit interface with the designed model

Fig. 6. The model is seen through a mobile smartphone screen on a table surface.

B. *Students Responses*

The survey responses for each of the parameters were aggregated and averaged out. The values were compared to arrive at the inferences in Fig.7.

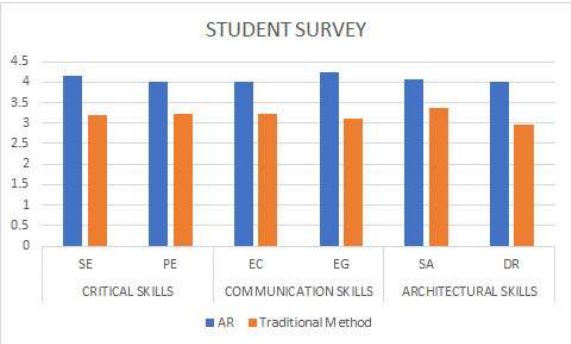

Fig. 7. Graph representing the survey results from students

C. *Faculty's Responses*

The survey responses from the faculty as they assessed students' projects through both traditional and AR methods were aggregated. The values were compared to arrive at the inferences in Fig.8.

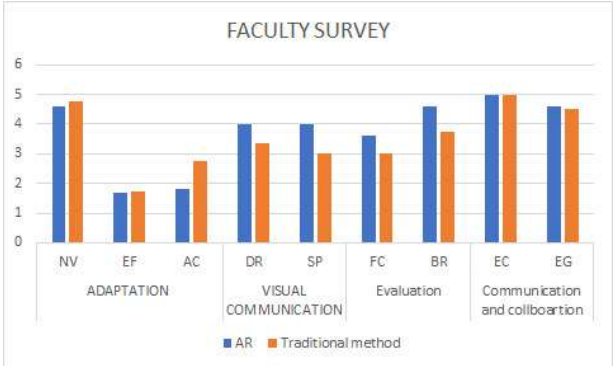

Fig. 8. Graph representing the survey results from faculty

D. *TLX Survey Results*

The TLX survey results, which assess mental demand, are seen in Fig.9.

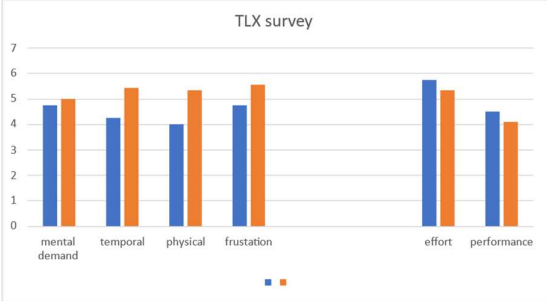

Fig. 9. Graph representing the TLX survey results

E. *Overall Inference from Survey and Research*

Students felt that the digital models represented their ideas better, with better overall output and details.

The software was easily accessible and easy to use, for both students and faculty.

Students felt that the ability to reassess and get feedback on work was easier and better with AR than with traditional methods.

F. *Inferences by Cross-analysis of Student and Faculty Survey*

- Adaptation to the AR software for evaluation is almost as difficult as traditional models. However, 5/9 faculty prefer traditional models (Fig.10 and Fig.11.).
- EC values of faculty are the same for AR and traditional however the EC value of students for AR is 1 point higher than Traditional.

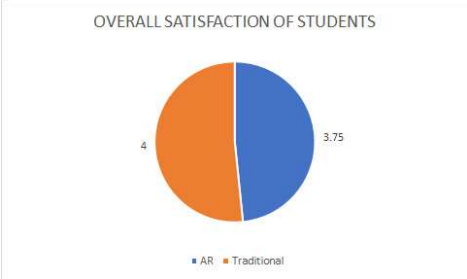

Fig. 10. Graph representing the overall satisfaction of students with using AR and traditional method

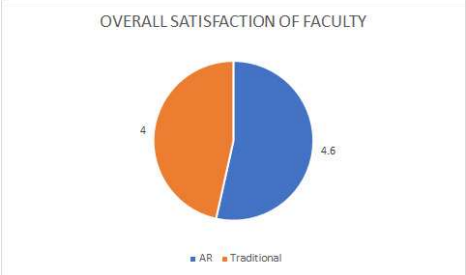

Fig. 11. Graph representing the overall satisfaction of students with using AR and traditional method

IV. Conclusion

Based on the survey results and the inferences taken from them, it can be understood that with the implementation of AR into architectural education, the benefits are immensely felt by the students.

AR in comparison with the traditional method, has improved the critical skills, architectural skills and communication skills of students. Thus, 48 % of students felt that AR is better than traditional methods.

The faculty have expressed higher overall satisfaction with the implementation of AR in architectural pedagogy, with visual communication, evaluation and communication and collaboration features proven satisfactory. Thus, 53 % of faculty felt that AR is better than traditional methods.

In conclusion, integrating augmented reality into architectural pedagogy does improve and benefit in facilitating effective visual communication between students and professors. Thus, there is a scope for AR to be implemented vastly in architecture education, in the future, and has the prospect to be received well by the architectural pedagogy community.

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Developing Software to Enhance Learnability and Usability of OpenFOAM

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***Abstract* — In engineering analysis, Computational Fluid Dynamics (CFD) enables the study of fluid behavior without the resources necessary for conducting experimental studies. CFD problems require extensive computational resources to iteratively solve the underlying Navier Stokes equations. Users rely on sophisticated software interfaces that can accurately model a continuum mechanics problem and interact with the resources. Most CFD software are commercial application tools that usually offer usability through an interactive solution modeling process but lack the aspect of learnability due to their proprietary nature. As per ISO/IEC 9126 [1], learnability is a major product quality assessment attribute, and source code transparency promotes this. OpenFOAM has garnered significant mindshare among the CFD cohort, perhaps due to its source-code access and equally competitive performance against commercial software; however, it relies on textual data input that dissuades usability. CFD already has a laundry list of prerequisites, and investing additional effort to examine a dense source code steepens the learning curve. Hence, the involvement of educational software in teaching CFD or an educational aspect within CFD software is imperative to alleviate the learning curve. A graphical interface is a must-have for such software, as GUIs typically have a shallower learning curve. The OpenFOAM GUI project at CFD-FOSSEE is an endeavor to build a graphical frontend to OpenFOAM that employs interface design paradigms to maximize usability and user experience. This paper discusses our efforts in the process of implementing a software development philosophy where the software design goals are driven by the needs of OpenFOAM/CFD users.**

Keywords* — *OpenFOAM, CFD, Python, GUI, Venturial, PyVNT.

I. Introduction

The process of solving a CFD problem can have several steps [2] but generally involves parameterizing the physical domain of interest (or the geometry), generating a mesh within the domain, establishing a simulation strategy, setting solver characteristics and post-processing resulting data. Usually most CFD software follow a procedural problem modeling workflow that conforms to the above process. But OpenFOAM doesn't strictly adhere to a procedural workflow and instead provides a highly customizable problem modeling process for various physical scenarios. To most newcomers, this process can be challenging to learn and in that, lack of direction is a barrier to get started with OpenFOAM. The time required to engage with a software to solve a problem is also a key factor in determining its usability. The plain-text based problem modeling process of OpenFOAM increases the time needed to handle text. Occasionally, imperfections in underlying software development practices may also implicitly intervene, impeding usability. Although OpenFOAM's syntax rules [3] were made easy to follow, there is no proactive syntax validation and users still require to familiarize themselves with the documentation. Any software should, as much as possible, cater to the needs and preferences of all its users. A software with a CLI (Command Line Interface) provides flexibility and scripting capabilities yet demands a steeper learning curve. Conversely, a GUI offers visual simplicity, intuitive interaction, and accessibility but can be resource-intensive. Some processes within OpenFOAM are mundane to be done through a CLI, and could benefit from having a GUI. OpenFOAM uses FOAM dictionaries to hierarchically delineate a systematic combination of keyword entries to define the CFD problem. Developing a full-featured GUI is a threefold task that first requires an underlying tool to manage FOAM dictionaries. Secondly, a UI that can manipulate graphical representations of OpenFOAM dictionaries. Lastly, an appropriate UX (User Experience) design strategy that associates an agile but reversible workflow relatable to CFD solution process, must be present.

II. Development History

The OpenFOAM GUI project at FOSSEE commenced with Reynolds-Blender [4], the underlying tool for the Reynolds [5] GUI. Written as an add-on to Blender 2.78, Reynolds contained case-specific interactive tools built with Blender's UI widgets, but lacked mesh handling capabilities and a general-purpose problem modeling workflow. Like Reynolds, several other commercial or open-sourced tools have produced a GUI for a part of OpenFOAM or for application-specific purposes. Some noteworthy mentions are HelyxOS, swiftblocks, hexblocker, Snappyhexmesh_gui. And others can be found on [6]. However, not much literature is available about their design or development process. Reynolds was written by CFD experts but further development required collaboration from software developers. The developers themselves are not necessarily knowledgeable in CFD but have strong programming skills to understand and implement advice from CFD experts. Since then, the project progressed with the development effort from FOSSEE fellows [7], most of whom were engineering undergraduates. The development process is reliant on effective communication between CFD users and developers. Hence, it is essential to document the pivotal changes in development history.

A. Rapid Application Development

In FOSSEE's semester-long internship in 2021 [8] interns identified potential areas of improvement in Reynolds and developed a prototype application to generate blockmesh dictionaries for OpenFOAM. This application delivered the expected results when tested on a small set of problems, but addressing complex problems required integration of more

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features. The application lacked a design strategy, but to some extent, it proved a conjecture - with a scalable and flexible design pattern, it was possible to address the complex problems. The students also presented the application in the 2021 SciPy India conference [9].

B. *Test-Driven Development*

The following year, the application was made more scalable and stable. Testing with various geometries revealed essential feature deficits, workflow disruptions, and usage inconveniences. Existing features were unit-tested to ensure stability and adherence to the workflow. The issue of irreversibility was highlighted when users found no way to retrace the steps of geometry handling. The features built so far were not independent but interdependent, hence users felt constrained to follow the stepwise workflow. Some leniency was required to alleviate the workflow strictness. After further testing, significant design changes were made to allow workflow flexibility. With a better interface and more reliable workflow, the application was introduced to CFD-FOSSEE's workshop [10] participants in a 90-minute instructor-led lecture [11].

III. JANUARY 2023 CFD-FOSSEE WORKSHOP

CFD-FOSSEE [12] conducts annual 3-day workshops, where faculty partners, advisors, and team members train workshop participants. Workshop participants ranged from first-year engineering students to industry professionals with a Ph.D. 167 people participated and earned workshop completion certificates. All participants were given dedicated guidance sessions to prepare the prerequisites two days before the workshop. Toward the end, participants had to fill out a feedback form. The feedback form documented their experiences, expectations, suggestions, and inclination toward future participation and contribution. The workshop lectures are distributed in the order of rising difficulty. In this way, participants are encouraged to start from scratch. The workshop provides a learning space for participants to be introduced to new CFD resources and tools.

A. *Teaching Experience*

The aim of conducting a pilot lecture on GUI was to understand how diverse users acclimate themselves to the GUI workflow. The lecture commenced with a description of composing hexahedral primitives to build a complex geometry. The workflow to compose the graphical hexahedral primitives was demonstrated to associate its guiding principle with OpenFOAM's concept of hexahedral composition. At the end, the software shortcomings were discussed as various areas of improvement in which user feedback and participation were sought. Feature requests were accumulated and matched with their areas of interest to understand the requirements of various users.

B. *Workshop Feedback*

The primary purpose of the feedback form was to identify if users unfamiliar with OpenFOAM or those whose institutes use commercial software, would be interested in migrating to OpenFOAM. Determining their specific needs and requirements can make the transition convenient. An essential aspect was to explore the potential of OpenFOAM GUI in attracting more users and supporting the migration. Figure 1 suggests that only 6% of participants used OpenFOAM in their institute. As much as 46 % use ANSYS Fluent and the remaining use software other than Fluent and OpenFOAM.

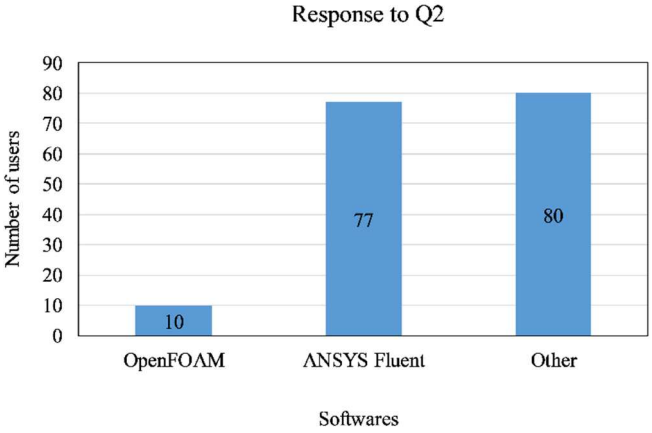

Figure 1: Number of OpenFOAM users vs. other tools.

Figure 2 and Figure 3 suggest that 70% of the users would like to migrate their lab to OpenFOAM; 89 % of the users were interested further in OpenFOAM GUI. Figure 4 indicates 88% users found OpenFOAM GUI convenient to use for meshing tasks and if it increased their productivity. Of the 88%, 46% users felt very confident of the same. The remaining 42% were somewhat confident.

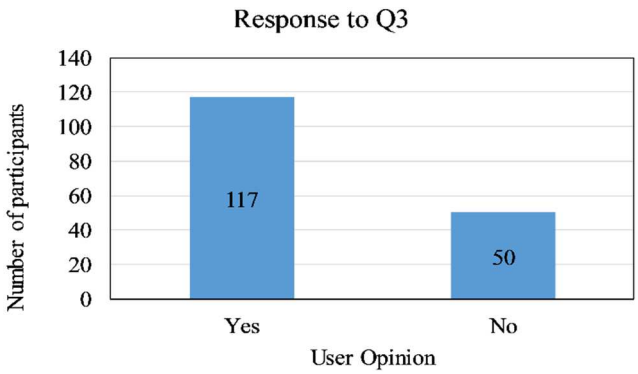

Figure 2: User Opinion on Lab migration to OpenFOAM

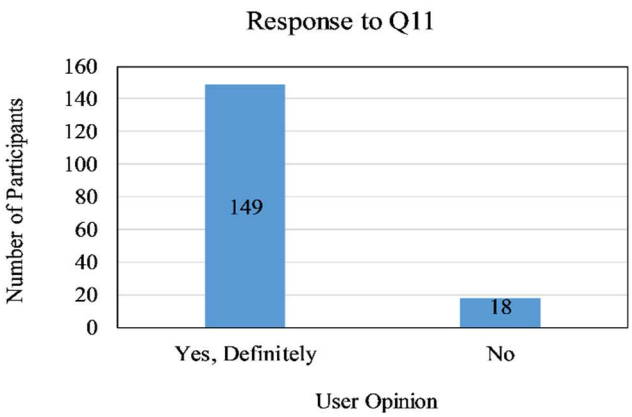

Figure 3: User Opinion on further interest in OpenFOAM GUI

User opinion on a list of planned features and that of their own were also collected (shown in Figure 5).

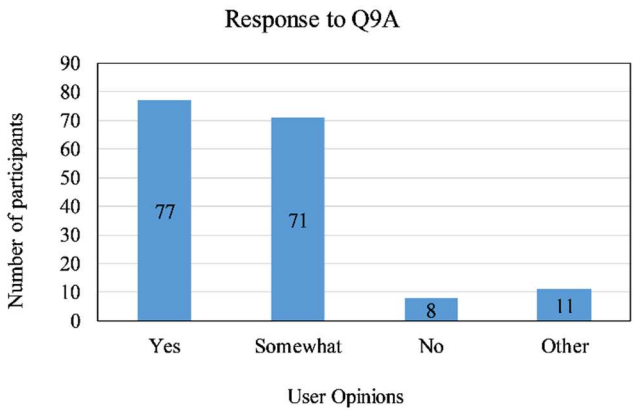

Figure 4: User opinion on ease of doing meshing with OpenFOAM GUI

The number of responses per feature enabled to determine the priority of addressing their development while keeping scope for future tasks. Blender's native application modules were inadequate in developing them, but some standalone modules and Python libraries could be used to develop them.

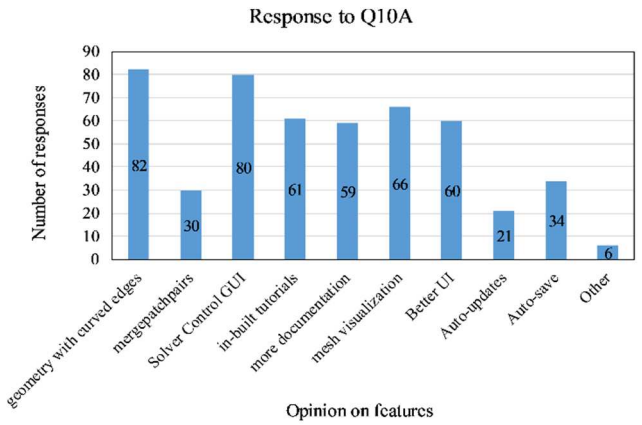

Figure 5: User opinion on features

C. *Workshop Learnings*

The workshop aimed to deliver an effortless entrance to OpenFOAM. Through exploration, most users eventually determined their starting points, but their pace of obtaining familiarity depended on several factors including their intellectual grasping power and perseverance. While the feedback collected quantitative data, workshop educators also gathered how adept the audience was. The majority of the audience was students beginning their CFD journey in pursuit of deciding which software to use. Some with prior CFD experience were able to grasp OpenFOAM quickly. The OpenFOAM GUI was initially designed to enhance productivity with OpenFOAM. As a result, GUI users were expected to have some extent of OpenFOAM knowledge. Some users found basic aspects of the GUI difficult to use such as relating the automatic vertex ordering of hexahedral primitives. If the GUI has to be somewhat of an educational tool, the process of ordering should be primarily guided, but optionally automated. Some advanced users also expected further solution modeling and mesh visualization tools. Those familiar with OpenFOAM automation tools were interested in seeking script-like reusable journaling features. Journaling enables the recording of GUI actions into Python scripts. Aside from the technical feedback, the developers conceived how closely the interface design is related to the user experience. To incorporate advanced features, the GUI required some fundamental changes. Dynamic interfaces were now a priority to allow for ways to make the workflow fully reversible.

IV. New Design Strategy

All GUI/script operations should result in changes to the data structure and not directly to the UI data representations. Instead, the UI representation should be updated according to the changes in the data structure and vice-versa. The new design introduces *Venturial Tree Nodes* that represent OpenFOAM dictionaries with customized Python data structures. The tree object drives information across all components of the application. Objects also contain UI attribute information (as keyword arguments) and do not require the user to define them while scripting. The *Venturial GUI* uses the UI attributes while rendering the UI representation of the tree-nodes. Venturial contains several interactive tools built with *PyVNT* being the main dependency. *PyVNT* is a Python API to handle *Venturial Tree Nodes.* The API modules provide a variety of tree-node handling operations, some of which are Python wrappers of OpenFOAM case-file management tools. The primary purpose of PyVNT is to provide FOAM-like scripting in Python. PyVNT can also operate independently for scripting outside Venturial. The Venturial GUI [13] was designed to conveniently integrate large sub-systems such as prospective post-processing tools. Even the sub-systems are feature-scalable since addressing various fluid flow problems in OpenFOAM, often requiring ancillary features to be added to the main system. To drive the development effort of the new design, CFD-FOSSEE welcomed more developers through FOSSEE's 2023 Semester Long Internship and 2023 Summer Fellowship. All interns were computer science undergraduates from various colleges across India and successfully contributed to the project. Some interns also converted to part-time paid employees. Results of the new design were presented in the 18th OpenFOAM Workshop (OFW), July 11 -14, 2023 [14] [15]. Venturial was discussed as a simulation enabling tool to a more advanced audience. The workshop helped us to understand the interest of international OpenFOAM users.

V. Examples

The flow through a pipe problem [16] on Spoken Tutorials [17] can be performed with the GUI. Figure 8 shows the graphical parameterization of the blockmesh dictionary of a 3D pipe.

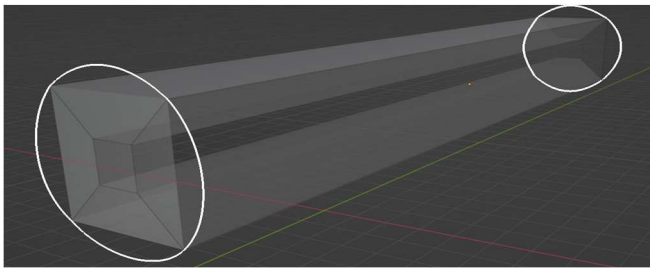

Figure 8: Pipe Geometry in Blender built with Curved-Edge Tool

Visualization of resulting mesh can be done by launching Paraview through Venturial (see Figure 9). Venturial also has convenience tools such as auto-save and mesh annotations that aid the workflow without disrupting it.

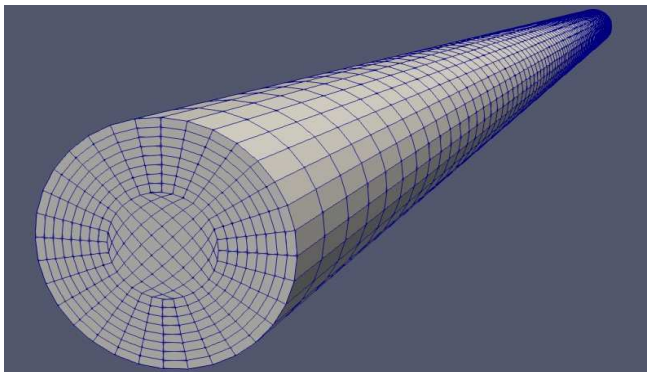

Figure 9: Pipe Geometry in Paraview (axis orientation may differ from Blender)

PyVNT strives to provide FOAM-like scripting with Python. A working sample code that can read OpenFOAM files is as follows.

```
from pyvnt.foamtools import FoamFile, RenderFoamTree

foamfile = FoamFile.read("~/pipe/system/fvSolution")
foamtree = foamfile.to_Tree
RenderFoamTree(foamtree)
```

The `RenderFoamTree` method presents the hierarchical representation of the keyword objects within the `foamtree` object.

```
fvSolution
├── FoamFile
│   ├── version
│   ├── format
│   ├── class
│   ├── location
│   └── object
├── solvers
│   ├── p
│   ├── pFinal
│   └── U
└── PISO
    ├── nCorrectors
    ├── nNonOrthogonalCorrectors
    ├── pRefCell
    └── pRefValue
```

VI. Conclusion

Historically, the OpenFOAM GUI project commenced as an initiative to promote GUI-driven learning of CFD problems on FOSSEE's spoken tutorial project website. Since then, it has transitioned towards creating a more general-purpose simulation-enabling tool for OpenFOAM. Interacting with users has highlighted the spectrum of features that can cater to their needs. Features could require integration at any level of software abstraction. Large subsystems like Venturial's run utilities are integrated at a higher level, and any comprising features are at lower levels. Feedback from workshops and experts facilitate design decisions. Hence throughout the development, collaboration between software designers and CFD expertise has been vital in determining the place of a feature within the software architecture. With the progress of implementing complex features, there is now a need to involve more software enthusiasts in Venturial's upcoming development cycles. Our team welcomes community development.

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Assessing the Engagement of Primary Learners with the Math Kids Application: A Digital Learning Exploration

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***Abstract*— The use of immersive technology, such as augmented reality (AR) and virtual reality (VR), has significantly changed how students learn in contemporary classrooms. The present study aimed to investigate the engagement of primary-grade learners with the Math Kids application and its impact on their math skills. The research employed a quasi-experimental design, with a control group, and included 100 participants, evenly distributed between the control and experimental groups. Data were collected through pre-test and post-test assessments, semi-structured interviews, classroom observations, and surveys. The findings indicated positive outcomes regarding the engagement of learners with the Math Kids application. Through interviews, students expressed high interest, motivation, and enjoyment while using the app. Classroom observations revealed active participation and increased focus among students during app usage. The survey responses further supported these findings, with students reporting a strong sense of interest, motivation, and enjoyment during their interactions with the application. Moreover, the pre and post-test results showed a significant improvement in students' scores after the intervention, indicating the effectiveness of the Math Kids app in enhancing their math skills. These findings highlight the potential of smartphone-based applications like Math Kids in promoting student engagement and learning outcomes in primary-grade education. The study contributes to the growing body of research on the benefits of digital learning tools in education and supports the integration of technology to foster positive educational experiences for young learners.**

Keywords*— *Dynamic learning, digital learning tools, pedagogical innovation, smartphone applications, educational experiences, primary-grade learners

I. INTRODUCTION

The integration of smartphones and mobile applications has revolutionized various aspects of our lives, including education. In recent years, there has been a growing interest in exploring the potential of smartphone-based applications in enhancing the learning experiences of young learners, particularly those in primary grades.

The primary objective of the present study is to investigate the impact of the Math Kids application on the learning outcomes and overall educational experience of primary-grade learners. By utilizing a mixed-method approach, the researchers gathered qualitative and quantitative data to comprehensively understand the subject matter. Qualitative methods, including interviews and observations, were employed to explore the learners' perceptions, experiences, and challenges when using Math Kids application. For quantitative measures, pre-and post-assessment were used to assess the impact of the Math Kids application on academic performance and engagement.

The findings of the study provided valuable insights into the effectiveness and implications of the Math Kids application in primary grade education. The research outcomes can guide educators, policymakers, and developers in making informed decisions about integrating such mobile applications into the curriculum to enhance young learners' educational experiences.

II. REVIEW OF RESEARCH LITERATURE

Smartphones and mobile applications in primary education have gained considerable attention. Studies have highlighted their potential benefits in enhancing student engagement and participation ([2], [7], [8], [11]). Reference [14] research investigated the impact of smartphone-based applications on student engagement in primary education, demonstrating the positive influence of these tools in promoting active involvement. Moreover, research has examined the overall effects of mobile learning in primary education. Reference [9] investigated the effect of mobile learning on students' achievement and revealed better scholastic achievement in the experimental group. Reference [2] conducted a meta-analysis, synthesizing the findings of multiple studies. Their research revealed positive outcomes of mobile learning, including improved learning outcomes and pedagogical transformations. This meta-analysis highlighted the potential of smartphone-based applications to positively impact primary education. Reference [5] reviewed research on smartphone usage for education sciences and found that it has the potential for rather positive effects, such as an increase in learning achievements or an increase in motivation. Reference [10] conducted a descriptive case study using digital tools for language learning. The study's results highlighted the importance of digital tools in professional teaching practice.

In addition, specific studies have focused on the effectiveness of smartphone-based applications for young learners. Reference [3] conducted a systematic review and meta-analysis, examining the efficacy of smartphone applications. Their findings indicated that smartphone-based applications are effective tools for enhancing learning outcomes in primary education, providing empirical evidence for their positive impact. Using focused group discussions and interviews, [7] evaluated mobile learning engagement among educational technology students. The researchers categorized seventeen different themes for their study and found that learners find mobile usage easy, accessible, and engaging. Furthermore, policy documents emphasize the significance of mobile learning in achieving inclusive and equitable education. The National Education Policy, 2020 [6]

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recognizes the importance of technology in education, while United Nations Educational Scientific and Cultural Organization (UNESCO) [12] provides policy guidelines for mobile learning. United Nations International Children's Emergency Fund (UNICEF) [13] highlights the role of mobile learning in education in emergencies, emphasizing its potential to ensure access to education for vulnerable populations.

III. RESEARCH METHODOLOGY

A. Research Design

The study employed a quasi-experimental design with a control group and an experimental group to investigate the engagement of primary-grade learners with the Math Kids application and its impact on their math skills. A mixed-method approach involving both qualitative and quantitative data collection methods was utilized to collect comprehensive data.

B. Participants

The sample of the study was 100 primary-grade learners from two private schools in urban area of Gurugram district of Haryana. The learners were chosen using purposive sampling technique and one section of class 4 was used as control group and another section of class 4 was chosen as experimental group in both schools. The participants were matched based on their age, gender, and academic scores in a monthly achievement test conducted by the school teacher.

C. Data Collection Tools

To collect qualitative and quantitative data following research tools were self-designed by the researchers. The tools were validated using face validity with 10 primary teachers and a pilot testing of the tool was also conducted with 10 primary grade learners chosen randomly.

- Pre-Test and Post-Test Assessments: Learners' math skills were assessed through a pre-test and post-test consisting of math problems based on the Math Kids application in alignment with the NCERT curriculum. The same test papers were administered to both groups. The mathematics textbook used in both schools was of private publication with content aligned as per NCERT guidelines.
- Semi-Structured Interviews: Interviews were conducted with a subset of learners from the experimental groups to gather qualitative data regarding their perceptions, challenges, and experiences of using the Math Kids application.
- Classroom Observations Schedule: Observations were conducted in experimental group classrooms to assess learners' engagement, interaction, and behavior during app usage.
- Surveys: Learners of experimental group completed surveys to measure their level of engagement, interest, motivation, and enjoyment while using the Math Kids application. Likert-scale questions were included.

D. Math Kids Application: The Intervention

The experimental group received intervention in the form of using the Math Kids application for a specified duration of one week during their math lessons. The control group followed the regular math curriculum using mathematics textbook without the use of the app.

Math Kids is a free learning game designed to teach young children numbers and mathematics (Fig. 1.)

Fig. 1. The interface of the Math Kids Application

Math Kids features several puzzles that teach while the child plays, including:

• Counting - Learn to count objects in this simple game of addition.

• Compare - Children can build their counting and comparing skills to see which group of items is bigger or smaller.

• Adding Puzzle - A fun mini-game where kids create math problems by dragging numbers on the screen.

• Adding Fun - Count the objects and tap on the missing number.

• Adding Quiz - Put your child's math and addition skills to the test.

• Subtracting Puzzle - Fill in the missing symbols in the math problem.

• Subtracting Fun - Count the items to solve the puzzle!

Subtracting Quiz - See how much your child has improved in their mathematics skills for subtraction.

E. Data Analysis

Descriptive statistics were calculated for pre-test and post-test scores, survey responses, and observation data. Qualitative data from interviews and observations were analyzed using thematic analysis to identify key themes and patterns.

IV. DATA ANALYSIS AND FINDINGS

The findings of the study indicate positive outcomes regarding the engagement of primary-grade learners with the Math Kids application. Through interviews, learners expressed high interest, motivation, and enjoyment while using the app. The following table summarizes the responses of learners under several themes (Table 1).

TABLE 1. RESPONSES OF EXPERIMENTAL GROUP'S LEARNERS' TO SEMI- STRUCTURED INTERVIEWS

S.No.	Themes	Responses of Learners
1.	Engagement and Motivation	"I feel excited and motivated when using the applications." "The interactive features make learning fun."
2.	Learning Experience and Enjoyment	"I enjoy exploring different activities and challenges in the applications." "It feels like playing games while learning."
3.	Perceived Benefits and Usefulness	"I enjoy exploring different activities and challenges in the applications." "It feels like playing games while learning."
4.	Challenges and Obstacles	"Sometimes, it takes time to figure out how to use new features, but I keep trying until I understand." "Sometimes, the screen size of the smartphone makes it a bit challenging to see all the details."
5.	Collaborative Learning and Interaction	"I can work with my friends on projects and share ideas through the applications." "We can comment and give feedback to each other on our work."
6.	Time Management and Balance	"I try to allocate specific time for using the applications so that I have time for other activities too." "I use a timer to help me manage my time effectively."
7.	Suggestions for Improvement	"It would be great if the applications had more interactive quizzes and challenges." "It would be helpful to have a feature that provides hints or explanations when we get stuck."

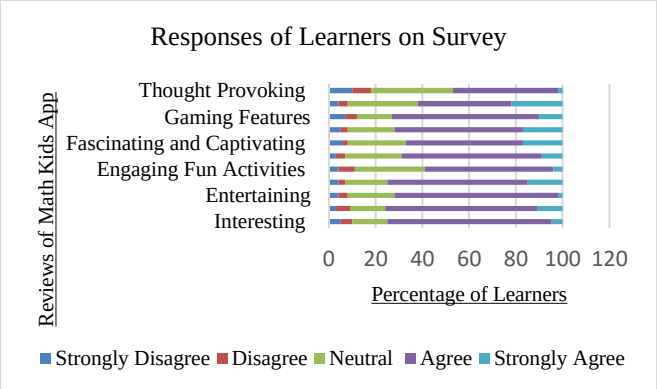
Classroom observations also revealed active participation and increased focus among learners while using the application. Table 2 summarizes the record of classroom observations under chosen themes.

TABLE 2. SUMMARY OF CLASSROOM OBSERVATIONS OF THE EXPERIMENTAL GROUP

S. No.	Themes	Instances from Classroom
1.	Engagement	Most learners were actively engaged throughout the session, showing high levels of interest and participation. Several learners displayed enthusiastic facial expressions and gestures while using the applications. Most of the learners spent the entire duration of the activities engrossed in the smartphone application.
2.	Interaction	Learners frequently collaborated with their peers, discussing tasks, sharing ideas, and working together. Interactions with the teacher were minimal, indicating a high level of independence during application usage.
3.	Technological Competence	Learners demonstrated a good understanding of the application's interface and features. They were able to navigate through different functionalities and select options with ease.
4.	Focus and Task Completion	Most learners-maintained focus on the assigned tasks, completing them within the given time frame. Few learners required occasional reminders to stay on task.
5.	Help-seeking Behavior	Learners sought assistance from their peers when encountering challenges, fostering peer support. Instances of seeking help from the teacher were limited, indicating a level of problem-solving independence.
6.	Self-Regulation	Learners exhibited good self-regulation skills, managing their time effectively and staying on task. They demonstrated persistence and worked independently without getting distracted easily.
7.	Attitude and Emotions	Most of the learners displayed positive attitudes and emotions, showing enjoyment and enthusiasm. A few learners expressed slight frustration when faced with more challenging tasks.

The survey responses further supported these findings, with learners reporting a strong sense of interest, motivation, and enjoyment during their interactions with the application. Graph 1 summarizes the responses of learners on survey questionnaires which were based on the Likert scale.

GRAPH 1. SUMMARY OF RESPONSES OF LEARNERS OF EXPERIMENTAL GROUP ON SURVEY



Pre and post-test results showed a significant improvement in learners' scores after the intervention, indicating the effectiveness of the Math Kids app in enhancing their math skills. Table 3 summarizes the descriptive analysis of the scores.

TABLE 3. DESCRIPTIVE ANALYSIS OF SCORES ON THE PRE-TEST AND POST-TEST OF BOTH EXPERIMENTAL AND CONTROL GROUPS

Paired Sample Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Control Group	Pretest	10.95	50	5.01	.074
	Post-test	11.25	50	5.12	.064
Experimental Group	Pretest	11.05	50	4.95	.074
	Post-test	14.25	50	5.25	.071

Overall, the study suggests that the Math Kids app positively impacts the engagement and learning experiences of primary-grade learners.

V. Results and Discussions

The findings of the study indicate positive outcomes regarding the engagement of primary-grade learners with the Math Kids application. The interviews conducted with the learners revealed that they expressed high interest, motivation, and enjoyment while using the app. They particularly appreciated the interactive features that made learning fun for them. The learners also reported enjoying the exploration of different activities and challenges, likening the experience to playing games while learning. These responses highlight the positive impact of the Math Kids app on the learning experience and enjoyment of the learners. Furthermore, the learners perceived several benefits and found the application useful for their learning. They expressed satisfaction with the collaborative learning and interaction opportunities provided by the app, enabling them to work with peers on projects and share ideas. While they acknowledged certain challenges and obstacles, such as getting accustomed to new features and limitations related to screen size, the learners demonstrated resilience and a willingness to overcome these obstacles.

Classroom observations further supported the positive findings. The learners were actively engaged throughout the session, displaying high levels of interest and participation. They exhibited strong interaction skills, frequently collaborating with their peers and displaying a sense of independence during app usage. Additionally, the learners demonstrated technological competence, effectively navigating the app's interface and features. The survey responses provided additional evidence of the positive impact of the Math Kids app on student engagement. The learners reported a strong sense of interest, motivation, and enjoyment during their interactions with the application. They found the app visually appealing, engaging, and interactive, which further contributed to their positive experiences.

Moreover, the pre and post-test results revealed a significant differences in learners' scores among control and experimental group. The descriptive analysis of the scores demonstrated that both the control and experimental groups experienced an increase in scores from the pre-test to the post- test. The mean pre-test score for the control group was 10.95, and it increased to 11.25 in the post-test. Similarly, the mean pre-test score for the experimental group was 11.05, and it significantly improved to 14.25 in the post-test. The results demonstrate a notable improvement in both groups' scores after the intervention. The control group showed a slight increase in their post-test scores, while the experimental group exhibited a more substantial

improvement. This suggests that the intervention, which involved the use of the Math Kids application, had a positive impact on the math skills of the learners.

Overall, the study suggests that the Math Kids app positively impacts the engagement and learning experiences of primary-grade learners. The app's interactive features, collaborative learning opportunities, and enjoyable learning experiences contribute to a positive classroom environment. These findings highlight the potential of smartphone-based applications like Math Kids in enhancing learners' learning outcomes and fostering their interest and motivation in math education.

VI. CONCLUSION

In conclusion, the present study examined the engagement of primary-grade learners with the Math Kids application and its impact on their math skills. The researchers have expertise in pedagogical theories and technological applications in education which have definitely influenced the research design and research questions. They faced challenges in data collection process as learners were very young and their actions, reactions and experiences shared were unpredictable.

The findings revealed positive outcomes, indicating that the Math Kids app effectively enhanced learners' engagement, motivation, and learning experiences. These results align with previous studies that have emphasized the benefits of integrating technology and digital learning tools in education ([2], [7], [9]).

Through interviews, learners expressed high interest, enjoyment, and perceived benefits while using the app. Classroom observations further confirmed active participation, increased focus, and technological competence among the learners. The survey responses provided additional evidence of the student's positive attitudes and emotions toward the application. Moreover, the significant improvement in learners' post-test scores after the intervention demonstrates the effectiveness of the Math Kids app in enhancing their math skills. Similar findings were reported in studies by [1] and [4], where digital learning tools contributed to improved academic performance and increased motivation in math education.

The present study adds to the growing body of research supporting the integration of technology in primary-grade education. By incorporating interactive features, collaborative learning opportunities, and enjoyable experiences, smartphone-based applications like Math Kids have the potential to enhance learners' motivation, interest, and overall learning experience.

Future research should explore the long-term effects of using smartphone-based applications in education and investigate strategies for optimizing the integration of technology in the classroom. Additionally, it would be valuable to assess the impact of such applications on a broader range of academic subjects and diverse student populations.

VII. FUTURE POSSIBILITIES AND SCOPE FOR IMPROVEMENT

The study on embodied learning experiences for preparatory level learners using technology represents a promising area of research with significant potential for future improvement and expansion. Similar studies can be conducted to assess the long-term effects of learning using embodied learning experiences. The progress of learners can be tracked for months to assess the sustainability of technology use in the classroom.

The study can be expanded to include a more diverse range of participants, including those with different learning abilities, cultural backgrounds, and languages. This can help determine the effectiveness of digital learning experiences across a broader spectrum of students.

If the teachers have been more efficient in using technology and effectively integrating embodied learning experiences in the classroom, the implementation of the intervention would have been more successful. Thus, it is required to invest in teacher training and resourcefulness.

Moreover, the application used by the researchers lack immediate feedback and reinforcement mechanism. The application could be improved by integrating more gamification elements like rewards, challenges and competitions along with a feedback mechanism to help correct mistakes, reinforce learning and making the learning more enjoyable and motivating.

Concluding, the researchers acknowledge that findings of the study are limited in their generalizability beyond the specific context of urban private schools. It would be valuable to assess the impacts of mobile applications on diverse range of learners from varying contexts.

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Analysis of Engagement and Retention in 3D E-learning Environment

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***Abstract*—This study aimed to conduct a comparative analysis of engagement and retention in through 3D material against conventional 2D-based learner support for school children. This study utilized a comprehensive 360-degree module through a virtual 3D environment called Labster. The research aimed to determine if 3D-based modules offer better learning outcomes and retention by comparing engagement and retention with traditional teaching methods. The study utilized 3D simulations for eighteen students from Grade 8 students about biology on the topic of absorption in the small and large intestines. The students from the control group learnt the topics through 2D slides, while the treatment group learnt the same topics through the Labster platform. The evaluation done right after administering the module focused on simultaneous learning, while the retention assessment done after several days aimed to test the participants' recall of the learnt material. The Wilcoxon Rank Sum Test, a nonparametric statistical test, was employed to compare the performances. The 3D instructional materials positively impacted student performance during the course, with the treatment group marginally outperforming the control group. However, the control group demonstrated better performance at the time of retention. The results indicated that while 3D simulations were effective in promoting student engagement and interest over conventional content, they did not necessarily contribute towards better retention. The study demonstrated that incorporating engaging technology can foster enthusiasm and improve the overall e-learning experience, and received a resounding endorsement from the students.**

***Index Terms*—biology; labster; 3D e-learning; engagement; retention**

I. Introduction

The adoption of immersive learning by ambitious universities and research institutes was primarily driven by the technological flexibility of hosting 3D-based modules. This initiative had a positive impact on millions of students who lacked access to e-learning at leading universities. The open nature of the online courses accessible through browsers made them popular among a wide variety of prospective students. Despite the numerous prominent e-learning platforms available, it is essential to note that 2D courses offer fewer learning options as compared to 3D learning, such as discussion boards, videos, streaming content, and quizzes. However, this limited number of learning tools is widely used because they represent the most fundamental forms of learning interactions that can be universally applied to various courses and subject areas. While some argue that 2D learning activities and content do not promote student learning, some researchers disagree and support their pedagogical validity. Despite the success of e-learning and its unquestionably substantial impact in making 3D learning a standard practice, the low completion rate remains the primary challenge of 2D courses. This is primarily attributed to the all-inclusive, flexible learning arrangement in which students frequently do not perceive an opportunity cost foregone by not participating in courses, resulting in more cancellations and fewer pass rates. Although video-based content delivery is widely used in 2D courses as a learning resource, many students watch videos as a hobby.

To investigate the potential for active learner participation in a 3D environment, this study incorporates problem-based, situated, and creative learning categories as an extension of the 2D content offering. The study finds that a 3D-supported course with these learning categories can enhance the learning experience of students compared to traditional video-based learning. The results and student feedback validate the challenges of learner attrition and disengagement and effectively investigate the research gap for the blending 3D environment. The paper concludes by presenting course information and the need for a 3D-based course, discussing results, statistical analysis of results, student feedback on the learning experience, and finally, outlining prospective research.

II. Background and Related Work

Numerous studies have been carried out previously to evaluate the efficacy of e-learning modules that utilize virtual reality (VR). Each study had its unique methods, and treatment groups produced mixed results. These initial investigations provide valuable information that can assist us in comprehending the intricacies of incorporating VR into educational programs.

Manzoor et al. [1] stated that electronic learning materials which incorporate the VARK principles (visual, aural, read/write, and kinesthetics) could boost the drive and involvement of e-learners in a virtual reality setting accessed via mobile devices. Souza et al. [2] have observed that the use of VR promotes cost-efficient as well as a secure and

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efficient medium to improve health education. Some studies, as reported by Hamilton et al. [3], suggest varied methods of utilizing virtual reality (VR) technology that there is no substantial advantage to using highly immersive VR as opposed to less immersive forms of the technology. However, the study reports benefits in some cognitive studies, particularly those that involve comprehension and visualization of intricate problems. One of the studies, as written by Alharbi et al. [4], indicates that male students displayed good results in 3D-VR effective learning while female students showed good results in traditional methods. Liu et al. [5] draw attention to the emotions of the students when they engage in VR classrooms and state that VR learning brings joy and excitement to the learning process, which promotes positive behaviors, carries out initiatives to ask questions, and promotes active participation. Different research revealed that the impact of an VR-based course varies among learners with different cognitive abilities [6]. The design of the system must pay attention to individual differences among the learners. Several works have also illustrated that students with no further experience in any form of VR found it challenging to operate the technology [7].

Moreover, studies also illustrated by Beteta et al. [8], VR tools have a positive impact on the ongoing enhancement of teaching practices. The degree of interaction during a teaching activity, rather active or passive, influences the level of engagement. The materials and delivery of the content are also critical factors, and it is crucial to encourage participation and collaboration among those involved. The research by Valenti et al. [9], discovered that VR had a beneficial impact on students' interest, resulting in a slight increase in scores and a reduction in anxiety levels. In certain instances, even with limited use, VR captured students' attention more than conventional online teaching. Mystakidis [10] proposed in his study that elements of gamification aroused students' interest, motivation, and independence in approaching critical engagement. Educators need to have the freedom to arrange learning activities and modify final evaluations in innovative ways to unleash student creativity. Chansaengsee [11] have similar results to most of the research; during the Covid-19 pandemic, students lost their interest in online classes. Hence, incorporating learning styles with advanced and easily accessible technology during teaching and learning can motivate students and alleviate boredom. The study's participants expressed interest in using virtual classrooms or virtual reality to learn science subjects. Strojny et al. [12] reviewed multiple types of research on VR learning. According to him, there were basically numerous challenges associated with these advanced technologies. Still, Virtual reality also is connected to particular difficulties that must be taken into account when developing and verifying training instruments. These include factors such as immersion, presence, social presence, and motion sickness caused by visual stimuli. There are several virtual learning platforms as open source, Gaffas et al. [13], through their literature research, found that the ease of use of the learner interface is a crucial factor in determining whether learners will utilize it, and this is closely linked to the quality of the e-learning application design. As per Lee and Shea [14], introducing VR from early school will intend them to use it in their classroom career. Therefore, the implementation of virtual reality (VR) technology as a teaching tool in elementary school classrooms should be included and utilized. It may include necessary equipment, such as smartphones, headsets, and apps, which are required to provide students with access to VR technology.

III. Methodology

A. Learning Process

The simulation which has been selected was chosen on the basis of certain objectives to quantify engagement in a 360-degree learning environment. The topic for the module was *Absorption in the Small and Large Intestines: Journey from the Stomach to the Bloodstream*. The topic was chosen considering the students have already learned primarily about absorption in their previous standard so that they can at least have some basic idea about the topic to begin with. The module was designed in such a way that students can learn and can be assessed during the course simultaneously. A total of 18 students from class VIII of KV IIT Jodhpur participated in the study and were not identified by name or any demographic information such as age, school, or gender. The data collected during the study is secured and only accessible to the investigators.

The study used computers provided by the school for the 2D presentations and laptops from the investigators for the treatment group with an internet connection. They were provided with the required objects during the study, such as a speaker, a keyboard, and a mouse to operate. The research was conducted in the computer lab inside the school premises, and every task was performed by the students in the presence of an invigilator/volunteer who could help them wherever needed.

B. Learning Objectives

A 360-degree module on 'absorption in the small and large intestine' aimed to achieve the following objectives:

- Exploration of the anatomy and function of the small and large intestines in a virtual 3D environment
- Visualizations of different types of absorption
- Manipulation and examination of the organs and tissues

The study aimed to compare engagement levels and retention rates in a 3D environment compared to traditional teaching methods. This can help determine if there are any significant differences in learning outcomes and if the use of 3D-based modules is more effective than traditional e-learning materials.

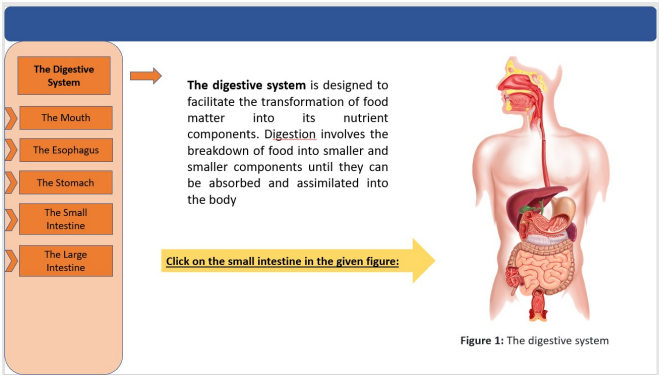
C. Learning Outcomes

The use of 3D models and visualizations enhances students' understanding of the anatomy and function of the intestine by immersing themselves in a virtual environment. At the end of the module, the student is expected to be able to:

- understand the nutrient absorption in real-time
- interact with structures in the intestine, such as villi and microvilli and understand the importance of a healthy digestive system,

This type of immersive learning aims to provide a unique and engaging experience that can enhance students' understanding of different topics, making learning more fun and memorable. It can also promote critical thinking and problem-solving skills by enabling students to explore and analyze complex concepts in a more interactive way. Overall, this approach can help students to develop a deeper understanding of the subject and enhance their learning outcomes.

The research for the treatment group was conducted in an online learning platform ***Labster*** [15], a virtual simulation laboratory (Fig. 1b). The simulation allowed students to explore concepts and complex theories without stepping into a physical science lab. For the students participating in the 2D environment, we created a PowerPoint presentation with similar content and identical assessment. Out of 18 students performed the task in groups, each group containing three members. A total of six sub-groups were formed, out of which three performed in a 3D environment and three in a 2D environment.

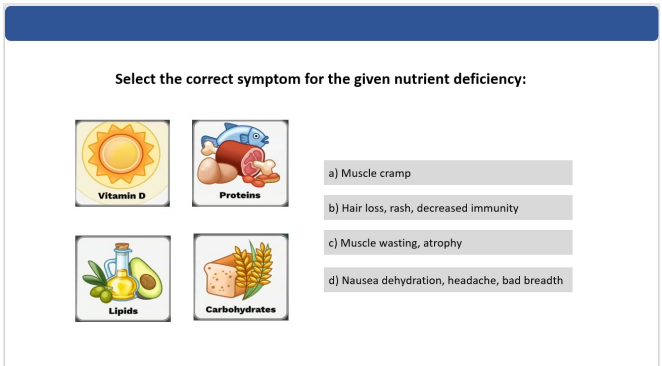


(a)

(b)

Fig. 1: (a) 2D presentation (b) Labster simulated environment overview

The virtual simulations were designed to teach students how the absorption of water and minerals takes in the small and large intestines (Fig. 2a, 2b). Users navigate the virtual world using the keyboard and mouse to look around. It was modeled after the parts of the human body that absorb food and water through various parts of the digestive system, focusing on the function and parts of small and large intestines.



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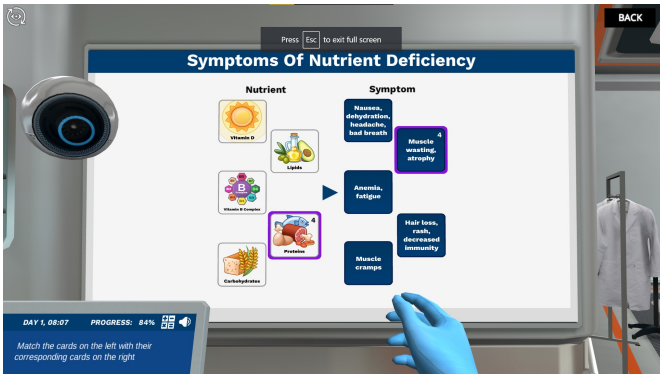


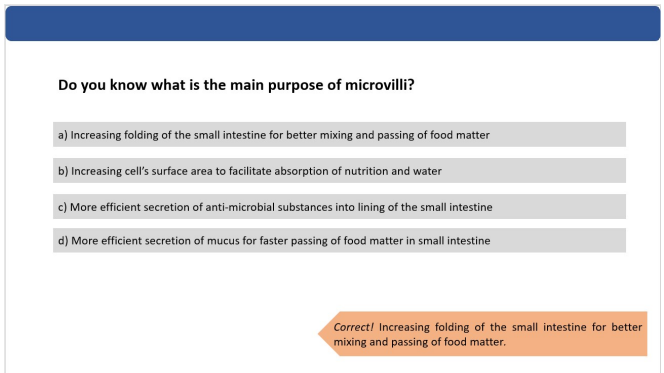
(b)

Fig. 2: Knowledge Checks from (a) 2D environment (b) 3D environment

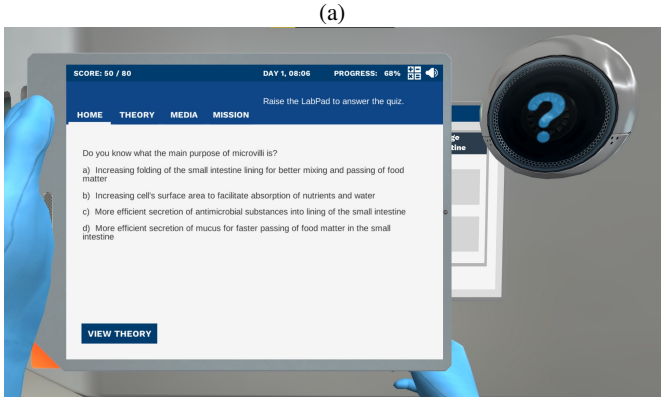
For both the control and treatment group, the questions were formed in an identical manner to serve them equally without any biases (Fig. 3a, 3b).

D. Assessment Process

For the evaluation process, two separate assessments were conducted, first at the time of course and another quiz was conducted after a period of ten days for them to recollect. The evaluation during the course was based on the topic which is being taught simultaneously, and at the time of retention, questions were formed primarily focussing on their capacity to recall the topic taught during the course. It includes a few questions similar to what they have already answered during the course, and some were regenerated on the basis of their recall capacity. Since the target students were from middle school, the questions were designed from lower-order thinking layers of Bloom's Taxonomy (*remember*, *understand*, and *apply*). Considering Remember, we assessed them on their recall fact and basic concepts, while some questions had their basic understanding of the concepts of the topic that had been taught. Whereas considering their capability to apply those concepts, we included a few questions as well.



(a)



(b)

Fig. 3: Questionnaire from (a) 2D environment (b) 3D environment

As a part of the analysis, we used the Wilcoxon Rank Sum Test. The test is a nonparametric statistical test that is used to compare the difference between two groups. Unlike parametric tests, the Wilcoxon Rank Sum Test does not make any assumptions about the underlying distribution of the data, making it a useful tool for analyzing non-normally distributed data. The test produces a test statistic, which is based on the sum of the ranks of the observations in the two groups. The significance of the test statistic is then evaluated using a reference table of critical values or a p-value.

If the test statistic has a p-value less than the significance level, typically set at 0.05, it suggests that there is significant evidence to reject the null hypothesis, which states that the two populations have the same median value. On the other hand, if the p-value is greater than the significance level, there is no significant evidence to reject the null hypothesis, and it can be concluded that there is insufficient evidence to suggest that the two populations have different median values.

We collected data from two groups of participants: one with the control group, while the other with treatment group. We measured the participants' marks obtained during the course and at the time of retention. We used the Wilcoxon Rank Sum Test to compare the difference in their evaluation for each group. Our null hypothesis was that there would be significant difference in the marks obtained by each group. Our alternative hypothesis was that the marks obtained by treatment group is higher compared to the marks obtained by the control group. On the basis of the given hypothesis, the Wilcoxon Rank Sum Test equation is formulated as:

$$z = \frac{|U - \text{mean}|}{\sigma} \tag{1}$$

where U is the test statistic for the Man Whitney U Test (Wilcoxon Rank Sum Test) and σ is the standard deviation. The test statistic (U) is calculate as

$$U = n_1 + n_2 + \frac{n_1\,(n_1 + 1)}{2} - R_1 \tag{2}$$

where n_1 and n_2 are the numbers of participants during first and second evaluation and R_1 is the rank of students in terms of their marks obtained.

E. Rationale Behind the Study

Several researches conducted suggest that the use of 3D environments in e-learning has been found to enhance engagement and retention among learners. This research is based on the rationale that 360-degree learning creates more engaging and immersive learning experiences for students. It promotes autonomy, motivates students to interact, and think critically for any course provided.

Previous researches have shown that introducing gamified contents into learning material can elicit students' interest to the extent that it leads to more positive response than the usual contents. Considering these elements, we tried to put the best experience for the students to have an unforgettable experience to the valuable tool which enhances the effectiveness, promoting students' critical thinking and success.

F. Student Feedback on the Learning Process

Starting with feedback analysis, we began with open-ended questions that allowed participants to express their thoughts and feelings freely. Asking them about the product, how easy it was to operate or how engaging it was. It did include questions on their agreement and disagreement to the product and whether they are likely to recommend it to others or not. For the future aspect, we included one question on whether they would like to take a similar course or not. Fig. 4 gives an explanation the feedback conducted during the class:

The questions asked on the students' engagement, (67%) from the test and (33%) from the control group rooted for excellence. Questions inquired on their usability showed (89%) of the treatment group and (67%) of the control group found it normal to use. They felt little difficulty at the beginning, but operated it quite well once adjusted. Questions of visuals got similar results for both the groups while for overall experience, (67%) of the treatment group and (22%) of the control group voted for excellence. At last, feedback was taken on whether they want to take a similar course in the future and if they are going to recommend it to others, both the groups agreed upon it.

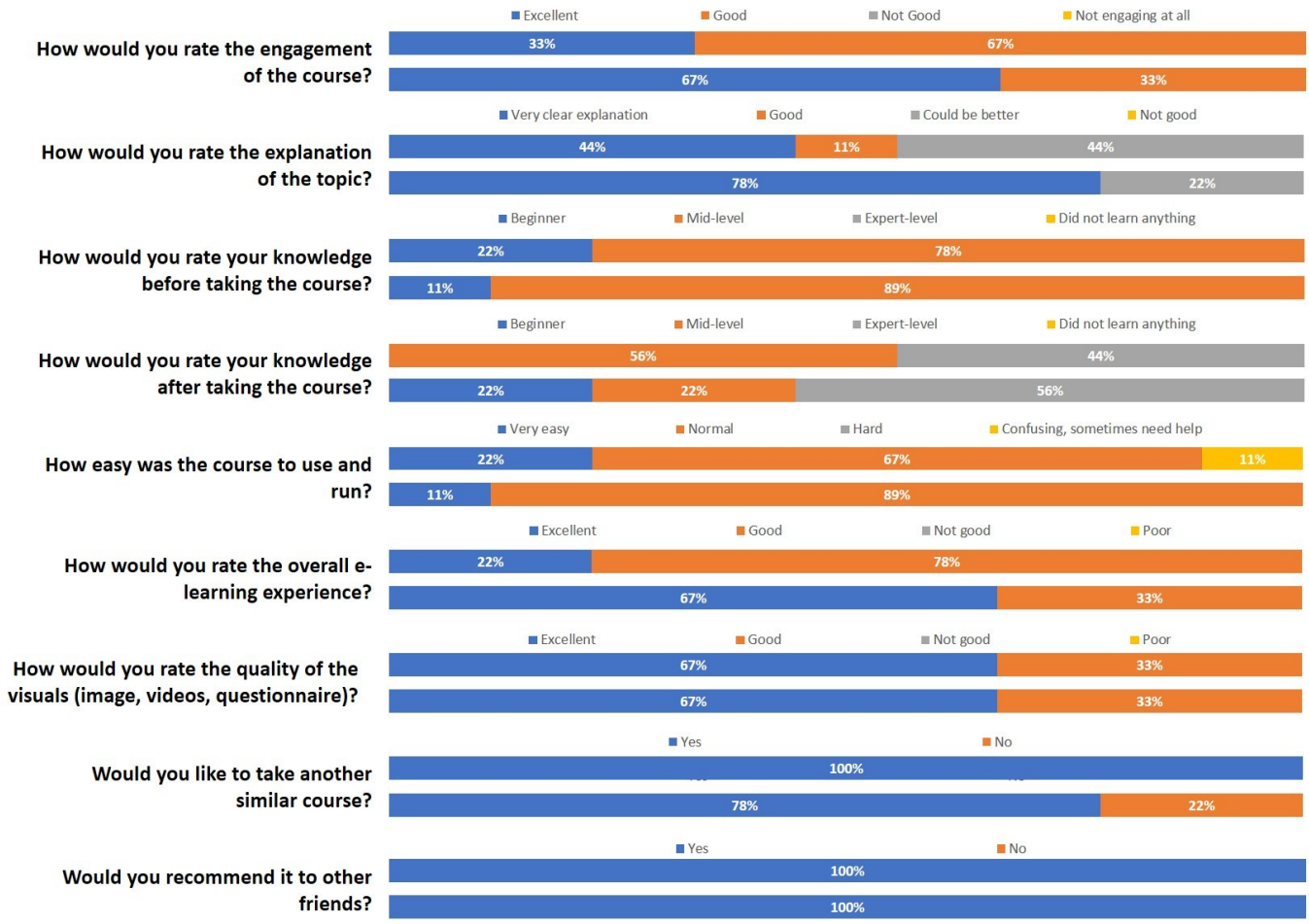


Fig. 4: Feedback of students for the course (For each question, the row on top corresponds to feedback by the Control group, and the row on the bottom corresponds to feedback by the Treatment Group)

In order to determine the sentiment linked with the association rules, we examined the comments that contained the identified word groups and observed that they were mostly associated with positive sentiment.

"Game was better and more engaging than powerpoint."

"Include regional language in the course for more better understanding"

"Like the course because it is exciting and helpful"

It also included negative sentiment associated with the usability and captions for the audio.

Therefore, questions containing multiple options for the students to choose the right option for their feedback has allowed us to analyze it for future expectations. And by combining such open-ended questions, it helped to create a comprehensive feedback survey that allowed us with valuable insights of the product to make improvements.

IV. Result and Analysis

The graph shown in Fig. 5 displays the average marks of class VIII grades for the test (3D) and control (2D) groups. The performance of students in the control and treatment groups within the cohort can be determined by comparing their grades on the Quiz administered during the course and after ten days of the retention period, the lesson that was taught using the same content for both groups.

By comparing the groups, the course delivered with 3D and 2D content for the test and control groups, respectively, we were able to determine the impact of the instructional materials on student performance. The performance of the control group is enhanced by traditional learning content. In contrast, the treatment group received inferior grades when utilizing advanced learning content after the retention period. The marks of the students analyzed during the course were remarkably different. The treatment group, which had 3D content, showed significantly better performance during the course, with a mean value of 78.75% in comparison to marks obtained by the control group, with a mean value of 70% (Fig. 5).

At the time of retention, as discussed earlier the questions were prepared keeping in mind the educational learning objectives. Questions were formed in a hierarchical form including

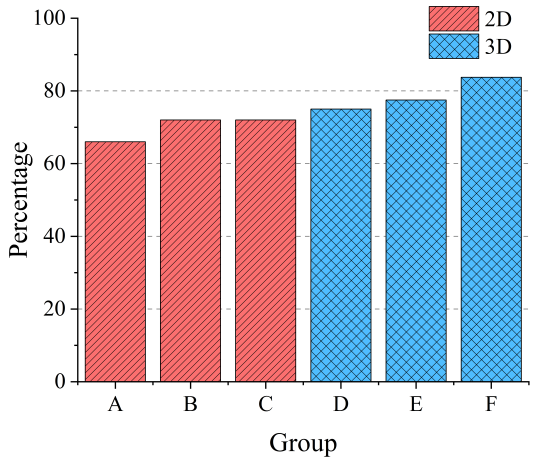


Fig. 5: Records of student's assessments during the course

different level of Bloom's taxonomy starting from basic remembering, understanding and application of the topic they have been taught during the course. Meanwhile, regardless of whether the students of treatment group performed well during the course, the students of the control group showed better performance at the time of retention (Fig. 6).

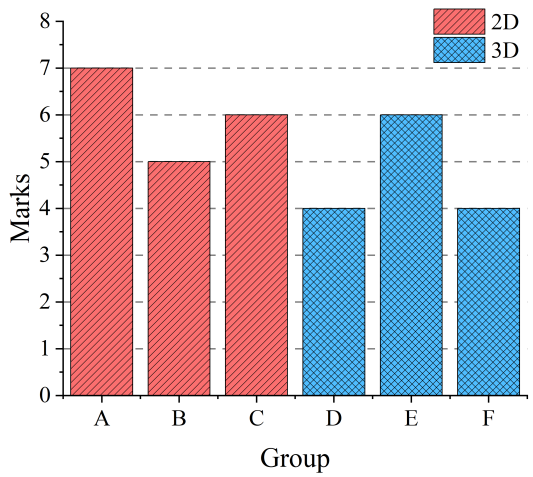


Fig. 6: Records of student's retention on the course

Meanwhile, when we analyzed the Wilcoxon Rank Sum Test, it revealed a statistically significant difference in the marks of the two groups. The control group's score for the marks obtained was 4.71, while the treatment group's score for the marks obtained was 5.27 which is higher than the null hypothesis value. This indicates that, there is no significant evidence to reject the null hypothesis, and it can be concluded that there is insufficient evidence to suggest that the two groups have different median values. On the basis of the results, it usually shows no significant evidence that 3D-learning is more effective than a 2D learning approach but it is apparent that 3D-learning does provide more enthusiasm to learn.

Overall, the Wilcoxon Rank Sum Test provided valuable insights into the effectiveness of 3D learning and helped us answer our research question. By presenting the test results in a clear and concise manner, we were able to provide a convincing argument for the use of this learning approach.

V. Discussions

The main objective of this research was to gain a more profound comprehension of how students learn and utilize technology-based learning tools and environments. The study uncovered notable dissimilarities in students' views regarding learning results, involvement, and ease of use when a 360 degree-based learning is included in the education module.

In the evaluation of 360 degree-based studies, there has been found a significant difference in learning gains. The study's descriptive outcomes indicated that students generally had a positive *perception* of using 3D as a tool for enhancing learning, engagement, and usability in an online learning environment. Although the results revealed no significant differences in actual learning outcomes among the control group, and 3D-based case study group, they did indicate that both the control and 3D-integrated conditions improved students' perception and experience of learning more than the 2D case study group. This suggests that when presenting situation-specific scenarios in technological education modules, as in the present study, the most effective approach involves integrating authentic and active learning activities such as 3D e-learning. This also supports previous research that has shown that student-centered methods that incorporate technology are effective in improving learning. Furthermore, the use of authentic and transformative learning experiences, such as 3D, can generate greater enthusiasm and motivation for learning.

Additionally, throughout the course duration, students in the experimental group demonstrated a greater level of *interest* in learning and exploring the course content. They had access to a considerable amount of material to investigate, although they were unable to explore it fully due to time limitations. In contrast, the control group, which had limited content to the course material consisting mostly of theories and diagrams, exhibited less enthusiasm and were more disinterested in the learning process. Overall, the experimental group's exposure to a more engaging and immersive learning environment led to a higher level of motivation and interest in the course material.

During the time of retention, as students of the control group have less content to explore, significantly condensed theories and straightforward questions, showed better results compared to the treatment group, who usually immersed themselves into the environment with more engagement and interaction that they could not recall the questions that have been asked from the course theory, and failed to score good marks at the time of retention.

A. Limitations

While this research has important implications for linking the level of technology utilized to present situation-specific scenarios with perceptions of learning, engagement, and usability, it also has constraints regarding the extent to which its results are being generated. The treatment group collectively

scored less marks than the control group at the time of retention and the reason could be the amount of content on different areas to explore which provided them with less time to memorize entirely.

Further, it is suggested that future studies should replicate this research in various educational settings, incorporating more advanced technical skills education, in order to establish whether there is a correlation between 3D and the extent of technology employed in teaching and learning, and learning outcomes, engagement, perception, and usability of technology-driven instruction.

B. Implications

These implications are particularly relevant for instructional designers and educators who are responsible for developing, designing, and delivering educational content. Given the increasing demand for technology-based instruction, it is crucial for instructional designers to possess a thorough understanding of the connections between online and digital learning tools and student outcomes, attitudes, and beliefs. For prospective instructional designers, it is essential not only to acknowledge the significance of student learning outcomes, but also to incorporate instruments that have a favorable effect on students' attitudes, perceptions, and ease of use when dealing with technology-driven learning systems. Moreover, this study affirms that the use of 3D learning to enhance the comprehension of educational concepts is an appropriate and even advisable technique when teaching technical education scenarios that are context-specific.

However, the adoption of high interactivity raises the intricacy of the simulations, leading to an increase in development time and a higher possibility of software malfunctions. Therefore, virtual reality developers must strive to strike a balance between the level of interactivity and the maintenance of a dependable and efficient simulation.

VI. Conclusion

This study was conducted to examine the potential of a 3D environment as a medium for delivering e-learning content, which could enhance student engagement and improve their learning experience. The researchers hypothesized that the interactive experience provided by 3D materials would be more appealing to students and increase their interest in the course compared to conventional forms of content such as video lectures. The study involved both 2D and 3D setups, and the results showed that 3D simulations were more effective in promoting student learning. The feedback from students revealed that certain key factors needed to be addressed to optimize the use of 3D content in e-learning. Specifically, the students emphasized the importance of audio quality and the availability of subtitles or other textual support while using 3D learning materials. Involvement of regional language for a better approach. The study recommends further research to explore these factors and incorporate suitable technology before implementing 3D content delivery as a mainstream approach.

The study had some constraints, primarily due to unavailability of sufficient number of students. Moreover, it was challenging to integrate multiple courses into the students' regular school curriculum. Therefore, it is essential to recognize that the 3D exercises and courses used in the study were relatively limited in scope, and the findings cannot be broadly applied. To address these limitations, further research is recommended.

It must be stated that although the tools and techniques (especially the use of Labster) may not be cost-effective for a long-term use, the concept can still be implemented effectively with other cost-effect VR learning materials. The study has shown that incorporating an engaging technology such as 3D can generate enthusiasm for course activities, thus providing a significant opportunity for e-learning designers and educators to address the challenge of student engagement and enhance the overall learning experience.

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Reflective prompts for productive uncertainty management: Enabling shift in positional framing

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***Abstract*—The ill-structured nature of engineering design problems brings inherent uncertainties as engineers attempt to solve them. Such a problem-solving activity requires extensive collaboration among team members towards productive uncertainty management. The nature of this collaboration varies among groups depending upon the positional framing among the members. Novices often have unsupportive collaboration structures leading to unproductive uncertainty management. This paper discusses the effects of prompting novices to reflect while they solve an engineering design task. A study was conducted to analyze the role of reflective prompts in productive uncertainty management. As the participants begin to reflect due to prompting, a shift in positional framing was observed among the members. It was also observed that team members actively participated and contributed to the problem-solving activity because of reflection due to prompting. The potential role of reflective prompting in shift in positional framing towards productive uncertainty management is thus explored and presented.**

***Index Terms*—engineering design, uncertainty management, reflective prompts, positional framing**

I. Introduction

Day-to-day engineering design problems are usually complex and ill-structured [1], [2]. As engineers attempt to solve these problems, they encounter unanticipated issues that lead to uncertainty in solving the problem [3]. These problems often have multiple ways of solving, solutions and conflicting goals which add to uncertainties faced by engineers. Effective problem-solving in such cases requires engineers to collaborate extensively to resolve these uncertainties productively [4].

The problem-solving knowledge in engineering is found to be distributed among the team members and hence effective collaboration is important in productive problem-solving [1]. Productive uncertainty management in engineering design is thus a social endeavor and requires effective communication among peers [5], [6]. It is found that peers in such a scenario could have i) supportive peer responses, in which peers either share a common uncertainty and address it or help others in resolving their uncertainties or ii) unsupportive peer responses, in which peers disregard each other's uncertainties and ignore to resolve them [3].

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Previous research on uncertainty management in collaborative problem-solving finds that peers assume different positional associations. These are called positional framing. It refers to how an individual entitles, expects or obliges oneself and others in a collaborative activity [7]. In such associations, one (or more) peers take the role of decision-making authority or of assistants or are regarded as insignificant members in problem-solving [8]. They also assume the role of legitimate collaborators in which they seek ideas and help from each other and collaboratively resolve uncertainty. In collaborative problem-solving novices are observed to have unsupportive peer responses due to which they tend to ignore uncertainties raised by peers or ignore the ideas and suggestions put forward by peers. The uncertainty management in such cases results in unproductive problem-solving as novices fail to expand their knowledge repertoire and build a tolerance to uncertainty [9].

Novices thus require support in critically analyzing the situation and comments from peers to acknowledge uncertainties and take logical decisions towards managing them. The skills to critically analyze and reason is challenging to learn and is uncommon among novices [10]. This skill can be fostered by triggering novices to reflect [11], [12] using reflective prompts. Reflection is a skill to develop new knowledge or perspective through critical analysis of certain situation or phenomena [11]. Davis found middle school learners to have better sense-making and critical thinking skills as a result of prompting them to reflect [13]. Previous research also finds using reflective prompts to help novices acknowledge, maintain and productively manage uncertainty as they solve engineering design tasks [14].

This research presents the analysis of change in positional framing among novices as they are prompted to reflect while they solve an engineering design task. The study explores answers to the research questions presented below.

(RQ 1): How do the participants respond to reflective prompts?

(RQ 2): How is positional framing associated with reflection due to prompting?

II. Study Design

A. The task

In this study, a group of four undergraduate engineering students were given an engineering design task. The team had to program an educational robot to autonomously navigate through a 7x7ft arena printed on a flex. The task of the robot was to navigate through the flex using line-following sensors and correctly identify the color of the color patch placed beside the node (a black square on the line). Fig. 1 depicts a section of the arena and indicates path, node and color patches.

Fig. 1. Section of arena showing path, node and color patches

B. Participants

The participants were a group of four undergraduate engineering students in the third year of electronics engineering. The group consisted of three boys and one girl. All of the participants had a similar academic performance history (CGPA$\geq$8.5), a similar (basic level) understanding of programming microcontrollers and no prior experience in solving such a task.

C. The prompts

During the problem-solving activity, the team members were verbally prompted using three types of prompts viz., activity, directed and generic prompts aimed to trigger reflection [13]. Activity prompts were designed to help learners reflect by making them list the past and current state of problem-solving. *"We will design our mechanism as.."* or *"We have the following components"* are examples of activity prompts. The directed prompts such as *"regarding this we think.."* aimed at making participants think and reflect regarding specific aspects and state of problem-solving activity. Generic prompts aimed to trigger reflection by giving participants a choice on the aspect to reflect on. Prompts such as *"we wonder.."* or *"we think.."* are examples of generic prompts.

D. Data collection and analysis

The team was given 90 minutes to complete the task. Their activities during this period were recorded through audio and video recording. The recorded data was transcribed and a qualitative content analysis [15], [16] approach was used to analyze the activities. A coding scheme derived from existing literature was used to analyze the uncertainties faced by the team members [3] and behaviors pertaining to reflection [13] and to categorize the activities as productive or unproductive [4]. Positional framing was analyzed using an existing interpretation framework to identify i) decision-making authority (lead), ii) assistant and iii) legitimate collaborative framing among the members [8], [17], [18].

III. Findings

A. RQ1: Participants' response to prompts

The participants' response to prompts was found to be of two types. In the first type, the members simply answered the prompts but were not found to deliberate or reflect on the prompt. A sample of such a prompting episode is presented below. The participants are referred to as P(1-4) and the instructor as I in all the conversations presented.

I: We wonder this material might be useful for?

P3: Color sensor will be used for detecting the color.

P2: Color sensor can also be used to control the velocity of the robot so as to stop when a red light is detected.

In another type of response, participants reflected and then responded to the prompt. An example of such an episode is given below.

I: Anything else that can affect line following?

P1: may be the surrounding lights..if its the dark room maybe it won't be easily able to detect the line (thinking deeply and reflecting while answering)

I: So..is there any other issue?

Team thinking (reflecting)

I: We wonder.. we might tackle these issues as..(directed prompt)

P2: Color sensor can also be used to control the velocity of the robot so as to stop when a red light is detected.

During the problem-solving activities, various approaches were taken by the team to manage their uncertainties. These activities were analyzed to check if they were productive or unproductive. This categorization was informed on the basis of scientific reasoning or understanding demonstrated by participants as they did these activities [4]. For example, an approach where team members changed randomly robot velocity for node detection (a trial and error approach), but had no reflection and reasoning on the success or failure of trials was considered an unproductive activity. Whereas activities such as conceptualization of the robot behavior on node or calibrating sensor values based on line detection were considered productive. For a temporal representation of the activities (see Fig. 2), the activities were mapped to codes presented in Table I.

TABLE I
Codes and activities for temporal representation

Code	Activity	Description
1	Unproductive - answer	Team responds to prompts without reflecting
2	Unproductive - approach	Team discusses/follows an unproductive approach
3	Productive – understanding	Team conceptualizes robot activities
4	Productive – reflection	Team reflects and responds to prompts
5	Productive – approach	Team follows a productive approach

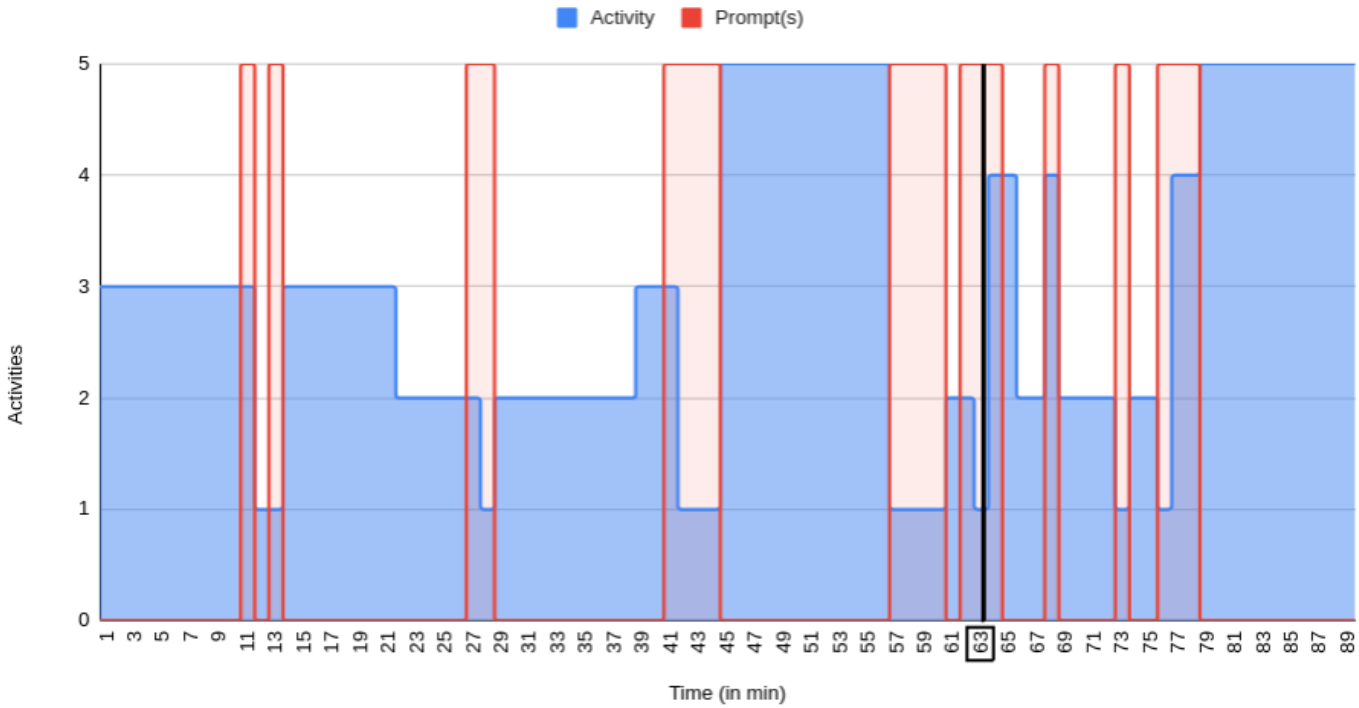

Fig. 2. Temporal representation of activities

From Fig. 2 we see the team engaging in both productive and unproductive activities. The prompts do not appear to trigger reflection initially. The team begins to reflect around the 63rd minute onwards. The analysis of productivity of activities before and after the team began to reflect on prompts (around 63rd minute) was done. We found the team to be productive for around 19% of the duration before 63rd minute and around 41% of duration after 63rd minute.

Thus, as the participants were prompted to reflect, their responses and activities were both productive and unproductive in nature. The prompts triggered reflection in the later half of the activity, specifically after 63rd minute, as the team gets acquainted with the problem to connect the prompts to the prior experience for reflection. [19]

B. RQ2: Association of positional framing with reflection

1) Reflection and participation in discussions: As seen, the participants are found to reflect and respond to prompts after the 63rd minute of the activity. Hence, we consider the fraction utterances by each member of the group before and after this event. The fraction of utterances by each member is presented in Table II.

TABLE II
CHANGE IN FRACTION OF UTTERANCES

Participant	Fraction (%) of utterances			
	Overall	**Before**	**After**	**Change**
P1	25.73	26.49	24.48	-2.01
P2	28.91	34.19	20.28	**-13.91**
P3	29.18	24.36	37.06	**12.7**
P4	16.18	14.96	18.18	3.22

We observe that Participant 2 had majority of utterances before the team members reflect and respond to prompts. But later, a change is observed and another participant, Participant 3 is observed to have majority of utterances. The change fraction of utterances is around 12-14% for both members. A slight change of 2-3.2% is also observed for other participants. ***Thus, as team members begin to reflect, a change in fraction of utterances of the team members was observed.***

2) Reflection and shift in positional framing: The shift in positional framing is analyzed with respect to the change in roles assumed by each member. The members were found to either lead the discussion or activity (Lead) or help and assist the lead (Assistant) or regard each other as legitimate collaborators (LC) during the activity. Table III presents the different roles assumed by different members for the fraction of duration before and after the team reflects and responds to the prompts (around 63rd minute).

TABLE III
CHANGE IN POSITIONAL FRAMING

	P1	**P2**	**P3**	**P4**
Fraction (%) of duration before 63rd minute				
Lead	14.05	**51.89**	27.57	0
Assistant	56.76	18.92	43.24	73.51
LC	29.19	29.19	29.19	26.49
Fraction (%) of duration after 63rd minute				
Lead	**27.87**	19.67	**26.23**	**6.56**
Assistant	44.26	52.46	45.9	65.57
LC	27.87	27.87	27.87	27.87

As we see, Participant 2 is observed to initially lead the discussion and activities for approximately half the duration before the team reflects while responding to prompts. A shift in positional framing is observed after later with participant 1 and participant 3 also leading the discussion and activities. Moreover, the fourth participant who did not take the lead earlier is also found to lead take the position as a lead for around 6.5% of the duration. ***Thus, as team members reflect while responding to prompts, a shift in positional framing was observed with different participants taking lead for more duration in discussions and activities.***

IV. Discussion

In this study, as the novices manage their uncertainties, we observe an increase in the productivity of their activities and more participants are found to take the lead as they reflect while responding to prompts. Reflection is typically found to develop a new perspective through critical analysis of the situation [11]. In our case, the development of this new perspective is found to help participants engage in productive activities. Reflection also helps in critical analysis of situation and sense-making [13]. Thus, we find that the reflective prompts enabled the participants to critically analyze and make sense of their problem-solving approach [13] and they begin to actively contributed in the problem-solving activity.

In the problem solving activity, participants thus communicated more effectively which helped them externalise their thoughts and ideas leading to productive uncertainty management [6], [9]. Further, different participants led the discussion and problem-solving activity. An increase in the duration of different members taking a lead and an increase in overall productive management of uncertainties after the team began to reflect shows that reflection also enabled members of the team to identify and take appropriate roles as they attempted to resolve uncertainties.

V. Conclusion

In this study, students' positional framing was analyzed as they were subjected to reflective prompting while resolving uncertainties in an engineering design task. We find that as the team begins to reflect on the prompts, the contribution to discussions in terms of fraction of utterances by different team members changed. Moreover, a shift in positional framing is also observed with different participants taking more lead in discussion as well as problem-solving activities. Reflection is found to be closely associated with these changes and to facilitate an effective collaboration towards productive uncertainty management. The findings show a promising role of reflection in aspects of positional framing in uncertainty management but have limitations with respect to the small sample size of the study. The findings are also limited with respect to the specifics of the task. Although none of the participants had prior experience in solving such a task, their prior experience and interests with sub-aspects of the task also requires to be analyzed to understand their positional framing. A future study can also focus on analysing the findings with respect to other social framings such as epistemological framing and with more participants and could lead to better assessing the role of reflective prompts. In summary, we find a promising of reflective prompts in facilitating a shift in positional framing and productive uncertainty management in engineering design.

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Imagining Pedagogical Agency vis-à-vis the Rise of Digital Parda (Veil): Understanding Gender and Blended Learning in Rural Haryana

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***Abstract*— The interface of feminist discourses with emerging techno-cultures of education has been a subject of intense debate in both techno-feminist and GAD (Gender and Development) frameworks. The paper proceeds through a study of cultural responses to technological dimensions of women's education in a patriarchal setting in rural Haryana, primarily within a university. While the pandemic validated certain new modalities of blended learning, enabling new choices, possibilities and agential expressions on the pedagogical landscape, it was also witnessed that this matrix was recast alongside new cultures of muting and digital veiling (the mike and camera control features) as well. Thus, the often cited culture of silence [5] and veil [3] find an avenue for resurgence. The paper brings out different dimensions of this exclusion/ empowerment dynamic while framing it within the feminist space of theorizing agency. The symbolic use of the term *Digital Parda* is explained in terms of the changing indices of identity negotiation and pedagogical horizons of imagining transformative futures for feminist inquiry. Beginning from a literature review of studies of feminist technoscience [9], [8], [17], the paper foregrounds ideas of morality, choice and agency [6], [13] on a pedagogical landscape of gendered subjectivities and newly encountered tech-enabled modalities. The methodological framework draws upon feminist pedagogy and ethnographic analysis of higher education cultures at a women's university in rural Haryana. In the final analysis, the paper argues for rethinking frameworks of integrating new technologies and pedagogical interventions for a gender-just future.**

Keywords*— *Digital Parda, Pedagogical Agency, Gender, Rural Haryana.

I. Introduction

There has been so much written about the interface of gender with technology that it appears just another thread woven into the longstanding debate if one mentions pedagogy alongside it. The feminist critique of science and technology, including technoscience, provides a rich reference to this debate. The debate involves countering patriarchy in its diverse forms in the uneven world of knowledge creation and masculine domination through (techno) scientific paradigms of shaping the world. The debate has its center in agency, the transformative, transcending space that feminist theories seek to claim. From Mary Wollstonecraft to Judith Butler, it is not difficult to highlight agential arguments of feminist praxis, waves notwithstanding. Feminist pedagogy thus envisions consciousness raising [11] accompanied with a practice of freedom [10] rooted in concepts of sisterhood and agency. This paper emerged out of an ethnographic observation and adherence to feminist pedagogical praxis, both experientially and analytically, while teaching at a women's university in rural Haryana. Being located as teachers on the university campus, the relevance of this study for the authors was primarily in understanding the pedagogical as transformative, alongside its interface with the newly emerging techno-cultural avenues.

Patriarchy arguably functions alongside a false divide of the public and private. Its configurations and dynamics vary from context to context. Education has emerged as a site for intervention right from the early days of struggles against gender inequality rooted in patriarchal social orders. In the shadow of the pandemic one witnessed a recasting of the public-private equations resulting in a disruption of the conventional boundaries separating the two. Further, with the mainstreaming of online learning mode alongside the face-to-face model of classroom communication, certain new realities have emerged which merit attention and analysis. The new modalities presented a window to articulate expression of pedagogical choices and voices within a new format. With the classroom and institutional setting for learning shifting its base, new challenges and opportunities also came up with regard to the feminist aspirations for a gender-just pedagogy.

II. Theoretical Linkages and Conceptual Framework with Review of Literature:

During the pandemic and in the wake of the New Education Policy (NEP) 2020, classroom contexts in India experienced certain shifts. These shifts have a lot to do with technological innovation and its integration with education. Once globalization had changed our space-time configurations of learning and imagination, a tidal wave of new technologies and modes of communication brought new horizons and possibilities up on the pedagogical canvas. However, there are a few pitfalls too. After all, technological advancement in communication and popular culture has many sides to it as highlighted in critiques emerging from the Frankfurt theorists like Herbert Marcuse, J. Habermas and T. Adorno as well as in theorizations by the latter-day feminist approaches, formulated

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as a result of encountering the new digital convergence and rise of social media based popular cultures [14], [7].

A. *The customary practice of Parda (Veil) in Rural Haryana:*

North Indian patriarchy is well entrenched in certain cultural practices which reinforce the silencing of agential voice of women through practices like a selective veiling of face (interchangeably called *Ghunghat* or *Parda*), especially in the presence of certain kin group members as a caste based customary act, also seen as a marker of respect for elders in this society [3]. It may acquire different forms depending upon the location and societal prescriptions but always assumes the role of a screen which separates and segregates. For example, while performing agricultural work the rural women mostly cover their face in such a way as to facilitate proper functioning of their hands and vision (called *Dhhattha*). Even this slight variation meets with social disapproval for being a dilution of the custom [3]. However, it is an improvisation rooted in the necessity of performing everyday tasks by women in public and is increasingly being adopted in different forms. In any case, the idea of a screen (also called *Parda,* the word used for a curtain) is central to this practice.

B. *Foregrounding agency vis-à-vis Parda:*

The idea of missing women, used extensively to point out the existence of adverse sex ratios, son preference and daughter aversion in India, leads one to ask about the possibilities of locating and salvaging the seemingly missing (feminist) subject in the present context. In this light, the search for the missing (rendered invisible) pedagogical subject arguably forms the core of feminist theorizations, including this study. Carol Gilligan has brought out the idea of agency within the framing of the care ethic and a different women's voice grounded in moral terms [6]. Multicultural feminist perspectives [19], [12], the debate on *Hijab* in educational institutions and a critique of the western liberal feminist project foreground a different feminist politics of cultural and moral subjectivities [13]. Foregrounding agency shows us a way in understanding the nuances behind the making of a feminist subject.

The gendered nature of the digital knowledge economy is also well established [16]. The symbolic use of the term *Digital Parda* helps us understand the complex processes behind navigating the subjective dimensions of identity and representation in the world of online learning and knowledge acquisition. The cultures of muting (silencing) and surveillance present the acting subject with constraining choices to circumvent a hyper-regulated mode of participation, leaving limited scope for resistance. This study brings out the agential expression of sisterhood through evolving a feminist subjectivity based on ownership of learning and the choice inherent in the screen presence or withdrawal feature in a pedagogical setting of an online classroom.

C. *Techno-feminism and its aftermath:*

The interface of gender with technology remained the basis of path-breaking theories, mostly characterizing the second wave of feminism in the west. The whole gender and development framework (GAD) articulated the idea of institutional change in definitions of work and gendered cultures of framing technology, both at the workplace and inside home. Eco-feminist approaches [15], alongside critiques of mainstream science [9], [17] as an objectifying discourse marginalizing women's voices and standpoint, emerged to explain the fallacious dichotomies of nature-culture, private-public, reason-emotion and mind-body etc. Feminist anthropologists and scientists fiercely criticized the technological appropriation of women's representation and life-worlds. The whole project of the market economy in alignment with technological design was seen as an extension of the logic of masculine domination in these formulations. However, with the coming of new popular culture assertions of the feminist solidarities and different voices (including that of friction and disagreement), new femininities were seen emerging which brought the idea of agency within the spaces seen as marginalizing in earlier representations. Judy Wajcman [20], an early theorist to have written on a techno-feminist framework, highlighted the scope for articulating agency within the emerging technocultural transformations and possibilities.

Contemporary articulations include assertions like complexification of backlash [14], feminist killjoy manifesto [1], surveillant sisterhood [4] etc. These seem to be creating unforeseen spaces for feminist articulation in popular imagination and techno-cultures. In these assertions one sees a response to the stereotyping of feminism and the consequences of the emergence of popular feminism which calls into question ideas like happiness, success and most importantly self-identification as a feminist. Thus, in a reconfiguration of the projections of the cyborg manifesto [8], one witnesses new challenges to the theoretical dichotomization of being and thereby the evolution of a post-feminist subject. Evidently, both Angela McRobbie [14] and Rosalind Gill [7] see a possibility of multiple feminist voices even in the face of denial of its earlier versions.

III. Pedagogies of Silence and Research Questions:

The idea of a culture of silence [5] appears overwhelmingly present in pedagogical cultures prevalent amongst women learners in rural Haryana. With the coming of the pandemic, classrooms suddenly went online. This presented an opportunity to understand the gaps and blind spots in feminist pedagogy approaches privileging voice and a liberal framing of the pedagogical subject. It was evident in the ethnographic observations that the idea of feminism (the term itself) was not having much of an appeal for many women students who were surrounded with cultures of caste-based honour and masculine domination, as evident in a north Indian patriarchal social order. The research questions were thus an attempt to understand this phenomenon and comprehend the working of pedagogical agency within this set up. Online education, with its disruption

of the normal, provided a window to do the same. Thus, the following questions were taken up for analysis.

1. How do the students see online experience of learning vis-à-vis their cognition of subjectivity, choice and agency?
2. How can technological spaces of learning become uplifting or constraining?
3. How is the normative and institutional framing of pedagogy reinterpreted in the new scenario?
4. Whether cultures of silence are reinforced or encounter a challenge in these new spaces with identity renegotiation and new mechanisms for participation?

The idea of finding resilience and agency within patriarchal regimes and their framing in popular culture is well established in feminist approaches. Rani Tokas in her study of women singers of Haryana points out the articulation of this agency in the performative domain and the blurring of folk-popular dichotomies through new technologies and popular cultures in social media [18]. Despite the frame being patriarchal with misogynist overtones, women performers are able to subvert the logic and carve out a niche for themselves with their agential voice and identity assertion.

IV. Methodological framework:

The methodological standpoint for this study has been ethnographic and reflexive analysis of the learning experiences of women university students in rural Haryana. The students were primarily pursuing courses in introductory sociology, sociology of law and sociology of gender as part of their undergraduate studies in an integrated law course. The time frame was almost one year (during 2021-22). The methodological framework was taken from feminist ethnography and feminist pedagogy approaches. The processes of meaning making were analyzed, situating them in their cultural context and interpretative theoretical frames. Thus a constructivist paradigm was followed while remaining open to alternative models of explanation. The method was primarily the observation of classroom discussions, including other related participative modes. The students' written responses were also considered important sources for understanding and interpretation. The voluntary participation of students in online creative activities and forum discussions was also incorporated as a significant dimension of fieldwork. The location of being a teacher both facilitated and presented a challenge for the authors in analyzing students' responses, especially the performative aspects, and necessitated an observant participation, reflexively achieved.

V. Findings and analysis:

The findings generated a referential argument for evolution of creative pedagogical interventions which have a contextualized significance for giving expression to articulation of agency of the learners. Given the background of a patriarchal setting, it was not simply expected that the very ideas which seem constraining can provide a platform for generation of a counter imagination and practice. The findings are summarized as below.

A. The agency of making pedagogical choices through a Digital Parda (veil):

This camera feature is very effective. Anytime we wish, we can appear or go behind the screen. Even if one is muted, it helps to bring the focus on oneself instantly. The other person has to listen to us. But when we do not feel good or comfortable, we can just put it off.

This narrative resonated with many students who believed that the idea of comfort is prior to communication. They feel that it is important to participate in public but one must have the option to stand at a distance as well. This has linkages with the understanding of privacy for the youth alongside consent in matters of participation in any collective deliberation. This also attests the assertion that the option of self-regulated (temporary) withdrawal from any communicative and pedagogical process also has significance in improving assessment of self-worth and enhances confidence in the learning mechanism.

The above observation has actually become definitive for almost all other inferences as well. The idea of being in control, in however small a capacity it may be, provides an alternative standpoint for empowerment and agential expression. This becomes much more significant from the perspective of a pedagogical search for transformative resistance and agency.

B. Feminism has many names:

An important observation of the study has been the shadow of doubt cast upon feminism as a reliable strategy to define one's belongingness and identity. There is a clear preference on the part of women students to seek 'safe' ways to 'success' and 'good life'. Many do not want to identify with the label 'feminism'. This is primarily due to the stigma created by trolling of feminist ideas in social media as well as the hyper-visibility of the term itself. The quest to seek validation has multiplied with a range of new avenues, primarily availed through social media, creating a huge appeal for women students today. Family is another significant factor, primarily seen as the most reliable support system. A student shared her anxieties about being seen as a feminist in the following words.

Why do we have to brand ourselves as feminists? I don't understand. We can have many roles at a time. All the roles have their place in my life. My success is also a goal I have because of my family background. I can't tell my family about feminism. They won't like it. It has a bad name and is considered harmful for family unity.

C. The blending must be harmonious, creative and non-confusing:

Students adapted to online education with certain limitations. The issues of access notwithstanding, the very demands of

staying on screen for long were not received well. However, they also felt certain features of online study were much more meaningful than the usual face-to-face mode. Especially the ones that gave them scope for creativity. They also felt that online learning should have its own, different ways of assessment.

How can we be tested just like the earlier times? If the time to write an exam is three hours even now, then what is the difference? From where does one charge one's phone for such long hours? Can't we be given an assignment instead of these conventional exams?

D. Sisterhood has no replacement:

One witnessed a persistent craving in students to go back to their hostels in the university. They eagerly awaited the resumption of offline classrooms. The reason was not their aversion to online learning. It was the feeling of being away from their peers. They wanted their help consistently. The ideas of sisterhood work in a thousand, micro ways and construct the journey of a student. The ideas of solidarity for students are grounded in processes of micro-adjustments on an everyday basis. They often use the word 'sacrifice' to refer to their connection with their perceived 'best friends'. One can easily relate this with ethics of care. A student who shared her contentment with online learning once mentioned that her technological devices are her best friends. This, however, was not what the majority felt despite the huge popularity of social media applications amongst the students.

E. It all depends upon the teacher:

The students feel that the teachers can actually make the online learning work. But they also feel that a sudden shift in modalities has overwhelmed the teachers. For themselves, they feel that the window of taking longer time to adapt is open. They also believe that the pressure to work with new systems of technology is good also, at one level. At the same time, it is stressful too.

Our teachers must understand our situation. Imagine taking an online class with one's parents sitting nearby. This idea of empathy is really good in theories of sociology. It all depends upon the teachers' understanding and making us understand as well. Even this online thing can become a good way to learn if teachers create new ways of learning through it. But it seems even they are struggling.

VI. The Search for the Missing Subject vis-à-vis Pedagogical Agency:

As explained in the theoretical outline of this paper, the search for the missing pedagogical (feminist) subject lies at the heart of this study. The subjectivity rooted in one's cognition primarily has a cultural orientation. If the pedagogical subject can locate herself amongst the conflicting discourses present within an institutionalized cultural set up of learning, the first step towards realization of agency is achieved. The next step is to find a collective, intersubjective belongingness which validates the moral positioning of the subject. Feminist pedagogical project has gained momentum with articulation of synergies present in different contexts and avenues of solidarity. Technological recasting of the idea of learning with blending and amalgamation of online and offline instrumentalities also provides an effective platform for such an imagination. To have a pre-conceived notion about the contextual variations in terms of rural, urban, international etc. can undermine the search for such transformative spaces as the one articulated with the idea of a *Digital Parda* (veil). The potential of drawing upon this paper mainly consists in extending this analysis to different spaces of articulating feminist agency where it appears veiled. *Digital Parda* thus unveils a new agenda for feminist intervention and research.

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Designing UDL-Informed Online Learning with Digital Tools

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***Abstract*— This paper explores the pursuit of addressing diverse learner needs in education, specifically online learning through application of digital tools to implement Universal design for Learning (UDL). It describes the integration of nine UDL checkpoints in "The Digital Teacher" course, an online course offered by UNESCO MGIEP. Eleven free or freemium digital tools are utilized to operationalize each UDL checkpoint. The paper describes how the affordances of these tools enables educators to offer learners alternatives for auditory and visual information, illustrate content through multiple media, activate background knowledge, vary methods for response and navigation, support planning and strategy development, minimize threats and distractions, foster collaboration and community, and facilitate self-assessment and reflection. It highlights how this approach enhances learner engagement, content comprehension, navigation, and expression. Overall, the paper emphasizes the potential of digital tools to effectively operationalize UDL checkpoints and to enhance the accessibility and effectiveness of online learning. It provides valuable insights for educators seeking to create inclusive and effective online learning environments.**

Keywords—Universal Design for Learning, low-cost technology, online learning, digital tools

I. Introduction

Addressing the diverse needs of learners stands as a paramount pedagogical pursuit in the realm of education. Extensive research has examined the challenges faced by teachers in achieving this goal [1, 2, 3, 4, 5] Based on the findings, the notion of addressing challenges by catering to specific "learning styles" has been discredited [6]. Instead, studies have shown that each learner has a unique way of learning, influenced by various factors, including neurology, culture, personal relevance, subjectivity, and background knowledge, among others [7].

Research in the field of cognitive neuroscience has shown that the three neural components of the brain namely, recognition, strategy, and affective network show different patterns of activation based on their people's past experiences, emotional states, meanings they attach to the stimulus and other factors. Therefore learners are inherently different in the way they comprehend information (using their recognition network), engage with learning experiences (based on their affective network), and plan, manage, and demonstrate their learning using their strategic network [7, 8].

The COVID-19 pandemic has further highlighted the importance of addressing diverse learner needs in online learning because of the unique challenges that it presents. These include the absence of real-time teacher guidance, limited just-in-time support and feedback, and increased student responsibility for independent learning management [9] .The endeavour to cater to such diverse needs poses a significant challenge for educators.

II. Universal Design for Learning

Universal Design for Learning (UDL) is a widely recognized framework to design curricular goals, methods, materials, and assessments that cater to a wide diversity of learners [7,8,9] . UDL was developed in the 1990s and early 2000s by the Center for Applied Special Technology (CAST) as a framework for developing curriculum that is more accessible for all, including students with and without disabilities [10].

The UDL framework is composed of three principles, each focussing on the three aspects of learning. These principles focus on how learners comprehend content, how they plan, manage and demonstrate their learning, and how they feel motivated to engage in the learning process. These pillars are providing multiple means of engagement, providing multiple means of representation, and providing multiple means of action and expression. Together, these pillars aim at guiding a proactive approach to creating flexible and accessible strategies, materials, and assessments that cater to diverse learners [11].

While the three principles emphasize the need to offer multiple options for perception, engagement and expression to learners, the guidance to implement these principles are contained in the framework's nine guidelines and thirty-one checkpoints of the framework. The nine guidelines within each principle, are both the dimensions that an educator needs to consider to facilitate comprehension, engagement and expression as well as the stages that learner goes through to become knowledgeable, purposeful and goal-directed. Further, the thirty-one checkpoints within the nine guidelines are instructional strategies that an educator can apply to facilitate learner in this direction. Many UDL experts concur that the application of UDL checkpoints effectively translates the broader concept of inclusion and curriculum access into actionable steps [12].

Empirical research has delivered promising results from UDL adoption in terms of academic performance and learner perceptions [12, 13]. Literature suggests a positive relationship between the application of UDL and student interest and engagement [14] as well as its potential to improve students' academic and social outcomes [13].

III. Implementing Universal Design for Learning

While UDL has gained widespread adoption in schools and higher education institutions across multiple countries [16], studies have revealed that implementing UDL can be ambiguous due to the multifaceted and complex nature of the framework [12]. Further, the ways in which UDL is described also varies greatly across studies because UDL application can take on many different forms [13]. Research has shown that even trained teachers interpret and apply UDL differently, causing confusion about what constitutes UDL [12].

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UNESCO MGIEP, a research Institute that focuses on transforming education towards SDG 4.7 launched an online course to build digital pedagogy skills of teachers in 2020 called 'The Digital Teacher' (TDT). The goal of the course is to enable teachers to use digital technology to create relevant, authentic, and engaging learning experiences. The course is offered in self-directed and blended format and includes online workshops as well as e-learning modules hosted on the institute's platform called Framerspace[1]. The course has been designed using the principles of UDL to cater to teachers with diverse learning needs and preferences. A number of free and freemium digital tools have been leveraged to integrate the UDL checkpoints in the course design.

IV. THE PURPOSE

This paper seeks to describe nine free or freemium digital tools and their specific affordances utilized in TDT course. It explains how these tools facilitate the integration of UDL checkpoints and the ways in which their integration enhances learners' engagement, content comprehension, navigation within the learning environment, and expression. The paper aims to further the much-needed work to educate educators on how to implement UDL in their practice, more specifically how to do so in the online learning environment.

V. DIGITAL TOOLS AND UDL CHECKPOINTS

This section describes eleven free and freemium digital tools and their affordances that were applied in TDT course to operationalize the ten UDL checkpoint from the nine guidelines within the three principles of UDL. It's worth noting that while there are thirty-one UDL checkpoints in total, our discussion for this paper is limited to these ten. Moreover, it's important to emphasize that each tool's use case extends well beyond what is mentioned in its checkpoint below as these tools possess the versatility to address multiple UDL checkpoints, and below we provide references to similar tools for operationalizing UDL checkpoints.

A. Offer alternatives for auditory and visual information (1.2, 1.3)

Being able to grasp or perceive key information is the first step towards gaining knowledge. The checkpoints 1.2 and 1.3 aim to address barriers that learners may face in accessing auditory or visual information. This is because information conveyed solely through sound or through visual is not equally accessible to all learners, some learners may need more support or time to process auditory or visual information [17]. Using only one mode of content representation makes content especially inaccessible for learners with hearing or visual disabilities. Research has also shown that since working memory has partially independent processors for handling visual and auditory material, it can be increased by presenting material in a mixed rather than a unitary mode [18].The strategy of offering both auditory and visual information was applied in TDT course by leveraging presentation tools like Genially and Google Slides that allow embedding video, text, and auditory side by side. This enabled learners to select their preferred format of the learning material thereby making the content more accessible for all.

Other examples of digital tools that support the checkpoint include NaturalReader2 and Amara3. NaturalReader is a text-to-speech software that provides auditory alternatives by converting written text into spoken words. It offers customizable voices and settings, accommodating individual preferences and supporting learners with hearing disabilities. Amara is a platform for creating captions and subtitles, adding text equivalents to audiovisual content, and promoting accessibility for visually impaired learners in online learning sessions.

B. Illustrate through multiple media (2.5)

Text can be a weak form of presentation for those who may have vocabulary or language related difficulties. Providing alternatives, especially illustrations, simulations, images or interactive graphics can make the information in the text more comprehensible for any learner [10]. Infographics are one of the forms of visual representation that employs a combination of graphic elements and textual content to effectively convey information and facilitate pattern recognition and retention. Research has found infographics useful in making learning 'more permanent [19]. Many infographics were created for the digital teacher course using tools like Canva and Genially. The benefit of using these tools is that they offer a range of readymade templates to create infographics. Availability of such templates not only saves the time and effort in creating visuals from scratch but also supports the conceptualization of visual representation by looking at other examples.

Other examples of digital tools that allow alternative representations and interactive engagement include H5P[4], Nearpod[5], ThingLink[6], and Prezi[7]. While H5P and Nearpod offer a variety of interactive content types, ThingLink allows for interactive images with multimedia annotations, and Prezi enables the creation of dynamic presentations with explicit connections between text and visuals.

C. Activate or supply background knowledge (3.1)

Information is more accessible and likely to be assimilated by learners when it is presented in a way that primes or activates relevant prior knowledge [10]. Research has shown the effectiveness of using advanced questioning techniques to activate prior knowledge activation improve learner retention. Carpenter and Toftness [20] argue that "asking students questions before they learn something has been shown to enhance memory for that information". This technique can be easily integrated in synchronous online sessions by using the chat and poll features available in most of the video conferencing tools like Zoom, Microsoft Teams[8], and Google Meet[9]. In the Digital Teacher course, the facilitators ask questions while introducing new topics or concepts and instruct learners to report their responses on polls or chat. Depending on the nature of the question asked, such questions helped learners to identify their knowledge gaps, foster a sense of curiosity for learning, or comprehend the relevance of the topic within their respective contexts. This technique also allows multiple learners to reflect and respond simultaneously.

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[1] FramerSpace: https://www.framerspace.com/
[2] NaturalReader: https://www.naturalreaders.com/
[3] Amara: https://amara.org/
[4] H5P: https://h5p.org/
[5] Nearpod: https://nearpod.com/
[6] ThingLink: https://www.thinglink.com/en-us/
[7] Prezi: https://prezi.com/
[8] Microsoft Teams: https://www.microsoft.com/en-us/microsoft-teams/group-chat-software
[9] Google Meet: https://meet.google.com/

Other digital tools that support this checkpoint include Sutori[10] and Popplet[11]. Sutori offers interactive timelines and presentations which incorporate key events, concepts, visuals and resources, especially curated for the topic. Additionally, its interactive templates support various activities to activate background knowledge, including quizzes, discussions, reflection prompts and KWL charts. Popplet's visual concept maps and organizers support the activation and supply of background knowledge by providing a visual representation of key concepts, relationships, and connections.

D. Vary the methods for response and navigation (4.1)

Learners differ widely in their capacity to navigate their physical environment [8], While there are limited opportunities for use of motor skills in online learning, learners often have varying levels of typing skills and comfort in navigating an online platform that requires clicking on multiple buttons in a particular order to perform an action, these can be understood as digital or computer-based fine motor skills. One of the ways to provide alternatives in the requirements for rate, timing, speed, and range of motor action required to respond to questions in the online settings is by offering multiple response options that require varying levels of such fine motor skills. In the digital teacher course, Mentimenter was used to elicit responses by offering learners to respond through descriptive sentences, single word answers, or simply respond to a poll without requiring a login. Using the same tool, the responses were presented back to the learners in the form of word clouds, results of polls or a wall of digital notes. Learners have reported greater engagement and greater confidence in participating in learning activities when mentimeter is used to invite responses [21].

Other examples of digital tools which allow an alternative means for navigation and response include Google Voice Typing and GazePointer. Via Google Voice Typing, learners can use their voice instead of manual typing, allowing them to overcome barriers related to motor demands and access instructional materials at their own pace and speed. GazePointer enables individuals to control a computer using eye gaze, reducing the need for manual input through hand or mouse control.

E. Use multiple media for communication (5.1)

To reduce media-specific barriers to expression among learners, it is important to provide learners with multiple options to express themselves [10]. Research in higher education context has highlighted the benefits of giving learners more choice and control in the assessment process [22].Thoughtfully designed assignments can enable learners to demonstrate their knowledge and understanding through text, images, audio files, animations, videos, or other digital format of their choice. TDT course used Padlet to enable learners to upload and share multiple types of file formats on a common digital bulletin board. The interactive elements of the tool enable people to view and discuss the submissions without navigating to another platform.

While Padlet can be used to facilitate learners to express in multiple digital formats, there are platforms that can enable learners to express their knowledge using multiple formats too. For instance, Canva is a versatile platform that allows visual expression and communication in diverse forms, using templates such as comics, storyboards, presentations, infographics and videos. Additionally, the digital tool Flip (Flipgrid[12]) can be used by learners to share their thoughts, ideas, and reflections through video-based communication.

F. Support planning and strategy development (6.2)

Self-regulated learning which entails setting learning goals and then attempts to monitor, regulate, and control cognition, motivation, and behavior to achieve them [23] is regarded as a critical component for success in the online learning environment [24] [25] [26]. This is because online learning often requires learners to navigate the learning environment independently or with little external support or motivation. UDL recommends posting goals, objectives, and schedules in an obvious place, providing check-lists, schedules of steps, embedding prompts to 'stop and think' and to "show and explain your work" amongst other methods to guide appropriate goal-setting (6.1) and support planning and strategy development (6.2). In the digital teacher course, these strategies were implemented through use of Basecamp. The specific features of Basecamp that enables goal setting and planning include features to post to-do lists, announce events and timelines on community calendar, set automatic check-ins and reminders, assign tasks, and mark and track progress on tasks.

Similar to Basecamp, the digital tools Asana[13], Trello[14], and Monday.com[15] offer features that support organization of goals and creation of task dependencies, allowing learners to develop effective strategies for task management and achievement in online learning environments.

G. Minimize threats and distractions (7.3)

The application of the Minimize threats and distractions (7.3) checkpoint in the course design involved leveraging the affordances provided by YouTube. While what is threatening or distracting may vary from learner to learner, UDL proposes that presence of background noise or visual stimulation, noise buffers, number of features or items presented at a time have to be optimized to offer a conducive learning environment to learners and generate their interest [27]. One significant feature of YouTube utilized to apply this strategy was the ability to add timestamps to videos. This function can be likened to an index in a book, allowing learners to easily identify and navigate different sections of educational videos based on their specific needs. In addition, the developers took advantage of the open embed code offered by YouTube. This enabled them to consolidate all the course content within the LMS, eliminating the need for learners to open multiple browser tabs, which can be distracting.

Other examples of digital tools that minimize threats and distractions include Mercury Reader[16] and Krisp[17]. While Mercury Reader offers learners a clutter-free online reading experience by removing distracting visual elements, Krisp improves virtual communication by removing background noise.

H. Foster collaboration and community (8.3)

As per the UDL guideline, fostering collaboration and community is one of the methods to sustain learner's

[10] Sutori: https://www.sutori.com/
[11] Popplet: https://www.popplet.com/
[12] Flip: https://info.flip.com/en-us.html
[13] Asana: https://asana.com/
[14] Trello: https://trello.com/
[15] Monday.com: https://monday.com/
[16] Mercury Reader: https://mercury-reader.en.softonic.com/
[17] Krisp: https://krisp.ai/

persistence. This checkpoint recommends facilitating opportunities for peer interactions and peer support. Research has shown positive influence of peer-assisted learning strategies on learner's achievement as well as motivation [28]. In the TDT course, peer interaction and group-work were facilitated using a tool called Jamboard. During the live sessions, a link to a Jamboard deck was shared with the participating teachers and they were asked to collectively brainstorm, cluster, and analyze their responses. Other tools leveraged for similar activities included Google Slides, MindMeister[18], and Miro[19]. Such group activities increased participants' engagement by enabling them to share simultaneously and learn from each other. The collective knowledge generated during the session also created resources that participants could contribute to or access in the future.

Other digital tools like Google Workspace[20], Google Classroom[21], and Microsoft Office[22] support the checkpoint by enabling the creation of cooperative learning groups, peer interactions through video meetings, chats, and comments, as well as real-time collaboration on tasks and activities.

Although many of these digital tools enable collaboration, some of them require participants to create their accounts. This additional step can discourage learners from participating in group activities and therefore selecting a tool that does not require sign-up may be more suited for such activities.

I. Develop self-assessment and reflection (checkpoint 9.3)

Getting feedback on one's progress during the learning process can positively impact a learner's motivation [10]. In fact, one of the key factors in learners losing motivation is their inability to recognize their own progress [10]. Studies have shown that in online learning environments, attention lapses may be even more frequent than in the classroom setting and that learners often lose attention while watching educational videos without realizing it [29]. Therefore, opportunities for regular self-assessment and reflection were embedded in the course by using diverse digital tools. One of the tools that allows creating pause points for reflection and self-assessment while watching educational videos is H5P. The tool enables course creators to insert subjective and objective questions within the videos to enable learners to assess their understanding of or simply reflect on the point made in the video so far before proceeding further. Creating videos with such pause points helps learners to engage with the content instead of merely consuming it passively.

Similar to H5P, the digital tools Formative[23] and Flubaroo[24] enable self-assessment through interactive quizzes and assignments, providing immediate feedback to learners. Additionally, they have progress-tracking features like charts which help learners to monitor their growth and reflect on their performance over time.

VI. LIMITATIONS

While digital tools offer transformative potential in harnessing UDL principles, their implementation is fraught with complexities. Even as tools aim for universal applicability, regional disparities in tech access and infrastructural variances can dilute their effectiveness and lead to uneven benefits. Scalability can also pose challenges, as growing learner bases might strain freemium tools both financially and in terms of performance. Addressing assessment adaptations, and ensuring data security and privacy further complicate the adoption. Furthermore, the educational administrators responsible for instituting the UDL framework face obstacles which stem from the inherent ambiguity surrounding the operationalization of UDL implementation [12]. In addition to this, the learning curve for educators coupled with the need for specialized teacher training, can sometimes be steep [12]. The inertia of integrating new tools, and the potential for technical glitches can further impede smooth UDL execution [30, 31].

VII. CONCLUSION

The paper has described an innovative approach to design an online course utilizing digital tools to implement the strategies outlined in the UDL checkpoints. The objective of this approach is to enhance engagement, content comprehension, navigation, and expression of a wide variety of learners. Further research is warranted to assess the effectiveness of this approach in optimizing activities, materials, and assessments within online courses, ensuring greater accessibility and impact on learning. While some educators may find the implementation of UDL guidelines challenging and complex [11], exposure to learning experiences that incorporate UDL checkpoints can serve as a valuable means to elucidate their broader application. It is our sincere hope that this paper will contribute to the ongoing efforts aimed at educating educators on the effective implementation of UDL, particularly within the realm of online learning environments. Further, we hope that the use of free or freemium digital tools will enable cost-effective and scalable solutions across a wide range of educational institutions. As the landscape of digital tools evolves, the possibilities for seamlessly integrating UDL principles in education expand. The synergy of advanced technologies like artificial intelligence, immersive realities, and refined analytics promises a future where diverse learners receive tailored and optimal experiences.

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Improving Teacher Adoption of Personalised Adaptive Learning: Strategies for Effective Integration

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***Abstract* - Personalised Adaptive Learning (PAL) tools have emerged as a relevant technology to offer customised learning experiences for students. A key enabler to implementing PAL solutions at scale sits with teachers. However, teacher adoption remains a pertinent issue with many yet to embrace EdTech in their classrooms. Ei Mindspark is one proven PAL software which has grown its footprint in India through various implementation partners including non-governmental organisations and state governments. As Mindspark attempts to scale in India's public education system, consistent student usage must be achieved to ensure improved learning outcomes. This requires Mindspark to become an integral part of the public school timetable and for teachers to monitor Mindspark sessions with little external support. However, both factors are contingent on teachers' adoption of Mindspark. This is often hindered by the absence of a conducive support ecosystem for EdTech, the restricted bandwidth of teachers and a lack of digital skills. This paper highlights the key barriers towards teacher adoption of PAL by presenting research from our experience of rolling out Mindspark in various settings. Adopting a pragmatic and behavioural lens, we also outline potential strategies to improve teacher adoption in low-resource contexts.**

Keywords — technology, personalised learning, teacher, motivation, learning outcomes

I. Introduction

Since The Right to Free and Compulsory Education Act took effect in India in April 2010 [1], student enrolment rates in India have significantly increased [2]. However, high enrolment rates have often not translated into improved learning outcomes for all students. For instance, in rural India, primary school enrolment surpassed 98% in 2022, yet only 43% of grade five students could read a basic text fluently [3]. This learning crisis is accentuated by multi-level classrooms where the heterogeneity in student learning levels increases the difficulty for teachers to provide individualised attention to each student. In these contexts, personalised learning tools have become an attractive solution in tackling high student-to-teacher ratios, mixed attainment classrooms and student learning gaps. There is now a growing body of evidence that has demonstrated that pedagogical interventions that leverage personalised learning approaches are effective [4] - [7].

Personalised Adaptive Learning (PAL) is a student-centred, technology-based pedagogical approach. PAL provides students with a unique learning path that allows them to learn at their own pace based on their prior knowledge, skills and learning needs. PAL software engages with each student differently by adapting content based on factors such as performance and prior knowledge. PAL tools also offer student performance data that teachers can leverage to adapt their pedagogy during regular classroom instruction. PAL solves two key issues prominent in education, particularly in low-resource contexts:

- Cumulative learning gaps: A learning gap is the disparity between what a student has learned and what the student was expected to learn at their grade level.
- Increasing number of students per teacher: The student-to-teacher ratio has grown significantly in India, making it increasingly difficult to provide individualised instruction to students.

Educational Initiative's (Ei's) PAL software, Mindspark, is just one example of a personalised tool that is being implemented in government schools across India. Mindspark has demonstrated positive impacts on student learning outcomes, where treatment groups scored 0.37 and 0.23 standard deviations higher in Math and Hindi, respectively, compared to a control group over 4.5 months of using Mindspark [7]. Mindspark is being deployed in over 600 public schools in India where almost 400k students are using it regularly. However, sustaining Mindspark's presence in public schools without external support has remained a pertinent challenge in achieving scale. Here, gaining teacher buy-in has been critical to strengthening Mindspark's integration into public schools.

Teacher adoption of Mindspark is considered a critical factor in attaining scale and sustenance of the programme. Integrating PAL as a component of regular classroom instruction and positioning teachers as pioneers, would significantly reduce the need for a high-touch external support system and its associated costs. However, teacher resistance to the adoption and integration of EdTech remains a challenge. This has not only been observed in the Indian context but also holds relevance for many EdTechs globally which are trying to scale operations [8], [9].

II. Mindspark Case Studies

Over the past decade, Ei has implemented Mindspark in diverse settings across India. These experiences have identified various teacher behaviours that contribute to their EdTech adoption. While some are self-motivated in adopting Mindspark, others are more resistant to change in their classrooms. To explore these characteristics in more depth and understand the supporting conditions for widespread PAL adoption, Ei has conducted qualitative research to assess the key enablers and barriers to teacher adoption of

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Mindspark. This has primarily consisted of focus group discussions (FGDs) and in-depth interviews (IDIs). The key research question explored through both studies was, "What are the key behavioural barriers and facilitators, if any, influencing teachers' adoption of Mindspark?" The following sub-sections outline the methodology and findings gathered from both studies.

A. *Teacher adoption of PAL tool, Mindspark: An EdTech practitioner's perspective*

Ei deploys Mindspark in schools with the support of dedicated practitioners who work closely with teachers regularly. Through this process, Mindspark practitioners[1] acquire an experiential understanding of a teacher's PAL adoption lifecycle during the academic year. To gather the perspectives of these practitioners, we conducted an online, 90-minute FGD using purposive sampling methods to select eight participants. These participants had worked in schools across seven Indian states including Rajasthan, Madhya Pradesh, Chhattisgarh, Gujarat, Karnataka, Uttar Pradesh and Maharashtra. We recruited an equal number of practitioners who had worked in government and private school settings for at least two academic years to participate in the FGD. This approach enabled the sharing of diverse experiences from various geographical locations in India and facilitated meaningful comparisons. We designed the FGD guide to include several open-ended questions to evoke the lived experiences of Mindspark practitioners with teachers. We limited the number of participants to eight to ensure a sufficient degree of participation from each individual. It is important to acknowledge that findings from the focus group reflect teacher behaviours as perceived by Mindspark practitioners. This poses a slight limitation in the study's findings.

We recorded the FGD online, transcribed it and subsequently, conducted thematic analysis using an inductive approach. Three key barriers to teacher adoption of Mindspark emerged from the analysis.

- Limited bandwidth: Teachers often face pressures from school principals and parents to complete the school syllabus and ensure high scores in board exams. In addition, the numerous non-teaching tasks assigned to teachers often reduce their bandwidth to take on additional responsibilities. These external pressures lead to teacher's emphasis on rote learning methods while impacting their motivation to teach.
- Digital literacy: Digital literacy was found to vary significantly among teachers, with those lacking digital skills often feeling apprehensive to engage with Mindspark. This factor also stemmed from a concern that their students were more technologically proficient than themselves.
- Absence of a conducive ecosystem: Multiple external factors also appeared to contribute to low Mindspark adoption rates among teachers. These included perceptions around inadequate teacher training on PAL, lack of buy-in from government officials and requirements to duplicate work to meet online and offline demands from principals and parents.

B. *Voices from the ground: Perceptions of government school teachers in Punjab on personalised adaptive learning*

We selected 18 government school teachers for IDIs using a convenience sample based on the operational feasibility and availability of participants. We selected teachers across three districts in Punjab to represent populations from urban, peri-urban and rural areas. This assisted in establishing generalisability within the sample. Teachers were from schools where Mindspark was either active or to be launched. The sample equally represented teachers from primary and high schools where all teachers had five or more years of teaching experience.

We applied vignette research methodology in this study using two key instruments depicting different scenarios to elicit the opinions and attitudes of teachers on the integration of EdTech in classrooms. We recorded audios from interviews (where consent was given) and subsequently transcribed them. We used thematic analysis to code interview responses which we then assessed against the prime research question. The following highlights the key themes that emerged as barriers and enablers for teacher EdTech adoption.

- Teacher motivation: Some teachers are intrinsically motivated by their want to be successful educators; however, many highlighted the lack of implications when they either succeeded in their role or did not meet expectations. Teachers generally valued recognition from heads or members of the state education department beyond that of school principals, and we found that the act of recognition served as a key motivational factor. Whether certification, awards, verbal appreciation or simply the retention of teachers' names was used to convey recognition, these actions held stronger importance when publicised by those positioned further up the educational hierarchy.
- Prior experience of EdTech: Teachers' perceptions of newly introduced programmes are often influenced by their prior experiences with EdTech interventions. Where teachers have experienced a lack of clarity on their responsibilities and the role of technology in previous programmes, this has negatively impacted their adoption of new EdTech tools and implementation frameworks. Teachers demonstrated that they were more likely to be receptive towards new EdTech interventions if they identified a common value between their pedagogy and the intervention.
- Teachers' self-perception of digital capabilities: Teachers generally perceived that handling devices in EdTech labs was beyond their capabilities and expressed the need for external support staff to manage labs. It was also not fully understood that teachers' presence in labs was important not solely for technical teaching but also for academic support.

Several recurring themes surfaced in both studies, particularly those focusing on the barriers to EdTech adoption. These included the large workload placed on teachers, their lack of confidence in using digital tools and their belief that more robust training is required for successfully integrating PAL. While the FGD primarily focused on the key barriers to

1 Mindspark practitioners refer to individuals that work on the ground yet oversee the implementation operations of Mindspark's programme in either government or private schools in India.

teachers' adoption of PAL, the IDIs brought forth more enablers for PAL adoption. These included teachers' intrinsic motivation to teach, their acknowledgement in technology's value and the impact that formal recognition can have on teacher efforts. Leveraging the insights gained from both studies, we have devised a series of potential strategies to increase teachers' EdTech adoption. These are outlined in the next section. Though these studies focused on PAL tools, particularly Mindspark, the findings and strategies are transferable to other EdTech programmes.

III. Potential strategies to improve teacher adoption of personalised adaptive learning tools

Using E.M. Roger's Diffusion of Innovation Theory[2] as a theoretical framework, we observe four key target audiences to address at different stages of the PAL implementation process to achieve widespread PAL adoption.

1) Innovative teachers and those who are enthusiastic about EdTech integration can be targeted for the early adoption of PAL.

2) Providing teachers with clarity on their role, a sense of agency and a peer support system can address a significant proportion of teachers inclined to leverage PAL.

3) Teachers who have not yet experimented with PAL can gradually be onboarded by securing influence within local governance structures.

4) Laggards are more resistant to change and are likely to adopt an innovation after it has been trialled and proven successful by the majority.

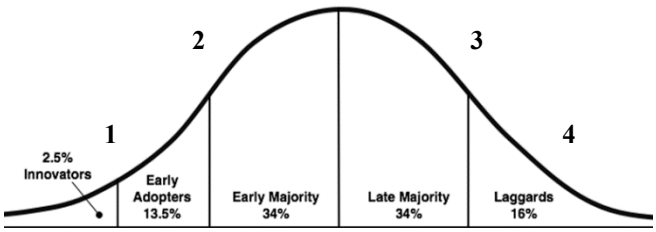

Fig. 1. The Diffusion of Innovation Model

The success of technology integration in its early stages heavily relies on early adopters with high levels of intrinsic motivation. Subsequently, it requires support from the EdTech ecosystem to introduce sources of extrinsic motivation and generate a larger group of PAL adopters. Teacher motivation is often dependent upon multiple factors including teachers' prior experiences with technology, availability and accessibility of support systems (both through peers and practitioners) and effective capacity building and EdTech trainings.

In Indian government schools where the focus on learning outcomes is weak, technology-driven reform of teaching practices demands persistent and dedicated efforts. This requires a multi-pronged strategy that addresses the potential factors influencing technology adoption throughout the diffusion process. The key components of this proposed strategy are suggested as follows:

- Co-developing effective training modules with teachers and thoroughly planning for their delivery to teachers.
- Incorporating EdTech into the educational governance system where notifications or government guidelines could promote EdTech adoption at a systemic level.
- Delivering data-based nudges to highlight the benefits of PAL on student learning outcomes to teachers.
- Encouraging PAL adoption in classrooms by offering non-pecuniary incentives and recognition to teachers.

A. *Training methods and strategy*

As highlighted in Section II.A, some teachers' lack of confidence in their digital skills hindered their adoption of PAL. To address this, teacher training modules should focus on teacher self-perceptions as well as digital literacy gaps. Capacity building processes can also be leveraged to stimulate teachers' intrinsic motivation as they become more confident in their digital proficiency. We propose the following elements of EdTech teacher training for increased adoption.

Firstly, providing teachers with a guided, hands-on experience of using PAL can demonstrate that these tools do not significantly differ from the technology they are familiar in using in their daily lives and can boost their confidence. This first-hand experience can also provide teachers with a better understanding of the pedagogical logic embedded in PAL tools, making them more likely to embrace them. Additionally, teachers can gain an insight into the student user experience, enhancing their appreciation for the potential benefits in the learning process.

Secondly, training should ensure that teachers have clarity on their roles and responsibilities to enable them to be better prepared during the rollout of PAL. Similarly, when teachers are aware of the assistance and resources available and are easily accessible, they feel more supported and equipped to handle challenges that may arise during the implementation process. Both factors can lead to a more effective integration of PAL in classrooms.

Lastly, underlining the complimentary role of PAL in day-to-day teaching can help teachers understand how it can alleviate their workload. As PAL tools can enhance teaching practices through providing continuous student learning data, teachers can become more receptive in embracing technology as a valuable tool for teaching.

The training delivery method and channel are also important factors in assessing training efficacy. For example, during the IDIs, teachers shared that the training of trainers (ToT) model that is commonly used in large scale EdTech programmes falls short in invoking genuine teacher interest in new interventions. This delivery method is also more likely to cause information transmission losses. Therefore, using a training delivery method at a decentralised level is often found to be more effective. Implementing training at a cluster-school level is just one mechanism to address this and ensure increased participation and effective teacher onboarding.

B. *Promoting changes in education governance*

While teacher training and capacity building can be an effective strategy for securing early technology adoption, gaining support from laggards requires a systemic approach. Government-advocacy efforts are central in influencing teachers' extrinsic motivation and encouraging adoption at the last mile.

2 Developed in 1962, the Diffusion of Innovations theory explains the gradual spread of new ideas, behaviours, technologies, or goods throughout a population.

In countries such as India, PAL adoption is being supported, to an extent, through policy frameworks such as India's National Education Policy (2020). This has stimulated many state governments to actively promote teacher technology adoption in schools. Institutionalising the regular usage of EdTech in schools organically introduces an accountability mechanism for teacher adoption and increases the familiarity of PAL tools with high-level bureaucrats.

C. Data -based nudges

Teachers are more likely to adopt PAL tools when they are guided by data-based insights. Regular learning outcome reports, student progress information, and actionable insights can aid teachers in comprehending the significance of PAL tools for their performance and foster trust in the technology.

Findings from primary data collected through IDIs, suggested a shift in teachers' perspectives as they utilised PAL tools over an academic year. The extended PAL usage over multiple months often increased the optimism among teachers about the tool and facilitated their acceptance of the technology.

D. Non-pecuniary incentives for teachers

Based on internal research studies, non-pecuniary teacher rewards can be a strong motivational factor to unlock teacher technology adoption. As a formal recognition system can foster healthy internal competition, data-backed recognition not only boosts the adoption of individual teachers but also of their peers. Teachers present in hierarchical government systems also attach greater importance to high-ranking officials. Given these social constructs, celebrating technology adopters through certificates or accolades, as just two examples, can motivate those that are more resistant to change. These processes can potentially accelerate EdTech adoption at scale.

IV. CONCLUSION

PAL has emerged as a promising pedagogical-technological tool to tackle the learning crisis in populous and low-resource contexts such as India. However, education remains one of the last sectors where technology adoption rates have remained relatively low. Despite several external factors contributing to this situation, the issue largely stems from teachers' behavioural hesitancy in adopting EdTech.

This paper examined the factors that hinder teachers' adoption of PAL tools, with the burden of non-teaching tasks, digital illiteracy and lack of a supportive EdTech ecosystem identified as key barriers. However, the research also reveals enabling factors for teacher PAL adoption, including recognition and prolonged exposure to PAL, that can increase teacher optimism towards EdTech.

This paper also highlighted how The Diffusion of Innovation framework can help EdTech practitioners target specific groups of teachers during the PAL implementation and onboarding processes. Alongside this, it established how intrinsic and extrinsic motivational factors of teachers can lead to more relevant and effective PAL implementation models. For instance, early adoption can be encouraged through experiential training and data-based nudges, while mass adoption can be promoted through strengthened advocacy efforts and institutionalising PAL within public schools. Non-pecuniary incentives can also play an important role in sustaining teacher engagement and fostering positive attitudes towards PAL tools over time.

While there are various strategies that can be tested to boost teacher adoption rates of PAL, the extent to which each is effective and at what cost remains unknown. Leveraging the insights gathered from both qualitative studies, Ei Mindspark has begun to design and execute a series of A/B tests[3] in the states of Punjab and Himachal Pradesh to assess what implementation strategies can influence teachers' engagement and adoption of PAL. We are beginning this quantitative research by assessing the impact of data-driven nudges that take the form of physical report cards highlighting benchmark usage data at both class and student-levels. Conducting additional quantitative research to evaluate the most impactful interventions on PAL adoption rates, can pave the way for better integration of PAL in low-resource educational settings.

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3 A/B testing in educational contexts refers to a research methodology used to assess the effectiveness of two or more variations of an educational intervention. A/B tests are rapid in nature and use an iterative optimisation approach where randomisation commonly occurs at an individual rather than cluster level.

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Posters

TOWARD SCAFFOLDING DOCTORAL STUDENTS in THEIR STUDY: A TELT-based CONCEPTUAL MODEL

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Abstract- **Technology Enhanced Learning and Teaching (TELT) is a dynamic field that has considerably evolved in recent years. It is a myriad of tools and theories that have emerged from numerous studies. However, there is a lack of empirical studies available in the knowledge domain explaining the significance and implication of TELT in higher education in general and in doctoral education in particular in Indian context. This research attempts to suggest a conceptual model based on TELT for creating a collaborative learning environment for doctoral students' studies.**

Keywords- Doctoral students, TELT, Conceptual model, Collaborative environment

I. INTRODUCTION

The doctoral education occupies a very valuable position in the life of any individual because it provides him/her with high academic status, economic prosperity and good quality of life. It helps the scholar in acquiring research skills and conducting empirical research. At the same time the doctoral journey is also expected to develop critical thinking, equip the scholars with high-quality oral as well as written communication and negotiate new socio- academic identities as a researcher and create sustainable social networks. The conventional and stereotypical image of the researcher as a 'lone scholar' is also shifting to potential collaborative academic leader [1], [2]. Policy shifts all over the world have juxtaposed this conventional model of study with a more collaborative one that is based on doctoral students' collaboration with different communities of practice.

This changed scenario necessitates the different kinds of preparation of doctoral students along with creating a more enriching collaborative learning environment for them. Today, extensive use of digital technologies form an integral feature of the doctoral students' world of personal and academic experiences. In this context, today the doctoral students are expected to acquire a richer set of digital skills and behaviors, practices and identities' [3].

All this would require systematic preparation of doctoral students for this challenging scenario. Hence this research aims at conceptualizing a model for scaffolding doctoral students in their doctoral study.

o. **Brief theoretical baseline**

This model is based on the Technology Enhanced Learning and Teaching (TELT) approach. TELT deals with a unique pedagogy model for Technology Enhanced Learning arrangements and teaching strategies.

Today, collaboration has become especially prominent with the emergence of learning theories such as Social Constructivism and has been found to be a key factor of the learning process. The huge body of research has emphasized the role of the TELT environment for promoting Collaboration among learners.

II. RESEARCH QUESTIONS

This study, sought to answer the following research question:

R. Q. What scaffolding structure could be developed based on the identified perceived benefits, adoption intentions and suggestions for creating a TELT based environment?

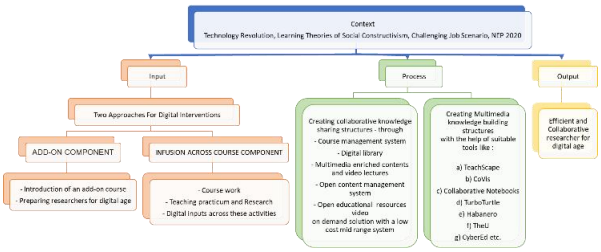
III. RESEARCH DESIGN

This study has dealt with designing a conceptual model based on TELT for creating a collaborative learning environment based on literature and our experience in the field of education. This study employed research and development (RD) design in the development of conceptual model. This study had three stages– the planning stage, development stage and the validation stage. The planning stage consisted of two specific stages, namely: initial preparation and detailed contextualization, whereas, the development stage involved the designing and developing conceptual model, and the validation stage will focus on the validation of the model by a panel of experts, revision and finalization of the model.

IV. THE MODEL

This conceptual model is based on the CIPO-modeldeveloped by Jaap Scheerens [4]. The context-input-process- output (CIPO) model is a basic systems model of school functioning, which can be applied to several levels within education. The model also functions as an analytical framework through which the quality of any program can be reviewed. According to this model, education can be seen as a production process, whereby input by means of a process results in output. Input, process and output are all influenced by context. The context gives input, provides resources for the process and sets requirements to the output. In this way all components of the CIPO-model are interconnected to each other.

TELT - BASED SCAFFOLDING MODEL FOR DOCTORAL STUDENTS



V. Process

This component envisages creating structures for content development, knowledge sharing and knowledge building. Hence this component comprises of creating two technology based structures namely: i) Creating collaborative knowledge sharing structure and ii) Creating multimedia collaborative knowledge building structure.

- Collaborative knowledge sharing structure- The institution can provide the digital interventions by making facilities available like course management system, digital library, multimedia enriched contents and video lectures, open content management system collaboration and knowledge sharing systems. Open sources like Moodle and Wiki for content development, video on demand solution with a low cost mid-range system, open educational resources, MOOC etc.
- Multimedia knowledge building structure

The 21st century has witnessed the revolution in communication technology, thereby making technology assisted collaborative learning processes more effective. But the research has shown the superiority of knowledge building over cooperative and collaborative learning.

Comparing concepts of cooperative and collaborative learning, with knowledge building (KB) shows that KB goes deepest, establishing not only a mutual benefit among members but also being concerned with the advancement of knowledge in that community. Also, as the name suggests, the first goal in knowledge building is not accomplishing common tasks but the acquisition of knowledge [5].

Multimedia sources enlarged and extended the possibilities of better and more meaningful communication among the community of learners [6], [7]. It along with creating paths to improve their interactions, and feedback by increasing the accessibility and affordability of these sources.

Also enhanced the learners' skills and abilities to reflect on how different ideas are related and how they can better be integrated. This means that learners could raise their understanding at a new level of knowledge creation. When a community fulfils this level, their members are able to foster integration, enhancement and synthesis of new ideas of understanding from different sources.

Today several tools are available for creating KB structure like:
a) TeachScape; b) CoVis; c) Collaborative Notebooks; d)TurboTurtle; e) Habanero; f) TheU; g) CyberEd; h) SAIL; i) GroupKit; j) CoNotes; k) Belvedere; l) TOP; m) LessonLab.

VI. Conclusion

This model is expected to create a community of efficient, collaborative and dynamic researchers and academic leaders for the 21st century. The model emphasizes technology integration in coursework, teaching practicum, and research, along with collaborative knowledge sharing and building. TELT based scaffolding model should be a future of any doctoral program center. If doctoral students are to move beyond the largely, lone PhD journey and engage in more open, participatory and collaborative practices, then strong institutional support needs to be provided in order to achieve this [8]. But this issue also has economic attributes along with socio-cultural and academic, and to solve it a coordinated effort at institutional level, strong political will to improve the quality of higher education and linkage between academics and industry should be established.

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Gamification: A Paradigm shift during and beyond Covid-19 in learning of HCF and LCM

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Abstract- This study addresses challenges related to student motivation and academic progress in math. It explores the impact of gamified homework using quizzes on upper primary students' understanding of HCF and LCM. The research employed a single-group pre-test & post-test design with 42 students. The study incorporated online games to reinforce HCF and LCM concepts and found increased class strength, improved achievement, speed, and problem-solving accuracy. The gamification tools Mathematics Playground, IXL, and 99math proved effective for math homework, and Quizizz.com demonstrated potential as a formative assessment tool.

Keywords: Gamification, Online games, Mathematics, HCF and LCM, Gamified quizzes, Class strength

I. INTRODUCTION

During Covid teaching Mathematics was a challenge [1]. Moreover students often rely on memorization rather than understanding the underlying principles, thus leading to a lack of appreciation in many concepts among which divisibility tests, factors and multiples are few concepts [2].

Numerous studies have highlighted the challenges students face when applying their knowledge of Highest Common Factor (HCF) and Lowest Common Multiple (LCM) which are dependent on understanding of divisibility tests, factors and multiples. For instance, in one study, only a small percentage of students, approximately 11.9%, were able to correctly find the HCF [3]. Common difficulties related with these concepts include the inability to differentiate between multiples and factors of a number [4] and a lack of clarity in distinguishing between HCF and LCM concepts [5]. These challenges can, in turn, hinder students' problem-solving abilities, particularly in fractions [6].

To address these issues, researchers developed an implementation program that leverages gamification to engage and motivate students in practicing HCF and LCM problems. Consequently, this study aims to assess the impact of gamification on students' achievement in this area. The theoretical framework guiding this study is Self-determination theory (SDT). The null hypotheses formulated for this study are as follows:

There is no significant difference between the mean scores of Pre and Post-test Achievement of students in 1) H0 1: HCF and, 2) H0 2: LCM using gamification as strategy.

II. LITERATURE REVIEW

In recent years, games have emerged as a powerful tool for teachers due to its ability to provide students with a hands-on method to engage with the curriculum. It helps to engage students, and motivates them which helps in active participation [7]. Areed et al. [8] suggested that Gamified e-quizzes foster students' social interaction and competition, increase engagement and motivate them. Gamification in education has the capacity to significantly enhance motivation, behaviour, and learning outcomes, by addressing psychological needs, such as autonomy, [9], competence, and relatedness [10]. A game should be designed so that the difficulty suits players' skills: not too complicated or too simple [11]. Increased difficulty increases the students' level of competence, enables them to have fun and enjoyment while learning, and become more engaged in course discussions [12].

III. RESEARCH METHODOLOGY

In this quantitative study, we incorporated a single-group pre–post experimental design involving only one group in which all the participants were in an experimental condition. A pre-test was conducted at the beginning and a post test was conducted at the end of the intervention as a live gamified quiz to assess the achievement of students. As suggested by [13] one sample t-test is used to find the effect of intervention. A purposive sample of 42 students were taken for study who fulfilled the criteria of taking both tests, completing homework games, and attempting all formative tests. Data was analysed using t-test analysis to find the effect of the intervention programme. Both Pre and Post questionnaires were based on HCF and LCM which were identical and had 20 questions. Each correct answer gives a score of 1 point, meaning that each quiz had a total score of 20 points.

IV. PLANNING AND IMPLEMENTATION OF INTERVENTION PROGRAMME

Four gamification tools Mathematics Playground, ixl, 99Math and Quizizz.com were chosen to align with the Self-determination theory [14] promoting autonomy, competence, and relatedness. Homework was gamified using these tools. An intervention program with 22 online sessions via Zoom was implemented. A pre-test in live mode on the concept of HCF and LCM was implemented. Subsequent sessions covered key concepts.

These tools allowed students to make choices, engage in challenging yet achievable tasks, and receive positive feedback. Team play using Quizizz was used to encourage and foster a sense of belonging. Live games at the start of each session assessed prior knowledge. Discussions, problem-solving, and homework sharing were integral to the sessions. For taking previous knowledge 18 e-quizzes were designed which were implemented on a daily basis at the commencement of the online class. Quizzes were

implemented both in student pace and in teams. The reports from these games, along with the leaderboards, helped identify the topics, concepts, and questions that required further discussion to enhance students' comprehension.

For assessment, two full-length e-quizzes were designed, each consisting of 20 questions and a WhatsApp group was created for activity coordination. The initial scores on the pre-test were regarded as the pre-test scores, while the scores obtained at the end of the intervention program were considered as the post-test scores. The data collected from pre-tests and post-tests were used to quantify the mean scores.

V. DATA ANALYSIS

As data was normal and homogeneous t-tests were performed. For the HCF analysis the t value is -19.45 and for the LCM t value is -17.71 both t values are significant at $p<0.05$ level with df=41. It indicates that the mean scores of pre-tests and post-tests achievement differ significantly. In this context both the null hypothesis are rejected. Further, the mean scores of achievement of post-test on HCF is 7.69 which is significantly higher than that of pre-test whose mean score of achievement is 2.81. And the mean score of achievement of post-test on LCM is 7.97 which is also significantly higher than that of pre-test whose mean score of achievement is 2.93. These results were in line with the results of a previous study by Areed et al. [8] which shows gamified e-quizzes help students to evaluate academic performance in formative assessment, provide feedback to students, and improve their knowledge. Researchers also observed an increase in accuracy level. In the HCF post-test, accuracy increased from 22% in the pre-test to 73%, and in the LCM post-test, accuracy improved from 40% in the pre-test to 76%.

VI. RESULTS AND DISCUSSION

The study reveals that gamified homework and formative e-quizzes boosted student achievement in HCF and LCM. The use of Quizizz.com improved problem-solving accuracy and increased online class attendance, a key challenge during COVID-19. The study shows the Mathematics playground, ixl and 99math are effective gamification tools for assigning mathematics homework and Quizizz.com can be effectively used as a formative assessment tool [15].

Participating in live games during online classes, students could earn points and compete via leaderboards, keeping them engaged. Self-paced homework games provided practice opportunities, leading to improved skills, motivating further participation.

VII. CONCLUSIONS

The research noted improved scores and accuracy in post-tests after the intervention, and higher class attendance indicated students' self-motivation due to gamified learning.

The study reveals that Mathematics Playground, IXL, and 99math are effective for math homework gamification, enhancing student engagement. Quizizz.com also serves well as a formative assessment tool [15], aiding active learning and continuous evaluation. This supports the use of these tools in math education to improve homework and assessment. Gamification in learning suggests a paradigm shift in the whole education process as a teacher-oriented classroom is replaced by a learner-centered environment.

VIII. IMPLICATIONS FOR COMMUNITY

This study offers guidance for teachers on effective computer technology use in online math teaching, fostering student motivation.

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Visualization of Learners eBook Interaction Streams for Traversing Platform Engagement

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***Abstract*— Digital education has revolutionized the global teaching and learning techniques. There has been a global paradigm shift in creation and utilization of the teaching and learning based applications. Artificial Intelligence contribution to the education domain holds paramount importance in going beyond the traditional educational settings. Understanding the process of learning is important at all the levels of the student's education. However, with the increase in the ways of learning there always lies a need to assess the cognitive skills acquired by the learner which is an important component of their learning journey. To cater to the above needs the mechanisms for understanding the engagement of the user with the digital learning material becomes necessary. Addressing the above requirement this paper aims to visualize the e-Book interaction data of the users present in the interaction streams of the eBook dataset available at Data Shop. The results show visualization of the cumulative access time of the user with the e-learning material having relation with the platform related factors such as browser and operating system types. The future work for the same lies in extending the above analysis for identifying learners' engagement factors that can contribute significantly to understanding of the cognitive and metacognitive aspects of learning and their relations with learners in digital learning environments.**

Keywords*— *Learning Analytics, Visualization, E-Book, Log Data

I. Introduction

Human learning has been long associated with the interaction of the learners with the learning materials. Understanding the learning process requires going beyond the horizon of what is known in general. Digital reading has been widely adopted at all the educational levels of learning and helps to advance the identification of reading behaviours and patterns of the learners. The interaction data in the eBook log files can help to identify their activities and usage of platform resources. The reflection of the above gives useful insights into the eBook learning usage patterns and their time spent on particular activities. Learning analytics and its visualizations provide useful insights into the log data of users reading platforms usage and analysis. The goal of this poster paper is to visualize the eBook interaction data for gaining information related to users' activities with the timestamps and the resource utilization of the platforms. This paper does not carry out any specific design principles and is based on the feasibility of visualizations of the dataset. For determining the effectiveness of the proposed visualization, we have included different visualization implementations and its capability to run as an independent application for generating new insights. The dataset is anonymous and does not reveal any information about the participants personal details as it is solely based on the user interactions with the eTextBook. The features derived from it and its visualization is the main objective of this work.

II. Related Work

There are several existing works in the related to learners' interactions with eBooks platforms. This section reviews some of them. Research studies in the learning analytics have proved to have empirical evidence for identing the learner's engagement within the digital learning environment. The research in these lines have been extensive since the inception of the learning analytics field as can be seen by the study by Koedinger et al. 2010 [6]. Crossley et al. 2017 and Ocheja et al. 2021studied with respect to analysing the students' linguistic features and its relation with math success that has been identified and studied in the literature along with relation in other performance levels [4] [8]. Learning analytics for profiling and student engagement visualization has given trends of engagement levels and profiling learners for supporting and understanding the learning processes as studied by Hlioui et al. 2017 and Kebede et al. 2022 [5][7]. To study the user's engagement several indicators have been studied based on the user's interaction traces where Carrillo et al. 2019 have made an attempt to study them on mind mapping activities [2]. Multimodal learning analytics has been applied to study the high-level constructs related to student and engagement as studied by Chan et al. 2020 [3]. Along the line are studies on identification of reading styles from log data of eBook and its modelling that has been performed for identifying relations between students reading styles and academic success as in the study of Boticki et al. 2019 [1].

III. Methods

This section illustrates the description of the dataset used and the exploratory data analysis.

A. Dataset

We used the 'Fall 2019 use of OpenDSA Formal Languages eTextbook' dataset accessed via Data Shop (Koedinger et al., 2010) [9]. For exploratory analysis, we used the PSLC DataShop, available at http://pslcdatashop.web.cmu.edu (Koedinger et al., 2010).

B. Exploratory Data Analysis

The dataset has total interaction streams of 262205 with distinct 67 user_id, 2 inst_book_id, 48 names of the actions performed by the user, 14416 descriptions of the user activities,

30865 action times, 6 types of os_family, 1 device (PC used in all the cases), 8583 instances of the user activities related to created_at and updated_at features, 42 inst_chapter_module_id and 2 other distinct user is which has not been generally used in the analysis. The paper aims to identify the cognitive engagement of the users in the interaction streams of the eBook dataset. The results show the significance of the cumulative access time of the user with the e-material and how it relates to the cognitive engagement based on the features extracted of platform usage engagement. The future work for the same lies in extending the above analysis for identifying the various cognitive and metacognitive engagement factors from the analysis of the eBook interaction logs. The same would contribute significantly to understanding of the learning strategies of the learners and process of learning in digital learning environments.

Table 1. Dataset Description OpenDSA Formal Languages eTextbook

csv file	Features	Instances	Derived Features	Instances
Interactions Refined.csv	id	262204	-	
	user_id	67	-	
	inst_book_id	2	-	
	name	48	-	
	description	14416	-	
	action_time	30685	date_ts, time_ts	30685
	browser_family	5	-	
	os_family	6	-	
	device	1	-	
	created_at	8583	date_cr_ts,time_cr_ts	8583
	updated_at	8583	date_up_ts,date_up_ts	8583
	inst_chapter_module_id	42	-	
	user_id	2	-	

Table 2. Total engaging days of the learners

User_id	Total (in days)
560	810 days
579	234 days
605	396 days
606	1235 days
659	387 days
8670	891 days
8671	1558 days
8701	5902 days
8713	511 days
9192	1950 days

IV. RESULTS AND DISCUSSIONS

This section discusses the results obtained from the dataset. The visualization of the dataset has been done in the Python programming language on Google Collaboratory environment and Streamlit [10] has been used for creation of the app for better visualizing the eBook interaction data. The results of the above are presented in Figure1 and 2.

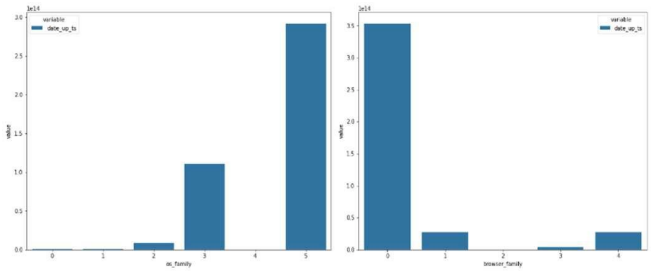

Fig.1. Visualization of interaction based on the date updated by the user timestamps per user_id, os_family, browser_family and name

Figure 2: Histograms of os_family, browser_family, device and name as calculated in Google Collaboratory and its visualizations in Streamlit app

What can the analysis talk about the learner's engagement with the e-learning content and their interest is detailed in Figure 3 by answering the Research Question. Further analysis can give us a hint about their learning process with the advanced analysis of the interaction-based log data. This is a preliminary analysis

based on visualization of the learner's interaction in the dataset. Our visualization results can answer the following research question of how the user interaction-based engagement time has a relation with other features. The RQ in this work relates with the initial analysis of deriving insights of the users' interactions with the eBook dataset based on their platform engagement features. The visualizations of learner's interaction data with the eBook are based on the derivation of the access time of the users in the platform from which further insights related to their cognitive engagement can be derived in the further studies. The categorization of active and passive eBook users can be looked upon in the further analysis.

RQ: How user interaction-based engagement time relates with other features?

Inference:

1. The more time spent by the users as derived from the interaction stream counts varies with the browser family, os_family type and device type.

2. As seen from the visual analytics in Figure 2, We can infer that for the eBook interaction time of the students is more for windows operating system, chrome browser family and activity interaction name of jsav node click.

3. We can estimate that the most commonly used browsers and operating systems and node clicks in the ebook interaction stream can lead to identification of active, medium and passive eBook users.

Fig.3. Research Question and Inferences

CONCLUSION

The paper aims to visualize the engagement of the users in the interaction streams of the eBook dataset. The results show significance of the cumulative access time of the user with the e-material as a one of the factors of engagement based on the type of operating system and browser used. The future work for the same lies in extending the above analysis for identifying other engagement factors that contribute significantly to understanding of the cognition and metacognition of the learners in digital learning environments.

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Enhancing Engineering Students' Learning through a "Writing Intervention"

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***Abstract*— This paper presents a case of Writing Across the Curriculum practiced at the Indian Institute of Technology Gandhinagar for an introductory Engineering course to maximize students' learning. The course consists of hands-on tasks of designing and manufacturing a product, and "writing interventions" are used to strengthen their learning in the form of project report and marketing pamphlet assignments. This paper illustrates design and execution of the writing interventions, which were possible by collaboration between the course instructor and the Writing Studio. With a range spanning from prompt-based creative writing to technical writing, these assignments have evolved to focus on enhancing the students' thinking clarity both in technical and creative aspects. This paper illustrates three writing assignments—project proposal, project report, and marketing pamphlet. Through them, students envisioned their task: foregrounding their work, establishing and monitoring a production plan throughout the semester, and receiving consistent feedback on their development from peers and instructors.**

Keywords—Academic writing, Project report in Engineering, Audience assessment, Writing Across the Curriculum (WAC)

I. Introduction

The current trends of writing education include Writing-Across-the-Curriculum (WAC), defined as a "comprehensive program that transforms the curriculum, encouraging writing-to-learn and learning-to-write in all disciplines [1]." Under this perspective, writing is used as an extension of thinking and a learning tool beyond its classical affiliations to English composition in the way of promoting the students' analytical and reflective thinking skills. In the context of Indian education of Engineering, [2] suggest a "student-centered approach with guided learning" for learners' professional competencies. Building on their suggested framework, the primary objective of the writing intervention is to maximize learners' comprehension.

This paper introduces writing interventions for the first-year engineering courses, *Manufacturing and Workshop Practice 1 and 2*, in which students design and manufacture a prototype as a group project. The courses have three writing components: project proposal, project report, and marketing pamphlet. These center around students' prototype design and manufacturing and are collectively done in a group of 6-8. Collaborative writing is beneficial in the sense that it functions as "a vehicle for knowledge construction [… and …] a social activity by a team of people working towards producing a common document [3]."

The development of the writing interventions were done in collaboration between the course instructor and the Writing Studio teaching associates (henceforth "tutors").

II. Three Writing Components

A. Project Proposal

The project proposal is assigned for the mid-term of the first semester. To facilitate their creative perception of their product, prompts (1)-(2) are provided:

(1) Know yourself
   a. Who are you?
   b. What do you do?
   c. Who do you do it for?

(2) Know your customer's aspirations and anxieties to add value
   a. What do they want?
   b. What do they fear?
   c. How is your product bridging the gap between the two?

Table I shows part of a project proposal on producing a utility bench, with problems and value additions:

TABLE I. Part of a Project Proposal on a Utility Bench.

"The style of a desk or chair can also affect how a student stands or sits. Your lower back may be stressed if a chair is excessively high and your feet hang off the edge. Of course, not many high school students struggle with this issue. More often than not, the chair is too low, causing your knees to be higher than the seat. Due to the added stress on your tailbone, this could be harmful. Experts advise sitting with your knees at a 90° angle, but because school seats are standard, it might be challenging to find comfortable chairs for every student."
"A bottle holder will be attached to the desk at some inclination angle towards the chair for a better user experience. There will be a bag holder at the side of the chair where the user can access the bag. This holder will be made up of a net with an elastic band at its upper edge. Thus the bag holder will be able to hold the bag tightly irrespective of its size and shape. Also, its location makes it more accessible for the user. The chair will be cushioned with a reclinable back adjustment. Along with this, the desk will have two footrests, one for the normal sitting position and the other for the reclined posture. Moreover, the footrest will be attached to the grooves made on the desk so that it can be adjusted whenever needed. To make it more comfortable, the desk-top will have an adjustment for its angle. Also, the desk-top can slide along the direction of the chair, which makes more work space for users."

Tutors provide a guest lecture on the conventional features of project proposal and the expectations of the course assignment. Also, students learn aspects of technical writing such as clarity, comprehension and accuracy. Since the project proposal and the eventual project report comprise elements of introducing the product, specifying its value addition and giving a detailed manufacturing process, the lecture emphasize the importance of precision. For example, students are advised to choose the most accurate verbs to describe the manufacturing process so as to make it replicable. Students also receive 1-on-1 tutoring at the Writing Studio. After the

proposal submission, tutors conduct a review session in class with feedback and suggestions for the next round, project report for the second semester.

B. Project Report of the Prototype

The project report serves as the written record of each group's two-semester-long product development project. The contents of the project proposal are further developed. In order to determine the contents of the report, the instructors and tutors build on [4], with modular components (e.g., abstract, nomenclature, design, materials and manufacturing process) and the timeline of tasks. In anticipation of the project report, learners keep track of the steps of their development process throughout the semesters.

A technical and formal tone of language are requested, which helps students get acquainted with the conventions of industrial technical writing. Furthermore, the tasks and timelines are presented in a GANTT or PERT chart.

In the provided template, they are given clearly marked and prompted directions as in (3)-(4):

(3) The introduction should clearly set up the proposal. It should include:
   a. A brief description of the problem with reasonable references/statistics/data supporting that the problem is important
   b. A brief about the current available solutions and how these are not sufficient
   c. A brief about the need for a different solution and bringing in the proposed value addition.

(4) Describe the final design of your project in this section. This section should include CAD drawings and sufficient images/views must be provided with clear labels. The description should include an explanation of all drawings and parts used in the design. The section should also clearly describe how the value addition is being achieved through the design.

C. Marketing Pamphlet

The marketing pamphlet is introduced as a component of the manufacturing exercise in the second semester. This component builds on the specifications and value additions elaborated by the learners in the accompanying project proposal and report, while optimizing their written expression to be comprehensive and accessible to prospective consumers. The writing center associates deliver in-class lectures that provide learner groups with prompts that help them envision their products as marketable goods. The lecture features lessons in persuasive writing, identifying the needs of the prospective consumers, and consequently building a brand narrative around the product that emphasizes value addition for the consumers. Although there is no prescribed format for the marketing pamphlet, the writing center associates and course instructors provide examples of marketing materials produced by various brands. Learners are encouraged to customize these components creatively according to the brand they intend to develop around their product.

D. Grading

Out of the overall 25 per cent weightage of the product design lab project, the project proposal, final report and the writing component amount to five per cent each. The assignments are evaluated on two separate rubrics: For technical components, grading is made by the course instructor and teaching assistants; writing components are graded by tutors and teaching assistants. The rubric was used to clarify the components of technical writing and help students develop proficiency for the writing component. An example rubric is as in Table II.

TABLE II. SAMPLE RUBRIC OF WRITING COMPONENTS

Criteria	*Expectation*	*Point*
Abstract	The abstract clearly provides with an overview of the report along with the key features and observations of the project.	2
Grammar and Syntax	Appropriate syntax and terminology are used without spelling mistakes.	4
Structure of the proposal	Following an intelligible narrative structure, features; use of connecting/bridging phrases	2
Logical Argument	Clearly making a case for design choices, results, and discussions: Facts are clearly outlined, stated, and supported by references; Logic is natural and well explained.	2
Conclusions, References & Citations	The concluding remarks of the report are concise, coherent, and convincing. Proper citations and references are given.	2

III. EVALUATION AND CONCLUSION

Since each group's manufacturing process, product specifications and target audiences were unique, the prompt-based approach resulted in an adequate amount of subjective autonomy being entrusted to the student. Writing interventions worked the best when the students were given autonomy to construct their own understanding of their respective processes. However, it was challenging to ensure that all students are equipped with the same extent of autonomy given that they were working in groups. At times, group members show varying degree of proficiency in writing. Thus, it was often challenging for them to divide the workload equally.

Through the writing interventions, students collectively achieved clarity in understanding the technical elements of the manufacturing process as well as the creative elements of building a brand based on their product. The continuous constructive feedback in-class and 1-on-1 tutoring ensured the quality of students' performance. It helped enhance students' comprehension and retention of the transferable professional skills.

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Impediments to Inclusive Education: An Exploratory Analysis of the Functioning of NIOS in Kolkata, Delhi and Jodhpur

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***Abstract*—The National Institute of Open Schooling (NIOS) is the largest open schooling system in the world, with a cumulative enrollment of 4.13 million during the last five years. A cardinal policy objective of NIOS is to provide inclusive educational opportunities to disadvantaged learners with socio-economically vulnerable backgrounds or disabilities who are unable to attend regular schools. This paper uses primary data from ongoing fieldwork in Kolkata, Delhi, and Jodhpur as well as 46 interviews with supervisors of facilitation centers, parents and learners to understand some aspects that shape participation in open-schooling, thereby offering a bottom-up perspective on 'inclusion'. The paper presents some preliminary findings on how differential access to NIOS, lack of technological competence, and unsubstantiated social perceptions about open-schooling, not only influences participation in the open-schooling system but also affects its efficacy. In this regard, it is recommended that more incisive strategies of information dissemination be adopted along with field audits of NIOS centers in order to facilitate its mission of guaranteeing inclusive education.**

***Index Terms*—NIOS, digital education, inclusivity, accessibility, open schooling**

I. Introduction

With a total enrolment of 4.13 million over the past 5 years, the National Institute of Open Schooling (NIOS) is the world's largest open schooling system [1]. An autonomous organization under the Ministry of Education, it was formulated to make education accessible to those who fail to attend regular schools, including students from marginalized backgrounds like Scheduled Castes, Scheduled Tribes, Other Backward Classes etc, students with disabilities, individuals with personal constraints, etc [1], [2]. As a teaching, examining and accrediting organisation, NIOS offers varied subject options for learners according to their interests and aspirations, and charges very low fees for admission and examinations [1]. This paper presents the results of fieldwork conducted across three cities in India, regarding the aspects influencing the decision to opt for open schooling as well as the perspectives of key stakeholders (facilitators, parents and learners) regarding open schooling education through NIOS.

II. Review of Literature

Many studies highlight that NIOS serves a wide gamut of learners, ranging from marginalised communities to affluent classes [3], [4]. At the same time, it is also emerging as an alternative for middle-class parents, who are homeschooling their children in cities like Bengaluru and Hyderabad [5], [6]. A majority of the research studies on the NIOS tend to be those undertaken by official personnel, leading to expository accounts of various aspects of NIOS. An important gap in literature is with regard to how learners as well as their parents navigate this system and how they perceive this system of schooling.

III. Theoretical Framework

This paper explores the idea of 'inclusion' based on Neil Selwyn's work on the socio-technical nature of educational technology [7]. This research critically examines the discourse around the power of technology for greater reach and access in open-schooling systems like NIOS by examining the abilities of various social segments to self-include themselves in online educational platforms and their subsequent abilities to benefit from such connections once they are established [7], [8]. Additionally, participation in schooling systems and beliefs about self-efficacy in learning are closely tied to aspirations about schooling which are the result of the intersectional interplay of aspects like class, caste, gender, geopgraphy, etc [7], [8].

IV. Methodology

Secondary data on NIOS from the official website and from the review of literature was used to map the number of active study centers in three states, West Bengal, Rajasthan and Delhi. Three cities were chosen based on convenience sampling, i.e Kolkata (with 9.85% of the active centers in West Bengal), Delhi (North-West Delhi and South Delhi, which represent a combined 45.5% of active centers in the city) and Jodhpur (with 7.47% of active centers in Rajasthan). Primary data was collected through preliminary fieldwork carried out in 6 NIOS study centers (3 each in Kolkata and Delhi) and through interviews. 6 supervisors of facilitation centers were interviewed. With regard to parents and learners, a snowball sampling method was used, beginning with participants in Jodhpur. 15 mothers, 1 father and 24 learners were

interviewed. Learners tended to be from middle and lower middle class backgrounds (with annual income in the range from from 3 Lakh Per Annum to 20 Lakh Per Annum). The parents were white-collar workers including social workers, pastors, businessmen, literacy and education consultants, ex-academicians, etc. Qualitative content analysis was used to analyse interview data.

V. Findings

A. Systemic issues that hinder access and participation

All the research participants (n = 46) mentioned that an information gap about the functioning of the NIOS is prevalent among NIOS personnel. The majority of the parents (n = 13) stated that there is a dearth of reliable information on the NIOS website. Students (n = 20) and the supervisors of facilitation centres (n = 5) stated that study centres are unregulated and that personal contact programmes, through which learners get to interact with tutors at NIOS accredited study centres, hardly gets conducted.

B. The growth of 'facilitation' centers

Since the process of obtaining education from NIOS is contingent upon technological proficiency, numerous private centres, which also go by the name of facilitation centres, have emerged. These private centres charge exorbitant fees from their students under the guise of provision of guidance to NIOS students in relation to admissions, examinations, inter alia. Students (n = 15) also alleged that sometimes these centres were complicit in cheating and that students who paid more money to the agent at the facilitation centres, had advantages in exams.

C. Perceptions about NIOS: Advantages and Disadvantages

All the interviewees (n = 46) mentioned that NIOS possesses a vast gamut of flexible features which have the potentiality to cater to systemically disadvantaged groups. While (n = 6) parents and (n = 12) students were of the opinion that NIOS promotes self-learning, critical thinking, (n = 6), other parents and (n = 10) students mentioned that it is a financially viable option and praised its attempt to move away from an exam-oriented curriculum. The option of writing examinations in several regional languages and NIOS' phased examination system were highlighted as advantages. On the other hand, learners who completed or were about to complete their schooling (n = 19) mentioned their anxiety about their futures on account of the wavering acceptability of the NIOS degree. They expressed that they were rejected by popular universities in India even after fulfilling the eligibility criteria.

VI. Discussion

Access to information about NIOS, lack of access to technological devices and/or technological competence, and social perceptions about open-schooling influence participation in this system. This makes it likely for the target groups of such an open learning system to face challenges in accessing its benefits. This gets reflected in data which shows that female students, students from rural areas, students with disabilities, etc remain under-represented in the NIOS [9], [10].

Furthermore, the many educational boards in India are encoded with different social perceptions. The choice of which educational board is suitable for one's children is shaped by beliefs about one's social (class) location as well as perceptions about the skills, dispositions, and capabilities of children as well as their parents [11]. Parents from upper and middle classes typically do need not rely on the inclusive features of NIOS for gaining access to education. While the phenomenon of home-schooling has led to the entry of more affluent learners into the NIOS system, the interviews demonstrate that middle class parents struggle with the social perception of NIOS as the last viable avenue to education for the disenfranchised sections of society. They are keenly aware of how this is tied to concomitant social perceptions of the NIOS learner as "academically and socially inferior".

As an ongoing research, a major limitation of this paper has been that the perspectives of most marginalized learners as well as parents are not yet represented. Their perspectives have a critical role in assessing the impact of NIOS in providing inclusive education. This represents a direction for future research.

VII. Conclusion

The paper highlights how social perceptions about open schooling, technological competence, and access to information about NIOS all play a part in shaping open-schooling participation. In order to support NIOS' aim of ensuring inclusive education, it is advised that more targeted information distribution tactics be adopted along with field audits of its centers, which incorporate users' feedback.

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Gamification of Reading Texts: Student Perceptions on Reading Process, Engagement, and Motivation

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***Abstract*— Gamification is one among the clusters of innovative pedagogical approaches that have attained great mileage in the diverse educational setting of the 21st century. This paradigm shift aligns with the preferences and expectations of Gen Zs and Alpha learners, who are often looking for interactive, engaging, and dynamic learning experiences. This paper presents a quantitative study regarding the perceptions of students on gamified reading, in the implementation of gamified reading texts in the blended classroom. This study was conducted using Kahoot in a semi-urban, CBSE school in Ernakulam (Kerala). The results showed that the learners have a positive attitude towards the reading process, engagement, and motivation.**

Keywords— Gamification, blended learning, Engagement, Motivation, Reading

Introduction

Digital learning has significantly altered the field of education. It has put forth the need for embracing technological advancements and innovative strategies for pedagogical approaches. Gamification is one among the clusters of innovative pedagogical approaches that have attained great mileage in the diverse educational setting of the 21st century. This paradigmatic shift has its reverberation in Indian, English as a Second Language (ESL) learning as well.

Gamification is a creative practice that takes its roots in Games. It can be best described as "the use of game design elements in non-game contexts" [1]. It is flexible in terms of design and implementation. The game design, game elements, and game mechanics can be customized based on the audience and the context of the application. It can also serve as a pedagogical strategy and tool in teaching and learning different skills and aspects of language.

Gamification as a strategy is suggested to have a positive impact on learners' engagement and motivation. Learner engagement is defined as "the extent of student's involvement and active participation in learning activities" [2]. Engaged learners are more motivated and invest more time and effort into the learning process. Gamification in general is often proclaimed as a way to engage and motivate learners.

One of the major areas which needs to ensure learner engagement and motivation is reading as it is no longer a passive activity that requires a silent period. The traditional Indian English classrooms used to read textbooks along with the teacher or by a command from the teacher followed by silent reading, which no longer amuses the learners. When it comes to digital learning, there are many attempts to incorporate technological advancements concerning listening, writing, and speaking skills. But, reading remains the same as offline. Accordingly, reading in the language learning classroom ought to be revisited and re-moulded to cater to the learners' interactive and fun reading experience. And gamification could be a suggestive solution for dealing with the lack of motivation and engagement in reading. The study was guided by the following questions:

1. Do learners perceive gamification as a pedagogical strategy capable of enhancing the impact of the reading process?

2. Does the gamification of text reading enhance engagement and motivation among learners in the Indian ESL context?

I. METHOD AND DATA COLLECTION PROCEDURE

This study involved a gamification design process and qualitative data collection procedures that were analyzed using descriptive statistics. The research was conducted by gamifying the reading texts of secondary school learners. The gamification of reading tests was done in the LMS, Kahoot. This study was conducted on 71 ESL learners from the IX class who followed the NCERT syllabus in a semi-urban school located in the Ernakulam district of Kerala

The gamification research design was modelled on the Hasso-Plattner design thinking method in five stages: empathize, define, ideate, prototype, and test [3]. The empathizing stage seeks to comprehend how reading takes place within the context of certain learners and the challenges they face when reading. For this, classroom observations were

made and this is the basis on which the gamification of reading texts was developed.

Following this, the problems were traced and the potential solutions that gamification could offer were examined. The ideation phase explored the LMS Kahoot's affordances, which supported the reading. In addition, the game elements and reading sub-skills were selected that could be conducive to scaffolding reading in the classroom. Finally, the gamified lesson was implemented in the classroom in the testing stage. Afterwards, the participants were given Likert questionnaires to determine the impact.

II. RESULTS AND ANALYSIS

In this process, a Likert scale questionnaire was given out to the participants with 15 questions, which were categorized into three sections including their perceptions of gamified reading texts; reading engagement, and motivation. The five-point Likert scale consisted of a range of agreements from strongly agree- strongly disagree (5-1), which were later analyzed using descriptive statistics. The standard deviation and mean of the categories are listed in the table below.

TABLE 1

Learners' perceptions on	**Statistical Measures**	
	Standard Deviation (SD)	***Mean***
The impact of gamification on the reading process	0.61	4.54
Engagement	0.71	4.23
Motivation	0.68	4.32

A. The impact of gamification on the reading process

The average perception regarding the effect of gamification on the reading process is 4.54, with a standard deviation of 0.61. This indicates that learners generally hold positive and favourable opinions about incorporating gamification into reading, and there is a higher level of agreement among these perceptions. Additionally, these perceptions suggest that responses are relatively consistent, with less variability among them.

B. Reading Engagement

On average, the learners' perceptions of reading engagement, including participants' scores for reading motivation and engagement, hover around 4.23. These perceptions exhibit a moderate level of variability, indicated by a standard deviation of 0.71. However, most of the respondents expressed a belief that implementing gamification in reading could indeed boost their engagement.

C. Reading Motivation

The descriptive statistics for learners' perceptions of reading motivation reveal that the majority of participants either agree or strongly agree, as evidenced by a mean score of 4.32 and a standard deviation of 0.68. These figures suggest that gamification enhances learners' reading motivation. Consequently, this implies that most respondents have positive perceptions, and there is a relatively high level of agreement among them.

III. CONCLUSION

This study examined the process of designing a gamified reading text using the LMS Kahoot and learner perceptions about the impact of gamification on the reading process, engagement and motivation. The findings showed that the learners hold a positive attitude towards the effect of using gamification for improving the reading process, engagement, and motivation. Moreover, this study shows that gamification can be used as a reading pedagogy in the blended classroom.

IMPLICATIONS OF THE STUDY

The particular study has the following implications:

- gamification could be a pedagogical strategy to aid reading both inside and outside the classroom
- Further studies could be conducted on developing gamified textbooks and reading apps
- Studies are possible to evaluate the impact of specific play elements on learners' learning and emotional screens.

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Educational and Psychological Effectiveness of MOOCs During and After the Pandemic: A Case Study of NPTEL LC 474

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Abstract

With MOOCs, one can expand knowledge and provide high-quality education. A renowned example of a state-supported OLS in India is NPTEL. Owing to significance of T4E, MSP Mandal's Shri Shivaji College Parbhani established LC of SWAYAM NPTEL (LC474) in 2016. During and after pandemics, it greatly aided learners and kept them informed and involved. The full-length paper interprets and justifies responses from faculty members and students regarding the effectiveness of LC474 during study period.

Key words –MOOCs,Pedagogy, Psychology, Pandemics, Post-Pandemics, Effectiveness, NPTEL.

I. INTRODUCTION

In order to offer top-notch education to anyone interested in attending an IIT, the Indian Institute of Science in Bangalore, along with seven other Indian Institutes of Technology launched the National Programme on Technology Enhanced Learning (NPTEL) project for the Ministry of Human Resources Development in 2003[9].

In order to encourage more students from different colleges to join, they have established SWAYAM-NPTEL chapters in colleges (with the management's agreement). These chapters will be led by a college staff member who will serve as the Single Point of Contact (SPOC), he can work as connecting bridge between SWAYAM-NPTEL and faculties and students of the college for its overall development [5].

The unavoidable lockdown and shutdown of educational institutions during pandemic greatly impacted the education system of rural and remote areas. The framework of the Indian educational system, which includes learning methodologies, teaching strategies, and evaluation methodologies, has been significantly affected during this period. As a result, online education has become more popular, with a strong emphasis on virtual education to achieve the established goals and objectives [1] & [7]. SWAYAM-NPTEL has proved to provide additional knowledge of concerned students.

II. REVIEW OF LITERATURE

Reddy A.Hanumanth (2016) in his article entitled, "NPTEL:A best e learning source for Engineering students" claimed NPTEL as best platform and concluded that if NPTEL's objectives are met, this is one of the most important developments in the field of online learning, not just in India but also globally [8].

Lata N et. al., (2020) found present days NPTEL as new conceived of advanced library collection, as a librarian and staff should know all the specialized or technical parameter of this video and web courses togive to the client viably [4].

Kant Premnath and Anurag Mehra (2022) mentioned that NPTEL/SWAYAM platform is a government funded MOOC platform. It is perhaps the most extensive scale attempted by any public / national system in the world to enable the use of these courses in the regular curricula. In their study they found that, this MOOCs based learning may not be effective in all disciplines of Science and Engineering. According to the authors, there may be multiple reasons for this and which may depend on the circumstances and socio-economic status of learners [3]. College students use the NPTEL content repositories as a supplemental knowledge source for personal enrichment. For students seeking better positions, NPTEL certification has also proved helpful [6].

III. MATERIALS AND METHODS

SWAYAM NPTEL Local Chapter (LC 474) has existed in MSP Mandal's Shri Shivaji College in Parbhani since 2016. In this paper, we'll talk about how Local Chapter LC474 performed both during and after the epidemic (AYs 2020–21, 2021–22 and 2022-23). 100 respondents in total were chosen for this study from among teachers and students who used the SWAYAM-NPTEL platform to broaden their knowledge through Local Chapter LC474.

A questionnaire containing 12 close ended questions and one open ended question was given to

faculties and students of the college to collect data of the selected case study.

IV. RESULTS AND DISCUSSION

Till to date, 1953 students and professors have used SWAYAM – NPTEL courses to improve their social and academic lives. In contrast, the period of investigation, which lasted from AY 2020–21 to AY 2022–23, included 918 teachers and students who benefited from the platform by enrolling in various courses. While there are 273 students who have registered for the examination thus far and 65 during the investigation phase (Table 1).

Some of the most significant questions are covered here.

Out of 100 responses, students made up 51.6%, and the remaining 48.6% is contributed by teachers. The percentage of students who found the various NPTEL courses to be useful was 88%, while all faculties deemed the courses to be useful or extremely useful. The majority of students and all faculty members want to continue their education through NPTEL courses. The majority of the students and the entire faculty gave favorable reviews for the various NPTEL courses.

We also solicited ideas. One recommendationwas made by a BCA TY student. He claims that students frequently struggle to turn in homework on time since they do not have access to a laptop. As a result, make an effort to include a compiler in the Swayam app, particularly the Android version. This will be really helpful, he continued.

Table 1 – Year wise Effectiveness of NPTEL LC 474 During and After Pandemics.

Sr No	Year wise Details	Academic Year			Total
		2020 -21	2021 -22	2022 -23	
1	No of Students Enrolled in NPTEL	75	426	417	**918**
2	Qualified NPTEL	03/07	05/13	11/45	**19/65**
3	Topper	01	01	--	**02**
4	Elite + Gold	--	01	--	**01**
5	Elite + Silver	01	03	02	**06**
6	Elite	02	01	04	**07**
7	Passed Successfully	--	--	05	**05**
8	Mentor	--	01	01	**02**
9	FDP	02	02	01	**05**

V. WHAT LC 474 DID?

Nearly all students were exposed to LC474 during the pandemic, and on August 4, 2021, DD Sahyadri, the state-run news channel, picked up the story,https://youtu.be/5_p1BhRPFIY [2]. On January 20, 2022, the college organised the NPTEL Awareness Online Workshop in cooperation with ICFAI University, Jaipur, and IIT Madras to increase student awareness of SWAYAM-NPTEL courses. This workshop received 4779 live views while it was being aired on YouTube Live.

VI. CONCLUSION

Many students sign up for numerous courses in order to learn from famous academicians across the nation. However, fewer students are registering, which may be a result of their poor socioeconomic status and the absence of an examination site in Parbhani. A similar type of conclusion was also drawn by Kant Premnath and Anurag Mehra (2022) while doing critical evaluation of NPTEL on students of science and engineering [3].

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Students' Preferences: An Assessment of Biology Textbook

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***Abstract*— This study examines the preferences of Grade XI students in higher secondary education for the NCERT Biology textbook. The study evaluates student engagement and effectiveness in a student-centered manner by combining preference assessment and self-reported usage data, using the Student Assessment of Textbook (SAT). The SAT tool, consisting of 60 questions about purchasing behaviour, preferences, and motivation, was used. The study employed data analysis techniques such as factor analysis and statistical analyses, including the use of SPSS 21 for factor loadings and correlational matrices. The analysis shows important connections among the variables. Cronbach's alpha coefficient was used to evaluate the internal consistency of SAT subscale scores. The study emphasises the significance of textbooks in higher secondary education and highlights the need for advanced research methods to comprehend the interaction between students and textbooks, and how it affects learning outcomes.**

Keywords- Assessment of Textbook, Preferences for Textbook, Student-Centred Approach

Objective:

Textbooks are widely regarded as fundamental educational resources that play a crucial role in facilitating students' learning and exerting a significant impact on their academic performance across various disciplines and educational levels.[1][2][3] In this study, the researcher aimed to develop a measurement tool for the analysis of biology textbooks. The students will be prompted to reflect upon their personal preferences, expectations, and perspectives regarding the subject of biology and its portrayal in the textbook.

METHOD

Participants

A cohort of 170 students from a higher secondary school were involved in meeting the research exposure prerequisite for this study. The study sample comprised 72 male students (42.35%) and 98 female students (57.64%). There were 124 students from GSHSEB-affiliated schools and 46 students from CBSE-affiliated schools. The study was conducted in Vadodara, Gujarat, India.

Material

This study utilises the Student Assessment of the Textbook (SAT), a self-designed assessment tool, and presents the findings using figures (Fig. 1, Fig. 2, and Fig. 3). The major objective centred on pedagogical research, is to evaluate the efficacy of the biology textbook through student engagement. The survey aims to investigates the reasons behind their purchase, genuine preferences, and factors that impact their usage. Experts validated the SAT tool, which consists of 60 questions. The evaluation encompasses three dimensions: purchasing, preference, and drive for utilisation. Demographic data was also gathered. The data was subjected to factor loading analysis, which explores cognitive processes, purchase drivers, financial implications, content relevance, practicality, reading habits, the availability of external resources, a student-centred approach, and effective resource utilisation.

Procedure

A survey was conducted to collect data from a sample of 170 Grade XI students regarding the usage of the NCERT Biology textbook in the Higher Secondary Section. The study offered voluntary participation to higher secondary students. The research tool was administered in December 2022, with participants allotted 30 minutes to complete the survey. The students received a debriefing regarding the survey and research ethics and were subsequently thanked for their participation.

Results:

Sr. No.	Item No.	Cron-bach α	Items	Factor Loadings: Learning & comprehension	Purchasing	Cost Effectivity
1	A1	0.83	To get good grades, I have to read my textbook.	0.51		
2	A2		By reading ahead, I can get better prepared for each class.	0.67		
3	A3		When I read the textbook, I can understand the lessons better.	0.78		
4	A4		Without a textbook, it's hard for me to follow the lessons.	0.68		
5	A5		Textbooks are a good way for me to learn more.	0.77		
6	A6		Reading is the best way for me to learn.	0.67		
7	A7		I love to learn more about the subject via textbook.	0.49		
8	A8		At school, I have to bring a book with me.	0.46		
9	A9	0.7	I will know more about my subject.		0.49	
10	A10		In every standard, I have to buy textbooks.		0.48	
11	A11	0.60	The book is less expensive.			0.35
12	A12		It was hard for me to get a second copy of the book.			0.48
13	A13		Everyone has already bought it, and so have I.			0.63
14	A14		I always bought all of the books I used in school.			0.86
15	A15		I got important questions from this textbook.			0.24

Fig-1: Students: Why did I feel compelled to buy the book?

Sr. No.	Item No.	Cron-bach α	Items	Factor Loadings: Applicability of content	Reading	Accessibility
1.	B1	0.72	I can use the information in my daily life.	0.47		
2.	B2		The main ideas are very well described.	0.78		
3.	B3		At the end of the chapter, there is a list of important terms.	0.68		
4.	B4		Simple words are used to explain the idea.	0.84		
5.	B5		At the end of each chapter, there is a list of terms.	0.45		
6.	B6		In the back of the book, there is a list of terms.	0.13		
7.	B7		The best way to learn is through examples.	0.41		
8.	B8	0.81	Reading textbooks helps me figure out what I want to do with my life.		0.59	
9.	B9		I want to learn more about the topic because I find it very interesting.		0.54	
10.	B10		The examples fit with what's going on in my life right now.		0.75	
11.	B11		Reading about the cases in the book is interesting.		0.72	
12.	B12		Glossary terms are given in small boxes or "information corners" all over the chapter.		0.45	
13.	B13	0.64	There is easy-to-get-to internet study material that can be downloaded.			0.59
14.	B14		I can read the book online or in hard copy.			0.56
15.	B15		There is a website with information that tells you more about material.			0.57
16.	B16		The online form of the textbook is easy for me to get.			0.49
17.	B17		There are several graphs in the course.		0.47	
18.	B18		There are several tables in the book.		0.48	
19.	B19		There are a lot of pictures in the guide.		0.48	
20.	B20		There are different ways to look at the images, such as from the back or the front.		0.65	

21.	B21	0.82	There are pictures of each person as a 3-D model.		0.67	
23.	B23		There is a flowchart that shows all the steps and processes in biology.		0.67	
22.	B22	0.72	There are QR codes for different kinds of information.			0.52
24.	B24		Every piece of content has a place where I can find out more.			0.61
25.	B25		Every piece of content comes from a source of basic knowledge.			0.78

Fig-2: Students: How much should I prioritise the textbook?

				Factor Loadings		
Sr. No.	**Item No.**	**Cron-bach α**	**Items**	**Student centric**	**Reso urce fuln ess**	**Easy to asse ss**
1	C1	0.9	Students can write about how they feel about different things.	0.49		
2	C2		There are more things with more than one choice.	0.67		
3	C4		At the end of each part of the chapter, a summary of the main points can be given.	0.58		
4	C5		The ideas can be presented in the simplest way possible.	0.76		
5	C7		The book can be used to give regular homework.	0.59		
6	C8		The teacher also teaches the subject through games.	0.87		
7	C9		There are different games in the guide to make the lessons easy to understand and fun to learn.	0.85		
8	C10	0.65	There are quizzes on biology on the schedule.	0.81		
9	C11		The teacher lets the students to make their own charts and diagrams.	0.59		
10	C19		There are places for students to write down their ideas.	0.55		
11	C20		Allow the students to convey their feedback.	0.58		
12	C12	0.83	A more in-depth summary can be given.		0.74	
13	C13		The teacher can also explain how to say different words in different languages.		0.65	
14	C14		In a bulleted list, the main points are summed up.		0.85	
15	C15		Hard words can be explained in easy ways.		0.84	
16	C16		Figures, tables, charts, and graphs (max. techniques) are used to sum up hard ideas.		0.79	
17	C17		Give statistics and data more.		0.71	
18	C18		In each part, there will be more questions.		0.52	
19	C3	0.87	There are study tools online.			0.36
20	C6		In the textbook, quizzes are given in the form of riddles or problems.			0.59

Fig-3: Students: What else can be incorporated into the textbook?

Interpretation and Discussion

The factor analysis aimed to explore associations between variables in the Student Assessment of Textbook (SAT), designed to assess three dimensions of a student's textbook experience. Items were identified and evaluated for factor loadings and Cronbach's alpha for internal consistency,. Results were organised based on three key questions.

1. ***Why did I feel compelled to buy the textbook?***

This study used factor analysis to identify three factors: learning and comprehension, purchasing, and cost-effectiveness. Students highly prioritise using textbooks for learning. All items exhibited high factor loadings, surpassing the accepted threshold of 0.4, suggesting stability according to research standards.[4] Respondents acknowledged the significance of buying textbooks as a customary practice at the beginning of the academic year. Textbook prices had a minimal impact on perceived cost-effectiveness.[5] Some items in Figure 1 (A11–15) had factor loadings below the accepted threshold. Textbooks are essential in classrooms, serving as primary or additional resources and offering content and activities. Wright emphasises the importance of teaching materials, like textbooks, in influencing syllabus objectives and guiding the roles of teachers and learners in instruction.[6]

2. ***How much should I prioritise the textbook?***

This study identified three factors influencing a student's prioritisation of textbooks: content importance, reading behaviour, and resource accessibility. Placing the textbook in front of respondents positively impacted their preferences, with a preference for high-quality content for performance improvement.[7] The study establishes a significant link between reading habits and textbook availability, improving subject knowledge, literacy, and general reading skills. Access to resources, whether online or via QR code, is crucial. Textbooks with rich visual resources enhance student interest, as reflected in Figure 2, with factor loadings exceeding 0.4.

3. ***What else can be incorporated into the textbook?***

This section analyses respondents' perspectives on future textbooks and suggests potential improvements. Examining student-centric approach, resourcefulness, and ease of assessment, the study revealed strong preferences for summarization, complex vocabulary, diagrams, and statistical data. The emphasis was placed on incorporating quizzes and a feedback zone. Factor loadings assessed students' information source preferences, indicating a prioritisation of resourcefulness in textbooks over exclusive reliance on online platforms. Despite the digital era's prevalence of Google and online courses, this study underscores the sustained importance of textbooks. Multiple factors, illustrated in Figure 3, notably influenced the variables.

Reliability of SAT Factors Scores

Cronbach's alpha assessed SAT factor reliability. This study explores factors influencing textbook significance, mandatory acquisition, and cost-effectiveness. Positive correlations were found between textbook importance and learning/comprehension (0.829), compulsory purchase (0.7), and moderate cost-effectiveness impact (0.61). Prioritizing textbooks is vital for academic achievement. Factors include content applicability, reading behavior, presence of visual aids, and accessibility from multiple sources (0.72). Students value a student-centric approach (0.90), resourcefulness (0.83), and access to additional information (0.87).

Conclusion

Students demonstrate a preference for textbooks equipped with study aids, chapter reviews, instructor integration, and user-friendly features. Instructors use of textbooks correlates with heightened student engagement and utilization.User-friendly textbooks are particularly favoured, aligning with expectations of convenience and accessibility.

Note: The study used varimax rotation with factor loadings > .50. Cronbach's alpha was used to assess the inter-item reliability of each factor.

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An analytical assessment model to assess engineering undergraduates through the program outcomes allied to the affective domain

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***Abstract*— Graduate attributes (GA) are fundamental traits of engineering graduates. Following GA, the National Board of Accreditation, India (NBA, India), an apex accreditation agency, proposed 12 program outcomes (PO). Within these POs, the most aligned POs with the affective domain are identified, and a unique numerical model is built for attaining each PO in line with assessment tools and events (existing and new), contribution, and alignment. This study discusses the precise attainment of the affective domain via a numerical model and ICT.**

Keywords*— *Graduate attributes, assessment, program outcomes, attainment

I. Introduction

Engineering is a fascinating field with numerous exciting employment options for its graduates. Still, the success of an engineering graduate is mainly determined by their knowledge, skills and attitude. Numerous scholarly research articles and surveys, notably the NASSCOM-McKinsey(2009) and Aspiring Minds' Engineers Annual Report (2019), mentioned that only 26% of engineering graduates are employable due to skill gaps compared to industry requirements in India. Experts cited various factors contributing to it, including an increased number of institutes, increased intake capacity, insufficient facilities, curriculum and teaching quality, and a lack of corporate involvement in curriculum development. However, a significant contributing factor that has yet to be investigated is engineering undergraduates' attitude and awareness of the desired graduate attributes (GA) and their progressive assessment[3].

Accrediting agencies worldwide have identified GAs as desirable skills to be provided to engineering undergraduates during graduation and subsequently used them in the profession [4]. NBA, India refers to these GAs as program outcomes (POs). Undergraduate engineering students must be trained and made aware of POs, their assessments, and progressive attainment numbers to take corrective action (if necessary) to maintain at least the appropriate attainment through threshold value for each PO until graduation [5]. The precise summative and formative assessment lag in many accredited institutes remains a concern. There is a strong need for linking every undergraduate's activity from admission to graduation to contributing GA with a weighted contribution as per its significance. Each undergraduate's assessment activity and its progression achievement must be visible to every stakeholder. Every undergraduate must be eager to maintain at least a minimum threshold number for each PO [6].

The assessment of every event and activity, its contribution to all POs, the number of assessment events, self-peer-expert assessment, and the assessment duration generate an enormous amount of data. Handling this vast amount of data is tedious for educational institutions, and most fail. With modern technology, the database management system, data science and unique analytical model may assist in assessing each PO. In addition, direct and traditional assessment tools, like conventional and practical examinations, can be utilized to assess knowledge and skill domains for learners. Nonetheless, assessing the affective domain is a challenging and neglected task.

This study initially classified twelve POs based on knowledge, skill, and affecting domains. During this study, additional online assessment tools were developed and identified new assessment events and feedback mechanisms with the participation of all stakeholders. It also contributes to a unique analytical model for calculating each PO, considering its contribution aligned to domains and assessment events. Meanwhile, this research paper concentrates on assessing and attaining program outcomes aligned to the affective domain with sample POs and events.

II. Domains of LearningS and Program Outcomes

A. *Domains of learning for engineering graduates*

Engineers are usually recognized in the market through their skills, knowledge, and attitude. As a result, an engineering graduate's most essential learning domains are cognitive, psychomotor, and affective. The cognitive domain strives to improve engineering undergraduates' knowledge and intellectual capacity. Physical abilities like gestural expression, dexterity, and kinesthetic awareness are all part of the psychomotor domain. Affective domains include mental processes such as emotions, opinions, values, interests, motivations, and attitudes.

B. *Program outcomes aligned to the affective domain*

Engineering knowledge, Problem analysis, Design and development of Solutions, Conduct Investigations of Complex Problems, Modern Tool Usage, Engineer and

Society, Environment and Sustainability, Ethics, Individual and Teamwork, Communication, Project Management and Finance and Life-long Learning are the twelve POs described by NBA. The author underlines the importance of assessing these POs through indirect assessment tools and events. Therefore, during this study, twelve POs are classified into three groups. The first four POs are primarily aligned with the cognitive domain, while Engineer and Society (f), Environment and Sustainability (g), Ethics (h), and Life-long Learning (l) are aligned with the affective domain. Else, the remaining four aligned to the psychomotor domain. This type of classification may be contradictory as it may vary with perspective and institute, and issues could be handled based on the speciality graduation.

III. ASSESSMENT EVENTS

Establishing educational goals and PO is the first step in the education process, followed by designing and teaching the curriculum and evaluating student progress through a summative and formative assessment, followed by their attainment. In between the above sequence, teaching happens within the framework of educational philosophy based on theories of student learning. Acquisition and participation are still the most essential parts of education, even if the techniques and approaches of teaching change. So, each student should have enough chances and opportunities through different academic and non-academic events to participate actively, acquire knowledge well, and be carefully assessed. As a result, institutions must scientifically recognize and implement a complete assessment plan using various assessment tools.

Assessment of POs is critical, particularly among engineering undergraduates, because entire graduation programs include numerous theory courses, practical courses, classroom sessions, laboratory appointments, projects, internships, industrial visits, tasks, participation in events (including cultural, sports, co-curriculum, and extracurricular), and many more. Every activity and action completed by the undergraduate during graduation contributes to the attainment of associated POs. As a result, it is necessary to recognize traditional assessment events and rigorously evaluate them, identify novel assessment events and apply them to assess POs. Adding more assessment events is better than the conventional practice, which only uses examination events for assessments because it increases the probability of precise assessment and realistic attainment. Besides ongoing examination events, additional assessment tools and assessment events, such as industrial visits, internships, projects, workshops, and training, are identified and used for a comprehensive assessment aligned with the skill and attitude domain assessment.

A. Data Management and ICT

As previously noted, the assessment and attainment of individual students for many events over the course of four years of graduation generates enormous data. This data also includes feedback and observations on students from peers, parents, experts, society, and employers, as well as records of students' participation and achievement. Massive data is needed for the assessment and attainment process, and its storage, management, and retrieval are significant concerns that need immediate attention. Hence, a technology-supported numerical model is proposed during this study using ICT tools with novel assessment tools like e-rubric, e-feedback and e-portfolio.

B. Methodology

Eq 1 gives a generalized mathematical model for the attainment of POs.

$$A = A = \left\{ \frac{\left\{x\left\{\frac{\sum_{i=1}^{n} D_i}{m}\right\} + y\left\{\frac{\sum_{i=1}^{n} ID_i}{n}\right\}\right\}}{\text{The maximum possible scoring number}} \right\} * \text{Target} \quad (1)$$

Where x and y - An administrator or panel of experts must use direct and indirect assessment tools to ascertain these factors based on their professional judgment of the precise PO contribution.; ID- Rubrics, feedback, and portfolio evaluation all contribute to the assessment score; Di– Direct assessment score through conventional examinations; m and n - The number of data entries linked with an event.

A common formula for all POs is inconvenient for attainment because each PO is unique and aligned to diverse, uncommon events.

C. Analytical mathematical model

PO h ethics are aligned with an event, e-rubrics, e-feedback, and e-portfolio with abbreviations c, e, g, s, w, x, z, j, u, and v developed throughout this study. As a result, a different analytical formula is developed for attaining PO h ethics, with 40% weightage and 60% weightage given to direct assessment tools. Meanwhile, under the direct assessment tool, students' ethical behaviour and personality are monitored and graded regularly during lectures, practical sessions, examination periods, projects, seminars, team events, and viva voce. Hence, a separate analytical model to find the attainment of ethics aligned with eq. 02 is,

Ethics

$$0.6\sum_{i=1}^{n} Di + 0.4\left\{\frac{\sum_{i=1}^{n} c + \sum_{i=1}^{n} e + \sum_{i=1}^{n} q + \sum_{i=1}^{n} s + \sum_{i=1}^{n} u + \sum_{i=1}^{n} w + \sum_{i=1}^{n} x + \sum_{i=1}^{n} z}{\alpha}\right\} \quad (2)$$

IV. CONCLUSION

The help of ICT tools and a mathematical model provided in this paper allows undergraduates to identify lagging skills and personality aspects well in advance and improve their lagging skills during graduation. It also helps the institute to identify lagging students and perform necessary corrective actions like coaching, counselling and infrastructural help. This system also helps monitor individual students' skills and behavioural aspects and involves all stakeholders.

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The Impact of Blended Learning: A Study of English Language Teacher's Perspectives

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***Abstract*—**The present study aims to know teachers' perspectives on using blended learning mode in English language learning. Participants of this study are 54 teachers of Z P P school in 9 talukas of Parbhani district, Maharashtra. The questionnaire is used as a tool for data collection. The results of the study are discussed after the analysis of the data, which showed an overall positive approach of the teachers about the use of blended learning mode to learn the English language.

Keywords*—Blended Learning, English, perspective, teachers*

I. Introduction

Researchers define language acquisition into two categories: first-language acquisition and second-language acquisition (Haznedar, 2003). First-language acquisition is a universal process regardless of home language. The second-language acquisition encompasses the process an individual goes through as he or she learns the elements of a new language, such as vocabulary, phonological components, grammatical structures, and writing systems. (Macaro, 2006).

As English language is learned and taught as ESL/EFL in India. The learner and the teachers must make special efforts or be more conscious (Azlan et al.; S., 2013). Teachers use different approaches, strategies, methods and modes to teach and learn language. Grammar translation method, direct method, total physical response method, task-based method, aural oral approach, art-integrated learning etc. The evolution in information and technology has changed the work culture of each sector. The education sector is no exception to this. E-learning, online learning, mobile-assisted language learning, computer-assisted language learning, and blended learning are the gifts of technology.

The blended learning mode is the innovative mode used to learn the English language (Dangwal et al.., 2017). Blended learning has positively impacted vocabulary instruction (Katasila et al.., 2022). It has been investigated whether blended learning is effective in the best circumstances (Topping et al.; N., 2022).

Most of the studies are conducted to understand the student's perspective. For example (Al et al.; Al et al.; Eddin et al.; Al-Rahman et al., 2013). (Vanslambrouck, S., Zhu, C., Lombaerts, K., Philipsen, B., & Tondeur, J., 2018). A teacher has significance in any educational change or implementation (Fullan, 1992).

In brief, to anchor blended learning successfully, it is essential to understand the teacher's perspective about using blended learning mode to learn the English language.

II. Conceptual Background

A. Defining Blended Learning

Here are a few definitions of Blended Learning.

C. R. Graham states, "Blended learning systems combine face-to-face instruction with computer-mediated instruction".

According to Garrison and Kanuka, it is "the thoughtful integration of classroom face-to-face learning experiences with online learning experiences".

Oliver, Martin, and Keith Trigwell observe 'The integrated combination of traditional learning with web-based on-line approaches.'

Thus, Blended learning, also known as technology-mediated instruction, web-enhanced instruction, or mixed-mode instruction, is an approach to education that combines online educational materials and opportunities for interaction online with physical place-based classroom methods.

B. Purpose of the study

The purpose of the study is – 1) to know the Zilla Parishad Primary school teachers' perspectives on the impact of blended learning mode to learn the English language. 2) To know whether the use of Blended learning mode is situational.

C. Review of the literature

The present study has reviewed the following major previous attempts that focused on the question under inquiry:

1) Lalima; Dangwal, Kiran Lata, 2017

2) Lalima; Dangwal, Kiran Lata, 2017

3) Bizami, Tasir, Z. & Kew, S.N., 2023

4) Arnab Kundu, Tripti Bej, and Kedar Nath Dey, 2021.

D. Methods and Sample

A questionnaire is designed as a data collection tool for the present study. It contains 10 close-ended and one open-ended question.

The sample is selected with a purposive sampling method. 6 participant teachers from each taluka of Parbhani district. From 9 talukas, 54 teachers participated in the study.

III. Results and Discussion

After analysing the data, the process has shown the following results.

1) 100% of participants mentioned that the blended learning approach enables English language teachers to present lessons effectively.

2) 100% of participants mentioned that BL enables teachers to design learning outcome-oriented activities for English language learning.

3) 96.3% of the participants agreed with the statement that BL creates an English language learning environment to

achieve learning outcomes of the English language. Whereas 3.7% were disagree.

4) 98.1% of participants said that BL motivates learners to achieve learning outcomes in the English language, and 1.9% disagreed.

5) BL enhances the achievement of English language learners; regarding this statement, 98.1% of people agreed and 1.9 disagreed.

6) 7.4% of the participants disagreed with it, whereas 92.6% agreed.

7) 94.4% of participants agreed with the statement that BL enhances students' participation in English language learning activities

8) 63% present of participants disagreed with the statement that the Usefulness of Blended Learning is situational. (COVID-19).

9) 96.3% of participants agreed with the statement, and 3.7% disagreed.

10) 92.6% of participants agreed that BL makes the evaluation process of the English language effective and easy.

11) 60% of the participants mentioned that proper training is needed to use technology-related parts effectively.

IV. Conclusion

Teachers show a positive approach to using Blended learning to learn the English language in Zilla Parishad Primary School. Blended learning is one of the most useful modes used for language teaching. It got a boost in the post-COVID-19 era. Not only developed countries but developing countries are also using technology-based pedagogical approaches.

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Development of academic laboratories in Chemical Engineering Simulation and Process Control: A Perspective

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***Abstract*—The Department of Chemical Engineering at the Indian Institute of Technology Ropar was established in 2017 in Rupnagar (Punjab). Four academic teaching laboratories seminal to chemical engineering - Fluid Flow, Heat and Mass Transfer Laboratory, Chemical Reaction Engineering Laboratory , Process Control Laboratory and Chemical Engineering Simulation Laboratory were developed to help undergraduate education. The author was given the responsibility to develop the Process Control and Chemical Engineering Simulation Laboratory. The courses in these academic laboratories are based on process systems engineering (Process Modeling, Control and Optimization). This poster essentially chronicles the development of these laboratories - the opportunities utilized, and the challenges encountered. The motivation of the poster is that this study may benefit future practitioners and create a dialogue on optimal laboratory operation aimed for achieving high quality educational objectives.**

I. Introduction

The Indian Institute of Technology Ropar was established in 2008 in Rupnagar (Punjab) as one of the next generation institutes in the IIT System. In July 2017, the Department of Chemical Engineering at IIT Ropar was established under the leadership of Prof. Raj Chhabra, Prof. Sarit K. Das. The Department was initiated in a building known as Transit Campus at Nangal Road in Rupnagar. The first student intake was initiated in August 2017, and the academic laboratories on Chemical Engineering Simulation were taught for the first time in August 2018 and Process Control Lab was taught for the first time in January 2020. This poster showcases the evolution of the Chemical Engineering Simulation Laboratory and Process Control Laboratory.

II. DEVELOPMENT OF CHEMICAL ENGINEERING SIMULATION LABORATORY AT IIT ROPAR

The Chemical Engineering Simulation Laboratory at IIT Ropar in the Transit Campus has been developed as two learning zones with 28 and 18 computers each. This designation was made to help undergraduate students and research scholars access the computing facilities. While conceptualizing a new laboratory, a few issues were experienced from the very beginning. In a new department recruitment of laboratory staff takes time. The first member of laboratory staff joined in October 2019, wherein the laboratory courses had to commence by July 2018 for the Chemical Engineering Simulation Lab. Identification of laboratory space and obtaining computers to commence operation also posed a challenge, especially in an academic institution where multiple departments in an institute are being established simultaneously. The first course in the Chemical Engineering Simulation Lab was taught by utilizing 26 legacy computers which were sourced from another department; and the furniture of a department which was not in use was utilized to seat students. The contribution of students from the pioneer batch played a vital role in making the lab ready for operation.

Figure 1 shows one of the Chemical Engineering Simulation Learning Zones. The Chemical Engineering Simulation Lab at IIT Ropar does not cater to one course, but encompasses the vast area of process systems engineering – inculcating an understanding of equation-oriented approaches, dynamic simulation, flowsheet sequencing, modeling associated with gas-solid processes. The lab in due course also helps educators with computational fluid dynamics and molecular dynamics.

Fig. 1. Chemical Engineering Simulation Learning Zone 1

Every set of educators teaching the laboratory face the option on whether the process simulation laboratory should introduce the use of a simulator, or the opportunity should be leveraged to teach numerical methods. Another set of educational decisions which exist that whether Computational Fluid Dynamics should

be taught be as a sophomore level course. In engineering curricula, often the introduction to computer programming is taught in Year 1. With this background should the instructor re-teach programming or should begin with chemical engineering computing concepts. In the author's opinion flexibility on imparting instruction through infrastructure and developing an academic and laboratory culture is of paramount importance.

III. DEVELOPMENT OF PROCESS CONTROL LABORATORY AT IIT ROPAR

The Chemical Engineering Process Control Laboratory at IIT Ropar in the Transit Campus has been developed as two designated areas: one to impart digital learning experience in accordance to Industry 4.0 and the other to give a physical learning experience. In the course of five years, the author has explored various software like MATLAB, SIMULINK, Loop-Pro (Control Station) and PI-TOPS and SIMCET (Pi Control), Dynamic Simulation in DWSIM. The usage of LABVIEW, Harold and ASPEN Suite is currently being explored. These cover suggestions shared in literature on a wide variety of exercises ranging from classical problems to model predictive control. Figure 2 showcases the nature of infrastructure developed in the Process Control Lab Computational Facility.

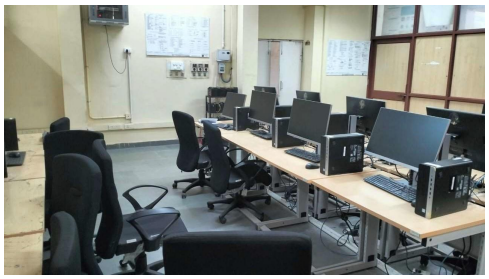

Fig. 2. Process Control Lab – Computational Facility

The physical laboratory equipment space at IIT Ropar consists of a multi-process control trainer, level control, tanks in series, valve control. The need for physical didactic equipment came from faculty members who felt that a laboratory based solely on digitalization may not give students the physical feel.

Fig. 3. Process Control Lab – Physical Equipment Space

IV. LEARNINGS FROM DEVELOPMENT OF ACADEMIC LABORATORIES

An academic laboratory is an integral part of the engineering educational experience. A typical development cycle involves planning for space, procurement of material for operating laboratories, giving inputs to hiring of laboratory staff. Based on the author's experience, in an Indian Educational Scenario the following are recommended:

a) A well conceptualized academic laboratory is an investment for the future for a department as it will encourage students to pursue the discipline. The assignment of developing the academic laboratory should be pursued in the spirit of Rabindranath Tagore's quote - *"The one who plants trees, knowing that they will never sit in their shade, has at least started to understand the meaning of life."*

c)The review of literature helps to understand diversity of opinion in prioritizing academic objectives. Academic laboratory infrastructure should be flexible. For instance, in Chemical Engineering Simulation Lab – as long as the Chemical Engineering learning outcomes and the consensus on imparting skills for research and industry are philosophically clear: which software is being employed are a minor point. For Process Control – the lab should be adaptable to help with instrumentation, virtualization, philosophy of developing one's own code vis-à-vis training on industrial software.

c) The development of a computer simulation laboratory and process control laboratory may be simplified by visiting existing academic laboratories, relying on senior colleagues in other institutions and vendors and going through the didactic equipment list. However, a review of the existing literature should be done.

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Exploring the synergy of virtual internships, collaboration with academia and industry to train future energy professionals: A case study from India

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***Abstract*—In April 2023, professors from IIT Ropar, iHub – AWaDH, a Technology Innovation Hub established by the DST – Government of India at IIT Ropar in the framework of National Mission on Interdisciplinary Cyber-Physical Systems, and the Energy Mentors, a US based non-profit organization, entered into a Memorandum of Understanding (MoU) to identify and encourage talented students from South Asia and Africa. The aim of this MoU is grounded in the hypotheses that to the degree we can grow more energy professionals where they live with better capabilities and competency, the better positioned under-resourced communities could be to solve their energy trilemma: access to affordable energy, resiliency and assurance in energy supply, and to obtain such energy sustainably and at lower greenhouse gas (GHG) intensity. This poster summarizes the first implementation of International Energy Mentors Internship Program in May 2023.**

Keywords— Virtual Internships, Energy, Sustainable Development

I. Introduction

Virtual Internships have evolved to be an important mechanism to help students gain professional and authentic engineering educational experiences in academia [1]. In April 2023, the International Energy Mentors Internship Program program was conceptualized and assembled agilely in using existing, low cost, readily available infrastructure [2]. The program enables bringing advanced technical training and capabilities to any student, no matter how remote or low-resourced, as long as they have: a) an educational foundation for entry into a university degree program, moderately powerful personal computer, a broadband internet connection, and a work ethic and desire to bring sustainable energy solutions to their community and the large world. The associated challenges with students in India were reported by authors in the 2019 T4E conference in Goa [3].

II. Energy Mentors Program

The International Energy Mentors Internship Program of was initiated in May 2023. Student participants were solicited via social media with the aim to identify a pool of hundred students who may work on an interdisciplinary energy problem. The interdisciplinary energy problems were scaled down versions for the premise published for "Power the Community", an international college design competition created by Energy Mentors that will be conducted during the 2023-2024 academic year. Professionals with deep industrial experience were able to virtually lecture from locations across India, the United Kingdom, and the Unites States students spread across South Asia and Africa. Modern meeting platforms hosted upwards of 240 participants simultaneous and facilitated questions to the presenters via chat and upvoting mechanisms. Table I gives the form of generic deliverables from an Energy Mentor Project.

TABLE I. GENERIC DELIVERABLES FROM ENERGY MENTOR PROJECT

Stage	Typical Deliverables
Stage 1	Order of magnitude study, identify the use case, list customer requirements, initial energy balance, system sizing, understanding the supply and demand side of the problem
Stage 2	Generating the equipment list, sizing of component, layout, circuit diagrams / process flowsheets
Stage 3	Digital twin of the energy system along with dynamic performance, structural , electrical design, system ratings

The first week of the program included lectures from energy professionals from the solar, wind, process simulation, agri-photovoltaics, electric vehicles, battery storage and energy transition industry, distributed energy systems. The initiative was fostered by participation of organizations who provided software (e.g., Dassault Systèmes and MathWorks) for the first week of training, more than 200 students inducted and given know-how of energy sources, utilization, optimization and potential issues in the domain. The organizers subsequently organized a screening assessment on the basis of review of the assignment performance of the participants in which 90 scholars from South Asia and Africa were selected for complete training program. The results of the screening assessment were declared by June 1 and the students are currently undergoing the seven week mutlidisciplinary group project. Eighteen teams of five students each are working on the design problem in the Energy Mentors compeition. The problem statement of this year includes to design an energy solution for a community of 2000 individuals. Out of the 90 students selected, 81 students are from India, 2 from Bangladesh, 2 from Ethiopia and 1 from Cameroon, Belgium, Sudan, Nigeria and Kenya. Figure 1 showcases the discipline-wise distribution.

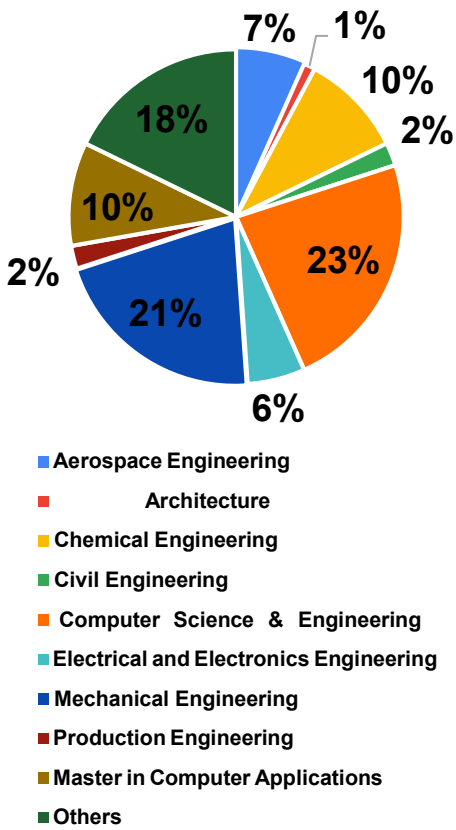

Fig. 1. Discipline-wise distribution of Energy Mentors

III. FUTURE WORK AND LEARNINGS

Some of the initial feedback received by the students that sources of data relevant to Indian Energy Scenario are difficult to access. Hence the authors are making efforts to showcase the ongoing effort by Government of India and make it accessible to students. The data on Solar photovoltaic potential versus geolocation coordinates for countries such as India, Bangladesh, and African countries, similar to those provided by the United States National Renewable Energy Laboratory (NREL) [4].

In summary, since the inception of Energy Mentor Program - 2023, 90 students from 8 countries in Africa and South Asia are actively participating on solving an interdisciplinary energy problem for their community.

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Implementing a Student-Centric Free and Open-Source Virtual Laboratory in Bioinformatics and Computational Biology

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***Abstract*— With the unprecedented growth of biological data from several projects and data-intensive approaches in bioengineering disciplines, a variety of tools and algorithms for biological data analysis and interpretation have come up in the bioinformatics domain. The diverse nature of biological data and the necessity of complex software programs and algorithms have been major challenges for integrating bioinformatics skillsets into tertiary education curricula. The paper explores the design and implementation of a set of user-interactive simulation-based experiments, as freely available Bioinformatics and Computational Biology Virtual Laboratory developed using JavaScript and HTML. As part of the design, the content of the experiments was matched to the currently implemented syllabi adopted by government accreditation bodies in India. In the context of education pedagogy, the goal of this virtual laboratory was to augment and assist students with the ability to learn common procedures in bioinformatics including data upload and analysis. Our freely available online laboratory includes the theory, step-by-step instructions, and quizzes that provide basic skill training in bioinformatics tools and complex algorithms allowing learners to practice repeatedly methods that are part of the curriculum for students in bioinformatics. The set of virtual laboratory experiments explores computational challenges existing in the biological domain. The free open-source bioinformatics and computational biology workbench allows learners and teachers from diverse domains to explore topics within and beyond classroom environments. Validating our previous studies among students and teachers, the deployment strategy was found relevant to make content available and ensure continuing education without the presence of a teacher as in conventional classrooms. This paper will discuss the scope, design, technical considerations, and implementational constraints, and will explore the training-to-practice goals that can be a significant application tool for promoting learners and supporting teachers in higher education.**

Keywords—virtual laboratory, bioinformatics, computational biology, pedagogy, higher education

I. Introduction

With the surge in genome analysis, research practices in life sciences have presented a robust need for computational techniques, bioinformatics tools, and big data analysis for storing biological data[1]. The Human Genome Project (HGP) integrated with high throughput sequencing technologies in bioinformatics has been expanding as a data-driven approach in life sciences education[2]. This demands bioinformatics tools and algorithms for increasing the opportunities in data analysis and maximizing the research output in biosciences. Given the evidence of bioinformatics skills in the landscape of genomics, implementing cost-effective computational approaches is crucial for tackling challenges and widening opportunities in the real world [3]. Even though basic skills in biological data retrieval, analysis, and interpretation were foundations for today's basic research, universities have been lagging in providing bioinformatics skills due to computationally intensive programs and the dynamic techniques prompting updated curriculum that poses academic challenges. Studies have proven bioinformatics education, big data analysis, and genome sequencing as an exceptional plethora in biosciences, henceforth training in bioinformatics and computational aspects are becoming prerequisites for improving domain knowledge [2].

Nevertheless, studies indicated the benefits of learning bioinformatics tools for extracting knowledge from existing biological data and the inclusion of bioinformatics education even in the secondary education curriculum [4], many biology students had minimum exposure to informatics tools. With the influence of information and communication technology (ICT) in the education paradigm, teaching employs didactics learning strategies including inquiry-based learning in bioengineering disciplines prompting structured instructional strategies for curriculum development following National Education Policy (NEP) 2020 [5]. Studies reported that conventional face-to-face bioinformatics education included in-person computer lab-based training for skill-based learning in bioinformatics courses to reinforce conceptual and active learning [6]. From a teacher's perspective, the major challenges for promoting computer-based training in classroom education included the 1) cost of computational infrastructure, 2) operational logistics, 3) instructor knowledge on installing software packages, 4) application of databases related to bioinformatics and biological courses 5) constantly changing software systems and 6) the need of knowledge on interdisciplinary fields[1]. Considering the advances of high-throughput technologies in biological sciences coupled with the application of bioinformatics tools, a congruent emergence of bioinformatics education in universities has been noted in recent years. The intention was

to minimize the complexity of life science research and to target tertiary-level students to learn basic skills in bioinformatics tools, and training for professionals in the teaching paradigm[7].

As a problematic approach, several initiatives such as integrating e-learning and web-based virtual laboratories in classrooms have been put forward to integrate bioinformatics curricula that promise the diverse user demands of learning tools and algorithms using a collaborative learning platform for integrating theory and practice [8]. Ministry of Education (MoE), the Government of India, implemented virtual laboratories in bioinformatics for undergraduate students of the Indian curriculum to understand retrieval of data from biological databases, learn basic algorithms, and understand computational analysis of structural features of biomolecules and homology modeling. A meta-analysis of the state-of-the-art virtual laboratories in education indicated a lack of user-interactive platforms for providing skill training to life science and engineering students on basic experiments including sequence alignments to advanced technologies such as next-generation sequencing[5].

The purpose of the study is two-fold. First, the paper discusses the design and implementation of a novel user-friendly, tutor-independent virtual laboratory on Bioinformatics and Computational Biology intended for university students, researchers, and teachers. Secondly, from a learner perspective, the goal of the study is to understand how the user-interactive, graphics-mediated virtual laboratory aids in learning basic bioinformatics tools and algorithms intended for users of interdisciplinary fields with usage simplicity.

II. Design, Development, And Implementation of Virtual Laboratories in Bioinformatics and Computational Biology

A. *Instructional Design of Experiments in Bioinformatics and Computational Biology*

Developing new approaches with the use of technology in instructional strategies is one of the problem-solving criteria for augmenting bioinformatics education in universities. Building an ICT-enabled virtual laboratory is a complex task with design considerations, visualization, and pedagogy features outlined by the TPACK model. The design of the online experiments in this work was based on the widely accepted ADDIE Model [9]. The selection of experiment topics (Table 1) for virtualization was based on the curriculum of Bioinformatics approved by the University Grants Commission (UGC) and All India Council for Technical Education (AICTE), meant to achieve a conceptual understanding of databases and algorithms for both bachelors, masters and research students in biology and engineering. The design of the asynchronous virtual learning platform was based on a user-centered hierarchy with a flexible front-end and back-end to achieve the pedagogical preferences of learners ensuring content quality for promoting technology-based higher education at tertiary-level institutions. The development process had a two-level coordination between subject matter experts and programmers from computer science for promoting technology-based higher education at tertiary-level institutions.

The graphical user interface (GUI) (Fig.1) and the interactive simulation were developed with HTML and JavaScript as the frontend language for facilitating explicit user interaction.

TABLE I. List of the experiments in the Bioinformatics and Computational Biology virtual laboratory

Sl.No	Bioinformatics and Computational Biology Virtual Laboratory	
	List of experiments	***Skill learning in Bioinformatics***
1	Visualization of Protein Structure	Protein Database (PDB)
2	Basic Algorithms in Bioinformatics	The dot plot, Needleman-Wunsch, Brute Force Comparison
3	Similarity search using BLAST	BLAST
4	To find out the number of times a sequence is repeated in a given DNA sequence	Pattern finding
5	Molecular Dynamics Simulation: GROMACS	GROMACS software
6	Conversion of sequence from one database format to another using file format converter	FASTA, GENBANK, EML file format
7	To analyze the sequence of a given DNA and find out the sequence composition	Understanding the genetic composition.
8	An introduction to Next-Generation Sequencing (NGS)	FASTQ Analyzer
9	Browsing genetic variation databases with dbSNP, ClinVar	ClinVar
10	Basic machine learning using the WEKA tool	WEKA tool

Fig. 1. The graphical user interface for the experiment browsing genetic variation databases such as dbSNP, ClinVar, a module in Bioinformatics, and Computational Biology Virtual Laboratory. BRCA1 gene with variant id 2565369 is given as input to execute the simulation. The list of parameters facilitates explicit user interaction with or without the instructor's dependency.

For example, by browsing genetic variation databases such as dbSNP, and ClinVar, the simulator provides the variant details such as Allele ID, Variant type, Cytogenetic location, Genomic location, HGVS, Protein change, Canonical SPDI, etc. of a desired gene. The users can identify the genetic variants associated with specific diseases and can determine the clinical significance of these variants. Overall, from a learner perspective, the array of experiments was

meant for biological data analyses and interpretation including sequence alignment, protein structure prediction, phylogenetic relationships, and drug designing.

To provide an educational context, the web-based platform included a content-oriented section (theory, procedure, and pre-test) and an experimental section. The content-mediated section describes the details of algorithms implemented in each experiment, a description of the step-by-step experimental procedure, and assessment questions for evaluating content knowledge. In the experimental section, user-interactive simulation was designed to execute experiments where interface aesthetics and visual style were achieved using CSS. A combination of JavaScript and CSS-enabled graphical controls, including buttons, toggles, and sliders were provided for user engagement. The designed JavaScript-based simulators can be executed on a desktop computer or even on a mobile device like a tablet or smartphone. Post-test questions are meant to evaluate the learning outcomes. The collection of these illustrative components provided strategies, and self-learning model approaches to accomplish the learning objectives.

B. Facilitating Client-server communication in the virtual learning platform

Implementing a virtual simulation-based experiment needs to satisfy both the server side and the client side requirements (Fig.2) in the context of multiple student users assessing the resources. In client-server-based experiments, the communication between the client and server is the primary process to execute the experiments and to provide inter-process communication and data storage. The server handled the communication between multiple clients at a time. The client-server communication included user requests, graphical user interface (GUI), Hypertext Transfer Protocol (HTTP) requests, Entrez Programming Utilities (eUtils), National Center for Biotechnology Information (NCBI) web server, and NCBI database. The eUtils are a group of server-side programs that provide a stable interface to the Entrez database system at NCBI. eUtils are therefore a structured interface to the Entrez system, which currently contains 23 databases covering various biomedical topics. eUtils translate a standard set of input parameters into the values (request ID (RID) for BLAST and query key for ClinVar) needed to search for and retrieve data. Data can be accessed by the platform that posts a eUtils URL to the NCBI web server, which retrieves the results, after which the data can be processed. JavaScript can easily communicate with a server using the Fetch API. The Fetch API offers a powerful and flexible way of handling HTTP requests. In web-based experiments, basic bioinformatics tools and techniques were represented with interactive components including images, buttons, and navigation menus for data representation and analysis.

For the experiment, visualization of protein structure, Mol*, developed by RCSB.org. is implemented as a web-based open-source toolkit for facilitating communication from user ends. The focus is to design and generate three-dimensional images of protein structures and entities available in the Protein Data Bank (PDB). The experiment has a set of user-defined input parameters, which are sent to the Mol* plugin. The JavaScript file in Mol* connects to the RCSB web servers using an HTTP request. The RCSB web server allows access to the required data, retrieves the results, and displays them on the graphical user interface (GUI) as experiment output (Fig.3).

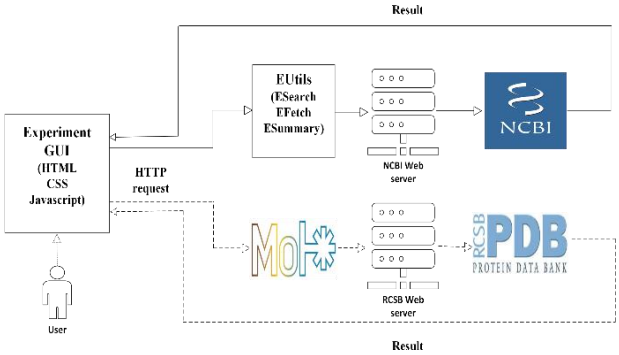

Fig. 2. The client-server communication for virtual lab deployment.

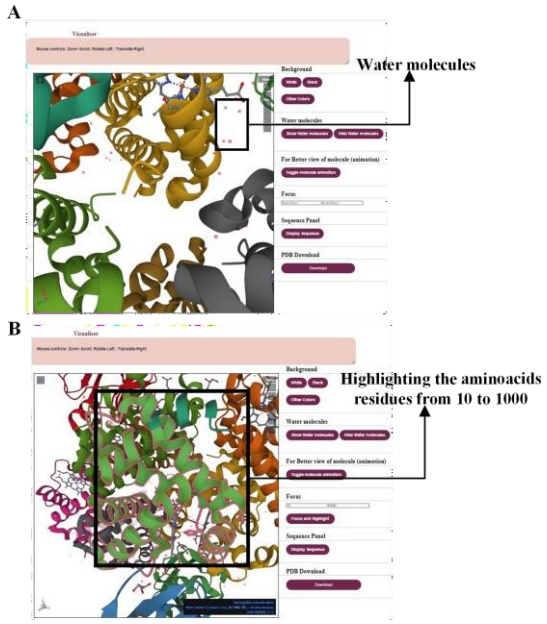

Fig. 3. The molecular structure of proteins in three dimensions (3D) is displayed on the 3D Canvas space of the experiment GUI. The platform helps in visualizing the structure of the protein of interest depending on user needs. A. Water molecules in the protein were visualized as dot representations. B. Specific amino acid residues are highlighted according to user preference.

The parameters in the experiment provided an interface to visualize and analyze protein structure and to highlight structural predictions with and without water molecules (Fig.3A) and specific amino acid residues (Fig.3B) specific for homology modeling and systems biology applications.

C. Defining algorithms in bioinformatics to implement user interactive web-based platform

Programmers designed a set of algorithms for creating a user-interactive platform with a high degree of modularity for biological sequence-based studies and applications. With the defined algorithms (Fig.4), the simulator for file format converter changes the given nucleotide file formats from GenBank to FASTA and EMBL to FASTA. The input can be loaded in the interface by file upload, and after input format selection, the possible output formats are displayed depending on the file format converter. Users can access and download different file formats for further studies. The advances in software tools for biological information analysis relied on

common file formats for the usage and exchange of biological data for educational and research purposes. File formats extended to achieve uniformity in the presentation of biological sequences and for storing and exchanging data in science and engineering communities.

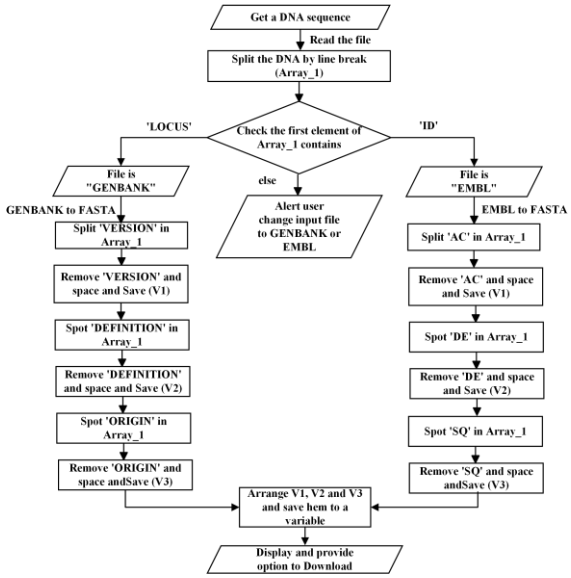

Fig. 4. Modeled web-based virtual laboratory with flexible user interaction for analysis. V1, V2, and V3 denote a set of variables in algorithms.

III. Discussion

The study presented the design and implementation of a free and open-source student-centric virtual laboratory in Bioinformatics and Computational Biology with a subset of ten experiments intended for usage by learners and teachers of the Indian curriculum. The education content design focused on the updated curriculum of government accreditation bodies and institution-wise stakeholders of education to promote basic skill-based training in bioinformatics education. The experiments were classified as web-based experiments and client-server-based experiments depending on the user requirements for experimentation. The server processes client requests and allows the client to run the experiment on a personal computer, workstations, mobile applications, and so on. In web-based experiments, users can upload data of their interest for processing the experimental output. The designed GUI helps learners to analyze the fundamental aspects of life science research including the biological, structural, functional, phylogenetic, and evolutionary relationship between the given biological sequences genetic variations in the human genome occurring mainly due to mutations and genetic recombination, next-generation sequencing (NGS) for addressing biological questions at a genome-scale and basic machine learning aspects with usage simplicity. The primary advantages of client-server architecture include the easier maintenance of the laboratory environment, scalability, and accessibility of multiple clients from different locations at a time. The key challenges reported were the need for skilled expertise for building the cyberinfrastructure platform and minor security issues with experiment execution. The interface also provided content-rich laboratory material for integrating both theoretical and practical knowledge. The design and implementation features indicated the relevance and need for a bioinformatics virtual laboratory for providing sustainable laboratory skill education in the absence of classroom environments or teachers. The flexibility by re-doing the experiment (repeated access) without any time constraints or financial assistance strengthen the opportunities for individualized learning by providing adequate laboratory requirements for students. Studies indicated that the technology adoption and innovation diffusion of computer-aided instructional material focused on a multitude of aspects including peer to peer social interaction and decision-making process at the learner level. One of the limitations of this study is the lack of targeted pedagogy-based implications to statistically measure the quality of the platform for promoting sustainable education Previous pedagogy analysis using Technology Acceptance Model and Open Education Resources (OER) survey indicated the adaptability, ease of use, and perceived usefulness with blended-learning approach of a similar virtual laboratory platform in bioengineering disciplines.

IV. Conclusion And Future Works

This work outlines the need for multiple technological design and implementation strategies for novel virtual laboratories to match different learner groups across the world. We foresee the transversal competencies in classroom education, bringing virtual laboratories as in-person learning material. In the next step, the presented lab will be integrated into the curriculum of Indian universities offering bioinformatics courses to study user acceptance behavior on the technology acceptance model.

V. Acknowledgment

This work derives ideas and inspiration from the Chancellor of Amrita Vishwa Vidyapeetham, Sri Mata Amritanandamayi Devi. The work was funded by the Virtual Laboratory Phase III NMEICT Project, the Ministry of Education, Government of India.

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Literature survey on usage of IOT, AI/ML in Educational Environment with A Case study on Recommender for suitable learning strategy

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Abstract

The integration of Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (ML) technologies into educational environments has revolutionized the way we approach learning and teaching. The adoption of IoT in education has transformed traditional classrooms into smart learning spaces. IoT-enabled devices, such as smartboards, wearable sensors, and connected learning management systems, gather valuable data on student interactions, engagement, and performance. AI and ML algorithms process this data to create personalized learning experiences, adaptive assessments, and real-time feedback. the practical implementation of AI/ML technologies in the development of a recommender system for suitable learning strategies. The recommender system leverages student data, such as learning preferences, past performance, and emotional states, to suggest tailored learning approaches. It takes into account the dynamic nature of student emotions and adapts strategies accordingly. the potential of AI/ML-based recommender systems to significantly improve learning outcomes. By personalizing learning strategies, students can maximize their engagement, motivation, and overall academic performance. Additionally, the ethical and privacy considerations surrounding the collection and use of student data in educational AI systems are explored, highlighting the need for responsible and transparent practices. This literature survey serves as a valuable resource for educators, researchers, and policymakers interested in harnessing the power of IoT, AI, and ML to create more effective and personalized learning environments. It underscores the transformative impact of these technologies on education and emphasizes the importance of responsible and student-centered implementation.

***Keywords*—Internet of Things, Artificial Intelligence (AI),PLEs, Predictions ITS, cutting-edge technology and ChatGPT.**

I. Introduction

The rapid advancement of technology has revolutionized various industries, and the educational sector is no exception. With the advent of the Internet of Things (IoT), a network of interconnected devices that can communicate and share data, new opportunities have emerged to transform the way we learn and teach. IoT has the potential to revolutionize the educational sector by providing innovative solutions that enhance student engagement, optimize learning environments, and improve overall educational outcomes.

Teaching and learning processes encompass both emotional and behavioral aspects, which play significant roles in academic performance from both cognitive and motivational standpoints (Artino et al., 2012; Loderer et al., 2019; Pekrun et al., 2017). Notably, research has demonstrated that these emotional and affective factors have a substantial impact on various aspects of the learning journey, including memory, attention, problem-solving, self-regulation, study techniques, and overall academic achievements (Barrett et al., 2019; Chevrier et al., 2019; Graesser, 2020) [2].

Smart Classrooms: IoT devices are being integrated into classrooms to create smart learning environments [2]. These devices include smart boards, interactive projectors, and sensors that monitor classroom conditions such as temperature, lighting, and air quality. Smart classrooms enhance collaboration, engagement, and personalized learning experiences. [1]

Wearable Technology: IoT-enabled wearable devices like smartwatches and fitness trackers are being utilized in educational settings [3]. These devices can track students' physical activity, monitor health parameters, and provide real-time feedback. Wearable technology can be integrated into physical education classes, health education, and research studies.

Activity-based learning is firmly rooted in constructivism**,** whereas the skills-based approach to learning has its origins in behaviorism. Behaviorism, which can be credited largely to Ivan Pavlov, the Russian physiologist (1849–1936), predates the constructivist school of thought.

This integration of IoT with AI/ML enables intelligent decision-making, predictive analytics, and automation in various domains, including smart cities, industrial automation, healthcare, and more. The combination of IoT's data generation capabilities with AI/ML's data analysis and prediction capabilities empowers organizations to derive valuable insights from the vast amounts of IoT data collected, leading to improved operational efficiency, optimized resource utilization, and enhanced user experiences.

II. Literature Survey

A. Text-Based Emotion Detection Model

The initial step in this approach involves acquiring data from various text sources, such as social media and product/customer reviews. These sources often contain unstructured text with slang words, emojis, short text, incomplete words, and other noise that requires preprocessing.

Common classification techniques employed in emotion recognition include machine learning and deep learning. Machine Learning: This approach uses algorithms like Support Vector Machine (SVM), K-Nearest Neighbor (K-NN), Naïve Bayes, and others to classify text into emotion classes. These algorithms rely on the engineered features for classification. Deep Learning: Deep learning methods, such as neural networks, do not require handcrafted features. Instead, they learn patterns directly from the data. However, deep learning models typically require a relatively large dataset for effective training. If the available data is limited, data augmentation techniques can be used to artificially expand the dataset. [1]

B. Different ways for detecting Emotions

1. **Keyword-based approach:** This approach appears to be based on a keyword-based method for emotion recognition and has been influenced by previous studies (Tao J. 2004, Ma C et al. 2005, Perikos et al. 2013, Shivhare et al. 2015) that also used similar keyword-based approaches. Essentially, it involves identifying specific words associated with emotions in the text and making inferences about the emotional content based on the presence and intensity of these keywords while considering negation cues. []
2. **Rule-based Approach:** This approach make use of linguistic rule to recognize emotions from text.
3. **Machine learning-based Approach:** This approach allow system to learn and improve on their own as a result of their experience.
4. **Deep learning-based Approach:** This approach uses neural network layers to learn unsupervised from unlabeled data.

III. PROPOSED METHODOLOGY

In traditional way of learning teachers use blackboard in the classrooms. As years pass they started to use PowerPoints, later as many tools came into picture to make class interactive and effect way to understand the course. Active learning concept came into picture based on the student's activeness in each course. There are many active based learning methods as follows: Think-pair-share, Problem-based learning, Role-playing, Educational game, Collaborative learning, Hang-man game, cross-words game, Peer instruction, Case study learning and so on. For each topic different learning strategies can be used by the teacher. While employing different strategies, the emotions of learners can be captured and analysed to determine the most appropriate strategy. When the emotions are happy, then the suitable strategy could be recommended for teaching the topic in future. When the emotions are sad or neutral, the strategy is not recommended for future lessons on the same topic. The proposed methodology is illustrated in figure 1.

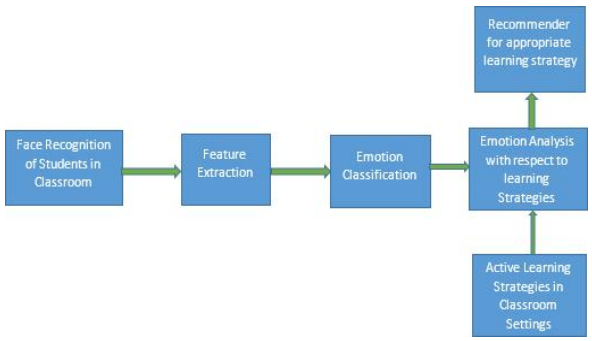

Figure 1: Recommender for suitable learning strategy.

The emotions of all the learners in the study is considered and a group emotion status is given to the ongoing class. Recommendation is given only on basis of group emotion status.

IV. CONCLUSION

In Conclusion, this study highlights how the Internet of Things (IoT) has enormous potential to alter the educational landscape by delivering individualized and interesting learning experiences. Survey talks about different ways to recognize the emotion. Face recognition and text-based recognition. We also focused on the different active based learning concepts and approaches. The proposed methodology states combination of both collection of emotional state of a student from the class and give real time state of selected approach active learning strategy based on that our method suggested which is the based active learning suitable for the particular subject. Based on the emotions we recommend the suitable strategy for the particular topic in the future.

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Appraisal of MOODLE LMS Based Education Platform in Karnataka State

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***Abstract* — similar to classical based education system, MOODLE LMS based education system are needed in an e-learning environments for research domain in a university. This paper will summarize how Visvesvaraya Technological University has taken pioneering steps in adopting MOODLE LMS based education for Ph.D coursework by taking into consideration of UGC norms.**

Keywords— Learning Management System, LMS, MOODLE, Research and Publication Ethics.

I. Introduction

e-Learning is sometimes described as pedagogy empowered by digital technology. Education by means of online services has emerged over the last several years worldwide as a crucial educational ingredient to supplement contact teaching in the classroom..

Visvesvaraya Technological University (VTU) has taken pioneering steps in e-Learning early on with the EduSat, e-Vidya, e-Shikshana and other web initiatives. In order to maintain VTU's leading position amongst technological universities in India, it is necessary to spread the initiative further to the research scholars by deploying state-of-the-art technologies. Therefore the study aims to assess whether the LMS can also be a platform to deliver the lectures of Ph.D. Coursework of new curriculum based on Research and Publication Ethics (RPE) – 20RPE000. The RPE e-Content Delivery and Assessment Mechanism was conducted through MOODLE LMS Platform. The organization of this paper is structured as. Section 2 describes MOODLE LMS Based Education, Section 3 provides methodological arrangement and preparation of MOODLE as a teaching learning platform. Further, analysis and discussion are briefed in section 4. Finally, concluding remarks followed by future research directions will ends the study.

II. MOODLE LMS Based Education

MOODLE is an open-source LMS platform which allows to build and upload e-learning content, deliver it to the learners, assess them on the content, track their progress and recognise their achievements. MOODLE LMS is popular due to its simplicity and content delivering mechanisms to users.

Fig.1.1: MOODLE LMS

III. MOODLE LMS Based Live Transmission

The UGC in its 543rd meeting approved "Research and Publication Ethics (RPE)" has made compulsory for all Ph.D students for pre-registration coursework and the same was taken into consideration by the Visvesvaraya Technological University authorities in "VTU Regulations Governing the Degree of Doctor of Philosophy (Ph.D.) – 2020" and recommended for conducting Online Classes and e-Content development as per the guidelines using MOODLE LMS open source platform.

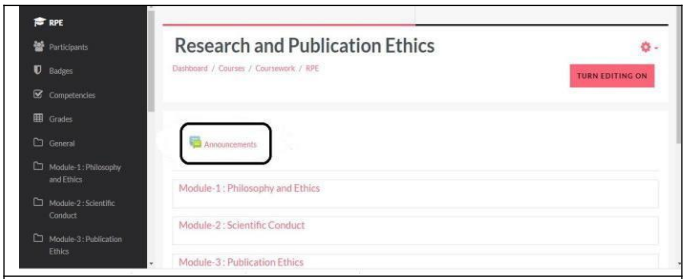

Fig.1.2: RPE Course page

The following plan of actions was framed.

- Circular corresponded to all the Research Scholars
- Module wise course experts were identified
- Administrative approval was taken
- User Guidelines hosted in VTU portals
- 75% attendance and IA for 40 marks is made mandatory as per the regulations
- 1156 Research Scholars enrolled to the RPE Coursework

The RPE online classes are scheduled from 06:30 PM to 08:30 PM from 31.10.2022 to 21.11.2022. The module wise internal assignments and interactive session were conducted. The consolidated IA marks and total attendance were submitted to VTU Ph.D Section within the due time for further process. 970 research scholars have registered and attended 20RPE000 – Research and Publication Ethics Ph.D coursework university examination.

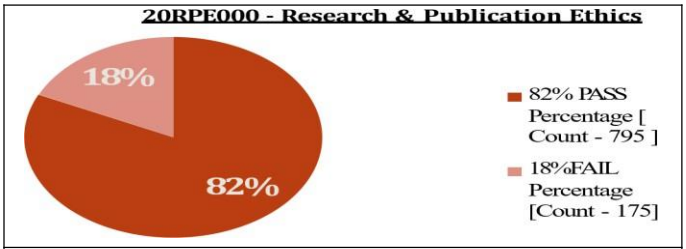

Fig.1.3: Result Data

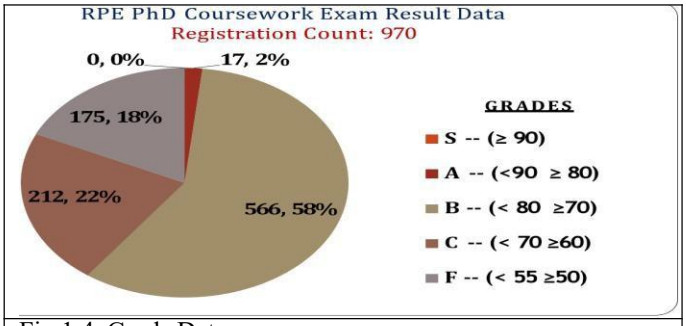

Fig.1.4: Grade Data

The feedback about the RPE Online Classes has been obtained (N = 665). The research tools used for collecting feedback are meeting with research scholars through conducting informal unstructured interviews, observations and MOODLE LMS feedback plugin.

The scope of questionnaire is limited to the study of teaching process of teaching end course experts towards verbal communication, teaching methodology, pace of teaching, effectiveness of power point presentation slides and in the MOOLDE LMS application. The feedback was measured in a 5-point scale (1 = Poor, 2 = Average, 3 = Good, 4 = Very Good, 5=Excellent). Table 1.1 illustrates the results and the scope of seeking opinion is limited to overall effectiveness of MOODLE LMS and seeking suggestions for improvements in conducting online classes and hosting of e-contents.

Sl. No	Question	Poor	Average	Good	Very Good	Excellent
1	The course helped to improve my Academic/ Research Knowledge:	0	24	160	258	222
		0%	4%	24%	39%	33%
2	The uploaded resources were helpful for my learning process:	1	26	196	250	192
		0	4%	29%	38%	29%
3	The assignments helped in my learning process:	4	16	172	249	224
		0.6%	2.4%	26%	37%	34%
4	The Co-ordination from e-Learning team in resolving the issues:	5	25	134	213	288
		0.7%	3.3%	20%	32%	44%
5	The course contents were relevant to my research and adequately covered its stated objectives:	2	32	226	245	160
		0.3%	4.7%	34%	37%	24%
6	How do you rate the overall Teaching/ Learning process?	0	15	158	253	239
		0	2%	24%	38%	36%

Sl. No	Question	Yes	No
7	Whether e-Learning team were supportive?	658	7
		99%	1%
8	Whether VTU-LMS Portal was easy to use and navigate through the course?	597	68
		90%	10%
9	Whether Ask a Question? in VTU-LMS were useful?	593	72
		89%	11%
10	Whether the interaction sessions were useful?	645	20
		97%	3%

Table 1.1 Total count and Percentage of the survey results. The sample size in 665

By referring the table, one can ascertain that most of the basic features of MOODLE LMS could satisfy the teaching learning process towards scheduling & transmission of live sessions, course announcements, notifications, uploading of e-contents, online questionnaire, module wise assignments, module wise interactive sessions, ask a question? Tool bar, online quiz, support from the host end, etc. As a result, these are identified with very good and excellent ratings

IV. INTERPRETATIONS OF MOODLE LMS

By referring the feedback and survey report, majority of the research scholars are from Bangalore & Mysore regions and are registered in part time mode. Since, the live classes are scheduled from evening 06:30 PM to 08:30 PM and the same leads to the research scholars to login in the middle of the live session, resulting to attend for the sake of attendance. The following suggestions and recommendations has been obtained by research scholars towards MOODLE LMS based education platform.

- To conduct the live classes during the weekends instead of conducting in weekdays during in late evening hours, since majority of the research scholars are working professionals and to provide module wise question bank. Since the UGC has framed the syllabus of the RPE, there is lack in the availability of the text book in the market.
- Since, VTU is a state university and the research scholars are spread across the state. It is suggested to identify a NODAL CENTRE for conducting online classes.
- Arrangement of the classes for PhD Course Work of other coursework papers by considering failure rates and to identify unavailability of course experts and resources.

The recommendations will be taken into consideration for forth coming sessions. Since, the same will require time and modification of the current LMS platform

I. CONCLUSION

In this study, we have discussed how best the Moodle LMS can be used for handling live sessions and for e-content delivery mechanism for Ph.D Coursework. In conclusion, the MOODLE LMS platform has positive outcomes in every aspect of the teaching, learning and assessment perspective. Regarding adaptation of virtual labs for module3 - Databases and Research Metrics, software tool, a specific recommendation for integration of virtual programming software is proposed for further study.

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Implementing Course Level Project-Based Learning (CLPBL) in the Fundamentals of Web Development Course

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I. Introduction

This report showcases the successful implementation of Course Level Project-Based Learning (CLPBL) in the Fundamentals of Web Development course for 210 second year engineering undergraduates, at KIT's College of Engineering, Kolhapur, India during the 2022-2023 academic year. This approach combined traditional teaching with hands-on projects, real-world applications, and NoCode web development tools. Using continuous evaluation, student engagement tools, and collaboration with an external mentor, the course enhanced practical skills and provided valuable real-world experience. This paper outlines the key components of the course, its benefits, and offers recommendations for educators for future implementations.

II. Description of the Best Practice

The course's success lay in its multifaceted approach:

1. Traditional Teaching: The course began with traditional classroom teaching to cover essential web development concepts.
2. Interactive Discussions: Real-world web applications were discussed to provide practical insights and connect theory to industry use cases.
3. Practical Lab Sessions: Hands-on lab sessions offered live demos for students to apply their knowledge and develop web applications, enhancing their practical skills.
4. CLPBL: Total 210 students from three divisions, worked in 54 groups with each group consisting of 3 to 5 students, to create functional websites, applying their theoretical knowledge in real-world scenarios. The group size was 3-5 students per group.
5. NoCode Tools: Students were introduced to NoCode web development tools like WordPress to broaden their skill set.
6. Collaboration with External Expert Mentor: Dr. Yogendra Pal played a vital role as an external expert mentor, providing guidance and support throughout the web development projects.
7. Continuous Evaluation and Monitoring: Standardized rubrics and Padlet for progress monitoring ensured fairness, consistency, and development of project management skills.
8. WhatsApp Community Feature: WhatsApp groups facilitated enhanced student engagement, communication, query resolution, and collaborative learning.
9. Prizes and Recognition: Outstanding websites received incentives in terms of prizes and recognition, fostering dedication and achievements among students.

III. Discussion of the Benefits

The advantages of CLPBL are evident in enhanced student learning and engagement. Firstly, students gained practical skills through the construction of websites and utilization of web development tools. Secondly, CLPBL provided students with valuable real-world experience, deepening their comprehension of web development. Thirdly, collaboration with an external expert mentor enriched their insights and provided essential guidance. The incorporation of standardized rubrics and progress monitoring as part of continuous evaluation strengthened project management skills and improved student performance. Fourthly, the use of WhatsApp groups facilitated effective communication and collaborative learning. Lastly, prizes and recognition served as motivating factors, encouraging students to excel in their projects.

IV. Recommendations

Educators looking to implement similar practices should consider the following:

1. Adapt to Diverse Contexts: Tailor the approach to the specific needs and contexts of the students. 2. Collaborate with Experts: External mentors can greatly enhance the learning experience. 3. Continuous Evaluation: Regular assessment ensures students' progress and skill development. 4. Technology Integration: Utilize digital or ICT tools like WhatsApp and Padlet for better communication and engagement.

V. Conclusion

The Fundamentals of Web Development course successfully implemented Course Level Project-Based Learning, resulting in enhanced student learning. The collaboration with an external expert mentor, continuous evaluation, and recognition of student accomplishments contributed significantly to the program's success. The adoption of Project-Based Learning empowered students with practical skills, real-world experience, creativity, teamwork, and problem-solving abilities, as reflected in their positive feedback. Continuous improvement will ensure an even better learning experience in the future. Educators are encouraged to explore and implement this best practice in their classrooms for improved student outcomes.

Implementing Course Level Project-Based Learning (CLPBL) in the Data Analytics Coursec

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I. Introduction

The best practice discussed in this paper revolves around the successful implementation of a Course Level Project-Based Learning (CLPBL) approach in the "Data Analytics" course during the 2022–2023 academic year at KIT's College of Engineering, Kolhapur, India. This innovative teaching method aimed to provide a comprehensive and hands-on learning experience for 181 third-year Computer Science and Engineering students.

II. Description of the Best Practice

The course integrated traditional classroom sessions for theoretical foundations, interactive discussions for real-world problem-solving, and practical labs with hands-on experience using popular data analytics tools such as Excel, TableAU, PowerBI, Python, Jupyter, and Anaconda. Notably, Course Level Project-Based Learning (CLPBL) was introduced, allowing students to collaboratively execute data analytics projects under teacher guidance.

III. Project-Based Learning

Student Data Generation Activity: As an integral component of the course, we conducted an In Semester Evaluation (ISE) component focused on data generation. During this activity, 181 students actively participated in generating "daily routine" data for a two-month period using daily surveys. The dataset created consisted of approximately 4800 instances and 60 different attributes. This real-world data served as the fundamental building block for their subsequent data analytics projects, providing an authentic and practical learning experience. By working with actual data they generated, students gained valuable insights into data collection, data preparation, and the complexities of working with real datasets, preparing them for the challenges of real-world data analytics scenarios.

Student Groups and Hypothesis Generation: A total of 181 students, with 51 groups from 3 divisions participated in the project. Each group was tasked with performing data analytics on the generated data and solving a minimum of 20 hypotheses. This undertaking not only exposed them to a diverse range of analytical challenges but also provided ample opportunities to apply various data analysis techniques and statistical methods to draw meaningful insights from the data. Working in groups encouraged teamwork, collaboration, and peer learning.

IV. Discussion of the Benefits

The benefits of this best practice are evident in the holistic development of students' skills. The hands-on approach through CLPBL enriched their understanding and prepared them for real-world data analytics challenges. Continuous evaluation using standardized rubrics ensured fair assessment, and a multidimensional evaluation approach provided insights into each student's proficiency in data analytics. Incentives like prizes and recognition during the Institute Project-Based Learning (PBL) Day celebrated exceptional efforts, fostering a competitive yet collaborative learning environment.

V. Challenges

Time Management: Balancing traditional teaching methods with CLPBL can be time-intensive. Student Engagement: Ensuring active participation of all students in data generation and collaborative projects. Long-Term Impact Assessment: Assessing the enduring impact of CLPBL on students' careers beyond the course completion may be challenging, requiring resource-intensive and time-consuming longitudinal studies.

VI. Recommendations

For educators interested in implementing this best practice, it is recommended to carefully plan and integrate CLPBL, ensuring alignment with course objectives. Adaptations can be made based on the available resources and specific needs of the students, Here we focussed on data generation as one of the major components. Future research opportunities lie in exploring the long-term impact of CLPBL on students' careers.

VII. Conclusion

In conclusion, the implementation of Course Level Project-Based Learning in the Data Analytics course at KIT's College of Engineering has proven to be a success. The combination of traditional teaching methods and hands-on learning experiences has enriched students' understanding and prepared them for the challenges of the field. The commitment to fostering enriching learning experiences through innovative teaching methods remains steadfast, setting a strong foundation for students' future careers in data analytics and beyond.

Culturally responsive pedagogy for an equitable computer science education

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I. INTRODUCTION

Computer Science in the context of K-12 education is often stereotyped as a subject that involves complex logic or hard to attain analytical skills. These misconceptions often hinder the confidence levels of novice learners and increase the entry barriers especially for the under-served and marginalised children. Standard computer science textbooks and online courses reaffirm this disposition, teaching students the detailed workings of a computer or the syntax of a programming language with no attention to students' cognitive load, their context or prior knowledge. In this paper, we share some of the best practices and strategies used in our culturally responsive video-based online course for Jammu & Kashmir, India, supporting over 6000 students, across grade levels VI to XII, especially young girls to learn and practice computer science as they relate it to their local context. Some of these practices and examples and how they were used to support teaching and learning are described below, Including students' tribe and role models in the curriculum: When students see themselves in what they learn, they are most likely to find learning more meaningful. We showed students role models like Kalpana Chawla,, Ayesha Aziz, the youngest female pilot, and Mawya Sudan, the first female fighter pilot from Kashmir. We also introduced a fictional, humanoid co-instructor for our 2course, A.I.S.H.A (Artificial Intelligence She/Her Humanoid Android) as shown in Figure 1.

Using semantic waves in a culturally-responsive way: Descending and ascending a semantic wave is especially challenging for computer science concepts with high semantic complexity, like algorithms or abstraction.

Figure 1. Co-instructor AISHA (Artificial Intelligence She/Her Humanoid Android), illustrated by Nitya Tiwari

To make this process seamless, we used culturally relevant examples (from Kashmir) during both the unpacking and repacking phase of the wave as shown in Figure 2.

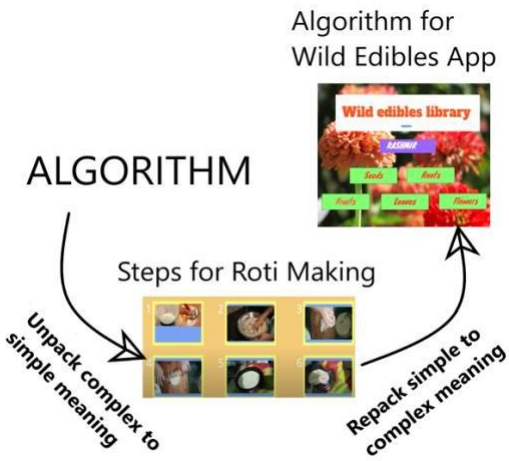

Figure 2. Semantic waves used to teach the concept of 'Algorithms' in a culturally responsive way

II. STORY-TELLING

Story-telling is an ancient, alluring and culturally universal form of teaching that has the power to reclaim the joy of learning computer science by making content personally relevant. The video lesson 'Let's cook a computer story', personifies computer parts as real-life characters as shown in Figure 3.

Figure 3. Meet GPU, Cache and Drive (from left to right) at their friend Sensor's birthday party (Illustrated by Nitya Tiwari, Edited by Vishesh Banerjee)

Dual approach to problem solving and using locally relevant examples: We opted a dual-approach to problem solving, using both design and computational thinking techniques, used elements from observable surface culture to help novice students build on familiarity and learn challenging and critical concepts like machine

learning and bias. The key is to first empathise and question if the problem is meaningful and choose the best solution before using a computer to solve it.

Figure 4. Left: Emotions as 'Variables', Right: Block-based code for emotions as variables

Infusing SEL elements to teach Computational Thinking: Research has found that CS majors are less likely to see their roles in solving global problems, or improving other people's lives. We teach students how to navigate their emotions as they code for emotions as 'variables' as shown in Figure 4. Such activities guide students to be a good human besides being a good coder.

III. Conclusion

Our analysis shows that after intervention, 83% of girl students were open to pursuing a career in STEM, compared to 32% at the beginning and 87% of students were able to articulate the link between Computer Science and phenomenon in everyday life, with more than 94% of students being novices to programming. We are contextualising the course across geographies and will analyse outcomes across various learning objectives to provide evidence base for implementation across contexts.

Power Play

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I. INTRODUCTION

Board games can enhance learning by simplifying complex concepts, engaging learners, and providing a safe environment for experimentation. In the context of K-12 History, learners need to not only learn facts but also learn to engage in perspective taking. Board games provide affordances to engage in differing perspectives and experimentation. In this paper the design and implementation of an education board game 'Conquest of Terranoria' is described. 'Conquest of Terranoria' is designed to foster understanding of historical atrocities through the lens of power. The primary objective of the board game is to cultivate a nuanced perspective on the use of power to perpetrate atrocities. The game mechanics stimulate scenarios where the students explore the intricate relationship between power and atrocities.

II. DESCRIPTION

'Conquest of Terranoria' is a multiplayer board game that provides scenarios to immerse students in the complexities of power dynamics and atrocities within communities. To begin with, the teacher facilitates the grouping of students into four communities. Students form four distinct communities, the Agrarian Alliance, Techno Titans, Desert Dwellers, and Nature Nurturers, each with unique attributes based on their background and resources for attacks, such as infantry, cavalry and artillery. For example, Techno Titans possess artillery given their background of being Industrialists. Students select a leader among each community. The selected leader represents the group's strategic decisions to expand the regions. The game utilizes a map of the mythical land of Terranoria, cards representing resources and their flags, as well as a set of rules given to each group that govern strategic actions and territorial conquests.

With each round lasting 10 minutes, communities, after a discussion, choose to either Attack, Sneak Attack, or opt for a Free Pass, aiming to secure their community's vision while navigating the consequences of their actions. An Attack will help the community capture more regions whereas a Sneak Attack are predefined tactics used to help in gaining resources or destroying resources of other communities, and a Free Pass will pass on the chance to another community without making any changes to their own.

During discussions, communities choose regions to attack using specific resources, leading to the acquisition or loss of lands. In the face of territorial defeat, the community leader must decide to remove one team member. With the power to make final decisions, the leader's role is pivotal. Several rounds of the game can be played depending on the class time, with the teacher marking conquered regions with community flags. The game's design intentionally grants certain community unfair advantages, such as the Agrarian Alliance's priority in attacking due to their larger number of regions. This prompts students to contemplate their responses to such imbalances.

The game culminates in a reflection session initiated by the teacher, where students delve into their actions, emotions, and underlying motivations. By examining their choices during the game, including attacks, resource acquisition, and destruction, students gain insight into the complex relationship between power and decision-making that may harm other communities. This reflective exercise encourages students to make connections between their actions and the motivations behind potentially harmful decisions, fostering a deeper understanding of the implications of wielding power and committing atrocities.

III. BENEFITS

Implemented in grades 5 and 6, the 'Conquest of Terranoria' game revealed that all students consistently opted for attacks or sneak attacks. One group in grade 5 shared that they were focused on winning by capturing regions whereas another group wanted to take revenge and attack Techno Titans as they had more resources. This game effectively unveiled the underlying motivations behind acts of atrocity, enabling students to confront the repercussions of misusing power and promoting critical introspection. It encouraged active participation, fostering critical thinking skills among students. Students struggled to plan ahead, fixating on immediate actions rather than formulating long-term strategies. Further design can also focus on the importance of long-term strategies.

As a educational tool, 'Conquest of Terranoria' not only stimulates student engagement but also enhances critical thinking within the classroom. Its multifaceted affordances, spanning from heightened student motivation to engaging in critical thinking abilities, underscore its usefulness for history pedagogical practices.

IV. RECOMMENDATION

For educators considering the integration of the 'Conquest of Terranoria' game, it is essential to provide comprehensive guidelines and clear instructions to facilitate a smooth implementation process. Fostering an inclusive and supportive classroom environment is crucial for ensuring active student participation and effective collaboration. Flexibility in adapting the game to accommodate diverse learning contexts and student preferences is instrumental in ensuring its successful integration across various educational settings. Future research endeavours should focus on exploring the impact of the game in understanding different atrocities like Holocaust.

V. CONCLUSION

In conclusion, this paper describes the design and implementation of the 'Conquest of Terranoria' game in fostering critical thinking and introspective learning among students, prompting a deeper understanding of power dynamics, motivations behind committing atrocities and its implications. Educators are encouraged to explore the incorporation of gamified learning strategies such as this game to unlock a world of immersive and experiential learning opportunities for their students to understand different perspectives.

Think like a Scientist at Shikha Academy

Afreen Shaikh, Noopura Patankar, Nikita Matthew, Shweta Sharma
Under the guidance of Snehal Joshi
Shikha Academy, Mumbai

Objective: To provide a problem-solving experience that encourages students to think like a scientist by using the learning platform 'Amplify' at Shikha Academy, Mumbai.

I. INTRODUCTION

At Shikha Academy, our primary goal is to empower children with 21st-century skills, fostering confident problem solvers and system thinkers. Inquiry model for science

leads students to design experiments, evaluate through a data driven approach and derive a conclusion. To support in this process 'Amplify' learning platform was picked as it follows the process of scientific inquiry through every unit. This paper underscores the successful application of the Amplify Curriculum at Shikha in cultivating essential scientific skills.

II. BEST PRACTICE

At Shikha, we enhance science education by providing students with hands-on, real-life connections to their classroom learning. For instance, we integrated the topic of plant growth into a gardening project, allowing students to design experiments for cultivating vegetables like brinjal, lemon, and curry leaves. They explored variables, controlled conditions, and recorded their findings. The project resulted in a harvest of vegetables, which students used in various recipes and shared their learnings on a public platform.1

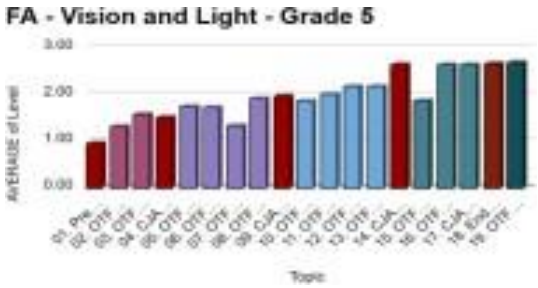
The same content of plant growth had a similar but more differential and resourceful approach in Amplify's 'Need for Plant and Animals' unit. Amplify's educational approach begins with pre-unit assessment, framed by central "big questions." In each unit, students adopt the role of experts, investigating real-world questions.

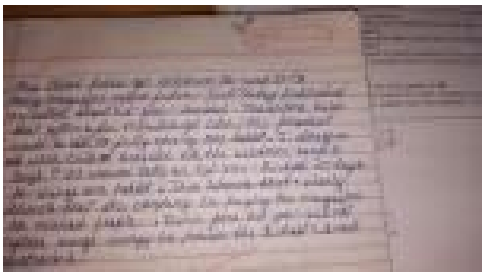
Active reading, technology integration like simulations and "flextensions" encourage scientific inquiry, while assessments are skill-based and provide real-time feedback. While Amplify provides a scientific inquiry framework and immense exposure, catering to current reality and bringing relevance was needed. Contextual support was planned for the units executed. Grade 2 while learning the 'Plant and Animal Relationship', children explored the school garden and plants. They connected how different living things like snail, worms and plants can live in the same places with help of each other. Similarly, Middle School students were exposed to blood reports when they were learning the unit of 'Metabolism' where they were learning about blood doping.

Amplify also does not include any labs which would otherwise be an essential part of the curriculum. Grade 1 while studying 'Need for Plants and Animals' the students conducted lab experiments on how sunlight and water affects the growth of plants. Similarly in Middle School, for the unit of 'Phase Change' in Amplify, students conducted lab experiments on making a water cycle by boiling water and cotton. In 'Metabolism', students prepared slides of cheek cells and observed chemical reactions.

III. BENEFITS AND CHALLENGES

Students using Amplify have shown growth in various assessments, including scientific argument writing and the integration of scientific vocabulary into daily





communication, as seen in the 'Harnessing Energy' unit. Amplify's hands-on learning experiences offer value. Amplify provides a structure for scientific inquiry in a scaffolded manner. Rooted in the US Next Generation Science Standards (NGSS), Amplify can be challenging for ESL students. alignment of Cambridge IGCSE Science Schemes of Work with Amplify NGSS standards supported supplementary teaching.

IV. RECOMMENDATION

Educators considering Amplify Curriculum to promote scientific thinking should prioritize resource customization to meet students' needs. Addition of supplement contextual activities and labs provide a holistic learning. Mapping Amplify's NGSS to board standards is essential, and supplementary standards can complement Amplify's diverse objectives in teaching. Future research aims to evaluate scientific skills post full curriculum implementation across all grades

V. CONCLUSION

In conclusion, the use of Amplify Curriculum contextualized with relevant activities and labs at Shikha Academy has been instrumental in cultivating essential scientific skills, nurturing system thinkers. Future research should focus on evaluating the development of scientific skills across all grade. For those considering its adoption, customization, alignment with board standards, and supplementing Amplify's objectives are key strategies for success

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Workshops

Workshop 1
Bringing Emotions into Education: The Need for Social-Emotional Learning for Teachers

Presenters
Bhavya Joshi, Anya Chakraborty, & Nandini Chatterjee Singh
UNESCO MGIEP, India

About: While teaching has been recognized as a rewarding profession, recent studies have also indicated it to be highly stressful leading to low job satisfaction (Liu & Ramsey, 2008) and compromised physical health (De Simone et al., 2016). Given that stress can be contagious, a secondary consequence of teacher stress has also been its negative impact on student well-being (Oberle & Schonert-Reichl, 2016). Accumulating research shows that social and emotional learning (SEL) interventions are extremely successful in managing stress and improving teacher well-being (Jennings and Greenberg, 2009). SEL is the explicit cultivation of competencies in recognizing, managing, and regulating emotions, forming positive relationships, making responsible decisions, and managing challenging situations (Payton et al., 2000). This workshop aims to familiarize key stakeholders with SEL concepts and activities, emphasizing the importance of integrating SEL into the education system and teacher preparation.

Workshop 2
Improve your socio-emotional quotient while thinking computationally

Presenters
Elavarasi Manogaran
Pi Jam Foundation

About: Computer Science is often perceived as a field that does not find any relevance with social or emotional competencies such as self-awareness, being empathetic or building morals. Research has found that CS majors are less likely to see their roles in solving global problems, fostering justice, improving other people's lives or learning about different cultures or religions [1]. There is a pressing need than ever, for a value-based, inclusive and equitable CS education, besides a skilled workforce. The workshop addresses this rationale by modeling ways to incorporate socio-emotional learning into computing classrooms where participants learn interesting ways to teach programming and computational thinking concepts while also teaching SEL competencies like self and social awareness.

Workshop 3
A Game-Based Approach to Climate Education in the Hard-to-Abate Sectors

Presenters

Dr. Balaji Kalluri[1], Dr. Ramanathan Subramanian[2], and Divyaansh Chhipa[3]

[1]FLAME University, Pune Bangalore; [2]World Systems and Solutions; [3]Gokhale Institute of Politics and Economics, Pune

About: This workshop proposes a game-based approach to climate education, targeting one of the hard-to-abate Architecture, Engineering, and Construction (AEC) and Facilities Management (FM) industry sectors in India. The Building-in-a-Box (aka BiBo) is a serious desktop game that engages participants in strategic decision-making related to building design, construction, and facilities management processes. The workshop aims to educate the climate emergencies and develop plausible solutions to wicked problems impending on AEC industry leveraging active learning, collaboration, and critical-thinking that gameplay offers. BiBo is envisaged as a social innovation tool to foster innovation among participants and users. The target audiences are young professionals, educators, researchers, consultants, contractors, architects, and trade unions who would like to drive innovation and just transition in India.

Workshop 4
Introduction to Epistemic Network Analysis

Presenters

Amit Paikrao, Sonika Pal and Herold PC

Educational Technology, Indian Institute of Technology Bombay.

About: The hands-on workshop aims to introduce two technologies that assist teachers, researchers and institutes. The Online Test System provides teachers with end-to-end solution to streamline student assessment process as well as saving them time and efforts of preparing test questions. On the other hand, the Educational Resource Information Communication (ERIC) API enables the integration of any two or more separate systems and enhances their interoperability while keeping any of the systems working independently like they were. The workshop will benefit Teachers of any discipline in primary, secondary, and post-secondary schools; graduate students including researchers working in the area of Educational Technology.

Workshop 5
Contextual and Cultural Maker Spaces (CCMS)

Presenters
Rahul Aggarwal

About: In this space we are interested in how local ideas, culture, and practices are both inspiring and being inspired by maker education, and how we can build a more diverse and meaningful movement. In this process we facilitate through 'culturally responsive pedagogy' which legitimises family knowledge, community experiences and document children's contributions towards inclusion, problem-solving and innovation. The objective of the workshop is to: 1. build and expand their knowledge of what CCMS is and why it is important 2. recognise the relevance of such spaces in Indian context 3. analyse the role of 3Cs — context, culture and community 4. work with an object, share and reflect on their learnings In this work, the real impact in our communities is by advancing with the ideals of constructionist learning and culturally — aware pedagogies locally and globally, and in doing so, have been able to explore new materials, approaches, pedagogies, and advance our own work with students.

Workshop 6
LA-ReflecT: Multimodal Learning Analytics of Micro-learning

Presenters
Rwitajit Majumdar[1], Kinnari Gatare[2] & Jayakrishnan Warriem[3]

[1]Kumamoto University, Japan; [2]Independent Ux Researcher, Mumbai; [3]IIT Madras India

About: The interactive demo highlights LA-ReflecT, an LTI-enabled platform that facilitates the creation of micro-learning activities with multimedia content and helps track interactions and artefacts created by students within the platform as xAPI logs. The platform facilitates reflection on action in the form of presenting information on a dashboard as a part of the learning activity. LA-ReflecT also enables an app connecting with Bluetooth sensors that stream time series signals. The sensor data from a user is synchronized with their particular activity and can be linked to their learning log. We are doing multiple pilots with research partners in Japan and India. We are open to discussing adaptors who want to potentially pilot LA-ReflecT for creating microlearning material and investigating the potential of the data logged in the platform.

Workshop 7
Perceptions of Ethics in AI Education

Presenters

Ashutosh Raina[1], Shitanshu Mishra[2] & Prajish Prasad[3]

[1]Member, Ed Tech Society, India; [2]UNESCO MGIEP, India; [3]Flame University, India

About: This paper underscores the pressing need for ethics education in the field of Artificial Intelligence (AI) within the Indian context. While AI's rapid growth transforms industries and demands a skilled workforce, the ethical and societal dimensions of AI often receive inadequate attention. This paper introduces a workshop aimed at enhancing awareness and understanding of AI ethics among Indian educators. The workshop employs critical thinking exercises and real-world ethical dilemmas to bridge existing gaps in AI ethics education, promoting responsible AI development. Through this initiative, we aim to contribute to the creation of standardized AI ethics education frameworks, aligning with international standards and industry expectations.

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Tools & Product Demos

eSim and Arduino on Cloud

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Abstract—eSim and Arduino on Cloud is an open-source web-based platform that enables users to build and simulate circuits. It has immense potential in supplementing hands- on practice along with traditional classroom education in the electronics domain. This software platform has the potential to reach out to those who do not have access to the real hardware. To add, this platform also has the capability to grade electronic circuits, a feature that has never been demonstrated nor attempted anywhere.

Index Terms—Circuits, ngspice, IoT, Arduino Uno, Auto- grading

I. Introduction

Millions of students in India pursue engineering and science every year and get trained in the field of electronics and microcontrollers. Even though electronic components are inexpensive, it is not feasible for every learner to own them. Every experiment needs different components and a learner might make an error and blow up the physical components.

eSim and Arduino on Cloud platform solves the above-mentioned limitations and offer a user-friendly experience. Being browser-based, the learners can build and simulate their own circuitry from any browser, obviating the need to own actual hardware or install anything. A basic low- end computer is quite sufficient for a learner.

eSim and Arduino on cloud platform is developed using similar technologies and is being addressed together in this paper. The cloud-based platform is hosted at [1].

II. Related work

Tinkercad [2], CircuitLab [3], etc. are proprietary (closed-source) products that provide a basic experience for simulating electronic circuits.

Conventionally to program Arduino, one uses a desktop- based Arduino IDE [4] to write and compile a sketch code and transfer it to the real Arduino board via a USB cable. However, this requires the need for actual hardware.

For eSim, tools such as open source eSim Desktop [5] and proprietary software like LTspice [6] are desktop based that require learners to install software on their machines. As stated, eSim and Arduino on Cloud platform is open- source and runs on any standard browser, allowing users to run and experiment electronic circuits without worrying about hardware or installation on any Operating System.

III. Platform Description

On eSim and Arduino on Cloud, the list of components is categorized in the left pane in an expandable manner based on component types, and the right pane is where the schematic is drawn by dragging and dropping the compo- nents. Using wires, the pins of the required components are connected to form a circuit. The properties of components and wires can be changed, i.e., resistance/voltage, etc.

In contrast to the physical hardware circuit assembly, the ERC (Electronic Rule Check) feature present in eSim and Arduino helps the learner detect whether all the components have been properly connected or not. This helps the learner in correcting the mistakes. Arduino platform facilitates auto-layout of wires, a key factor to produce non-messy wires while drawing complex circuits. It facilitates teachers to embed circuit assignments on any popular Learning Management Systems like Moodle, Blackboard, edX, etc., where the learners complete and submit the assignment. These assignments are then auto- graded based on the test cases, and the marks are reflected on the LMS. This auto-grading feature is neither at- tempted nor reported elsewhere in the electronics domain.

IV. Architecture

This platform, architected in a modular fashion, has a clear separation of concern, i.e., data layer for storing users, schematics, etc., middleware containing the busi- ness logic, API layer segregating the back-end from the front-end, and front-end for constructing, browsing, and rendering the circuits. A scalable queuing mechanism at the back-end ensures a seamless experience for handling a large number of simultaneous user requests. The auto- grading feature is developed using LTI [7] support.

V. Simulation Arduino

supports 4 types of simulations:

- Visual: This type includes circuits which involve visual effects like blinking of LED, displaying number on LCD, etc. For example, Fig. 1 displays a custom message on the LCD16x2 component based on the sketch file written by the learner.
- Sound: This involves circuits that produce some sound, i.e. beeping using the buzzer.

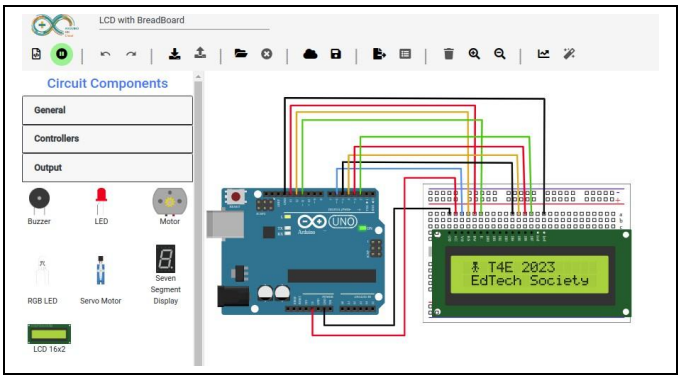

Fig. 1: LCD 16x2 Displaying Custom Message

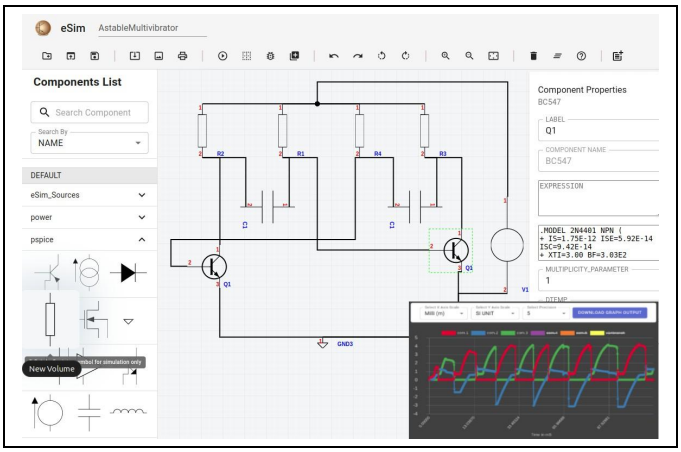

Fig. 2: Circuit: Astable Multivibrator and its waveforms

- Sensor-based: This type of circuit involves using sensors like light sensor, smoke sensor, etc.
- Movement: This type of circuit simulation involves movement of a component in real-time. A servo motor rotating is one such example.

eSim supports various simulation modes like DC solver, DC sweep, Transient analysis, AC analysis, etc. For example, Fig. 2 shows a circuit drawing with its waveforms for Astable Multivibrator using Transient Analysis.

VI. Auto-Grading

Below we describe the process by which an assignment can be auto-graded using any LMSs.

Initial Creation: The teachers create an assignment having either a blank or an incomplete circuit that will be displayed to the students on an LMS. The teacher then proceeds to create the actual/solution circuit which will be used later for auto-grading.

Test Cases for Grading: For eSim, the value at each node/component form test cases and the teacher can select which values are to be tested. For Arduino, the value emitted by Arduino at each pin is captured for X amount of time which then forms the test case.

Embedding and Submission: The teacher embeds the circuit on an LMS as shown in Fig. 3 and the students

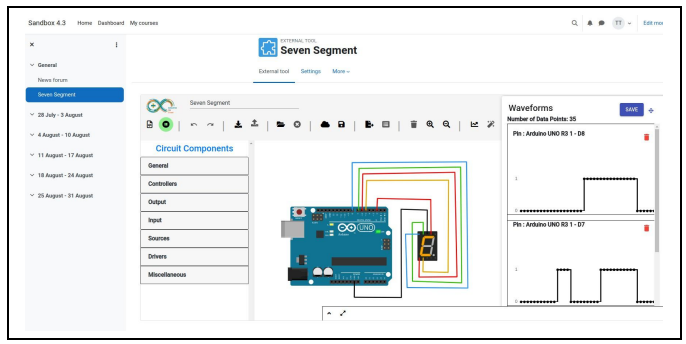

Fig. 3: Simulating circuit on Moodle LMS

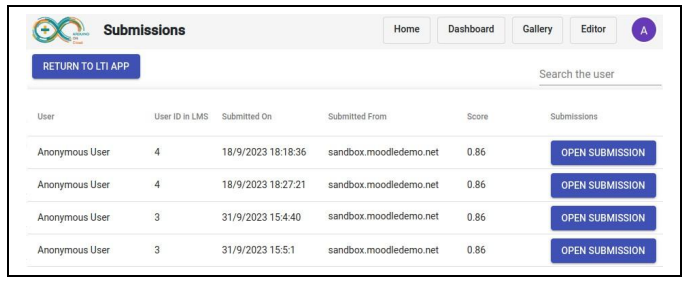

Fig. 4: Submissions received with partial marking

view, complete, and submit it. Based on the test cases, the submission is evaluated by the platform and the marks are awarded on the LMS. The teacher can then view the submission details of each student as shown in Fig. 4.

VII. Conclusions and future work

This paper showcases a web-based open-source plat- form for building and simulating electronic and Arduino circuits. The main features that make it unique is the auto-grading feature. In the future, for eSim, we plan to extend our work by introducing a sub-circuitry feature which is a very important direction towards VLSI design. For Arduino, we have plans to introduce IoT components and handle real-world communication. In the future, we also have plans to conduct large-scale training using this platform in the electronics curriculum and check its effectiveness in teaching and learning.

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Recommendation tools for improving learning environements

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I. INTRODUCTION:

The first model proposal uses facial recognition technology and machine learning to evaluate students' concentration levels in traditional and digital learning settings, aiming to improve the educational process by providing valuable insights to instructors and enhancing the learning experience. The second model focuses on creating a book recommendation system for university students based on the reading choices of past high-achieving students, using Collaborative Filtering to help current students select the most suitable books for their needs and preferences.

The purpose of the paper is to introduce and describe two novel models for improving the educational experience. The first model focuses on assessing students' concentration levels using facial recognition and machine learning, while the second model aims to assist university students in selecting appropriate books through a recommendation system.We hope that participants will learn about these innovative models and how they can enhance the educational process and the book selection process for students. The paper provides insights into the potential benefits of these models in terms of improving teaching and learning, as well as optimizing the use of university library resources.

The research introduces two models: one using facial recognition technology and machine learning to assess students' concentration levels and the other employing Collaborative Filtering for a book recommendation system. The theoretical support for these practices is grounded in the idea that technology can enhance the educational experience, whether by analyzing facial expressions or leveraging past high-achievers' book choices to aid current students. These models aim to make learning more personalized and successful.

I. DESCRIPTION OF THE TOOLS:

A. Students' Focus Levels Tracking system:

Key participants in the system are the Head of the Department (HOD), students, and professors. Their roles are as follows: HOD oversees attendance monitoring and receives students' focus information.Students provide facial data for attendance verification.Professors take attendance and generate reports for their classes. The data processing workflow consists of the following steps:

- Data Collection: Gathering performance, engagement, and student information.
- Data Preprocessing: Cleaning and formatting the data.
- Feature Extraction: Identifying relevant features.
- Data Integration: Combining learning modes for analysis.
- Data Analysis: Applying statistical analysis and data visualization.
- Concentration Level Model: Developing a model to predict focus levels.
- Model Evaluation: Assessing the model's performance.

The web server serves the "Home Template" for the home page and handles data submissions, saving images and details. It also processes face images and trains a recognition model and finally saving it. The "Attendance" page captures video streams, performs facial recognition, records attendance data, and sends SMS notifications to HODs for absent students and their emotions.This system streamlines attendance tracking, enhances data accuracy, and fosters a focused learning environment.

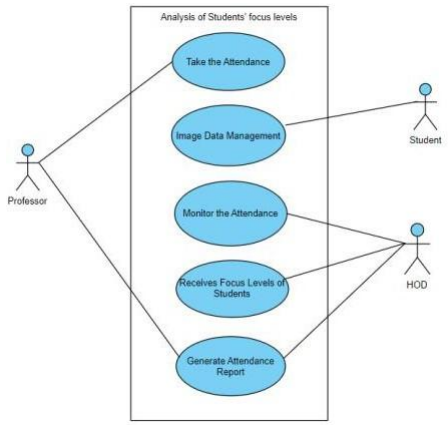

Figure 1. Students' Focus Levels Tracking system

B. Book Recommendation system

Input Data: Upon logging in, users enter their current semester and the desired subject for book recommendations.

- Data Optimization: The system employs collaborative filtering to reduce the dataset by excluding items with grades below S, A, and B.
- Similarity Calculation: The algorithm identifies courses and subjects similar to the user's input and presents books with grades S/A/B.

- Book Recommendation: The system then offers book recommendations based on the user's selected course and subject.

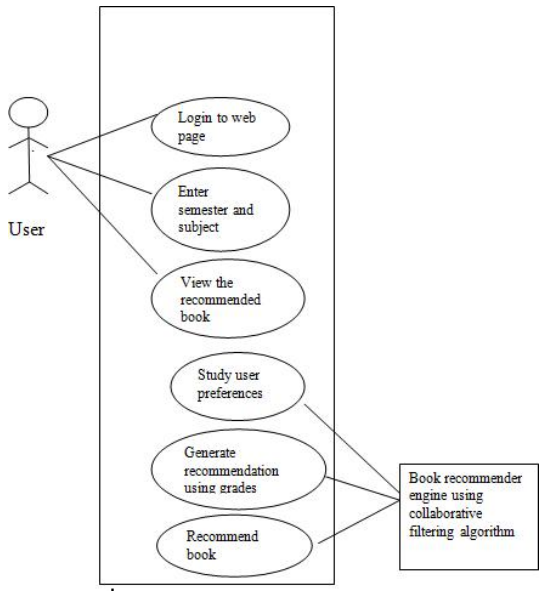

Figure 2: Book Recommendation system using collaborative filtering algorithm

The first tool supports teaching and learning by monitoring attendance, assessing student focus, and streamlining data processing. It provides predictive insights and improves data accuracy, encouraging student engagement and supporting educators in tailoring their teaching methods. This fosters a more focused and effective learning environment.The second tool supports teaching and learning by offering personalized book recommendations based on students' current semester and subject. This leads to more efficient resource selection, higher academic performance, time savings, and improved engagement. Instructors can also benefit from recommending the tool to their students, enhancing the alignment of course materials and teaching outcomes.

The tool for monitoring attendance and focus in EdTech can be integrated into various applications, including online learning platforms, learning management systems, virtual classroom software, and educational analytics platforms. It can also connect with parental engagement apps and be used in teacher training programs to enhance educators' classroom management skills. These applications vary but collectively support students and educators in EdTech.A personalized book recommendation tool in EdTech can enhance learning across various platforms, from online learning to e-book libraries. By suggesting relevant resources and aligning them with students' courses, it ensures efficient resource selection, improved academic performance, and increased engagement. Instructors can also benefit by recommending the tool, aligning course materials with teaching outcomes.

II. Discussion of the Benefits

The tools provide personalized, efficient, and data-driven support for students and educators, resulting in improved academic performance, enhanced engagement, and a more focused learning environment. The positive impact on student learning includes better results, increased motivation, and a more enjoyable and effective learning experience. To validate the benefits of the tools, evidence can be gathered through student feedback, attendance, and academic performance data. Analyzing comparative data and usage patterns, along with educator feedback, can provide insights into the tools' impact on learning. Long-term data collection helps assess sustained benefits. Challenges in implementing these tools include privacy and ethical concerns, data quality, technical infrastructure, user adoption, resistance to change, data security, integration, costs, algorithm optimization, and user support. These challenges can be addressed through measures such as privacy safeguards, data validation, collaboration with IT professionals, training, and cost management.

III. Recommendations

Educators considering these tools should prioritize privacy, provide training, and gather feedback. Collaboration with IT experts, alignment with the curriculum, and regular monitoring are essential. Ethical considerations, budget planning, and clear communication about benefits are also crucial. Collaboration with peers is valuable for sharing insights and best practices. Future research on the tools should explore their impact on academic performance and engagement. It should also focus on refining algorithms, addressing data privacy and ethical concerns, and customizing the tools for individual learning needs. Comparative studies across institutions, interdisciplinary applications, and user experience improvements are essential. Additionally, research should investigate the tools' influence on teaching strategies, mental health, inclusivity, cost-benefit analyses, and the development of legal and ethical frameworks. This research will advance the tools' effectiveness and ethical use in education.

IV. Conclusion

In summary, the key benefits of using these tools are enhanced engagement, personalized support, data-driven insights, improved academic performance, and efficient resource selection, all contributing to a more effective and engaging educational experience. Readers are encouraged to consider the implementation of these tools in their own classrooms. The potential benefits, including increased student engagement and the provision of valuable data-driven insights, should be taken into account. By these tools, a more effective and engaging learning environment can be created, benefiting both educators and students. The opportunity to evaluate and embrace these tools should be seized to further enrich teaching and enhance the educational experience in the classroom.

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CodeMitra, a mobile app to foster equitable, contextualized and accelerated learning of problem solving and 21st century thinking skills

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I. Introduction

76% of schools in India do not have computer labs, 92% of schools do not have a dedicated ICT teacher and only 24% of rural households have access to the internet. For most rural communities in India, creating with technology is only a distant dream as students struggle to get their basic literacy and numeracy right. Using CodeMitra, a free contextualized mobile app, we aim to not only break the digital divide to close the learning gap but foster equitable access to quality computer science education and essential 21st century thinking skills to the most under-privileged and marginalized students. Our contextualized and language-specific tool Codemitra aims to democratize technology education and makes learning equitable. Any student with a mobile phone can download the app and use it offline without an internet connection.

II. Tool Description

CodeMitra is a free, open source and contextualized mobile app that democratizes learning of 21st century life skills like problem solving, computational, mathematical and critical thinking for the underserved communities. It is a gamified app that uses visual programming blocks and puzzles and can be used both online and offline broadening the access and participation from novice learners and learners from under-resourced context. Learners drag and drop blocks of code to solve meaningful and relatable problems in their community and beyond. The app includes activities from various subject areas, math, english, science, arts, social science etc and teaches about the power of problem solving and how it is deeply integrated in different domains, including solving for SDG goals like climate action. It encourages underserved communities to take ownership of their learning and engage in active creation with technology rather than being mere consumers. Codemitra has been selected in top 15 scalable solutions in India by YuWaah-UNICEF and as one in a hundred most impactful and scalable innovations by HundrED global collection 2023. We have also partnered with Niti Ayog, Government of India across 14 states where Codemitra will be used extensively for content and learning dissemination.

III. How will users interact with it?

The app provides choices for learning tracks like:

- Programming with Blocks: A sequence of contextualized videos and guided problem-solving activities (with hints), based on the PRIMM (Predict-Run-Investigate-Modify-Make) model, for students to think, code and solve locally relevant and meaningful problems.

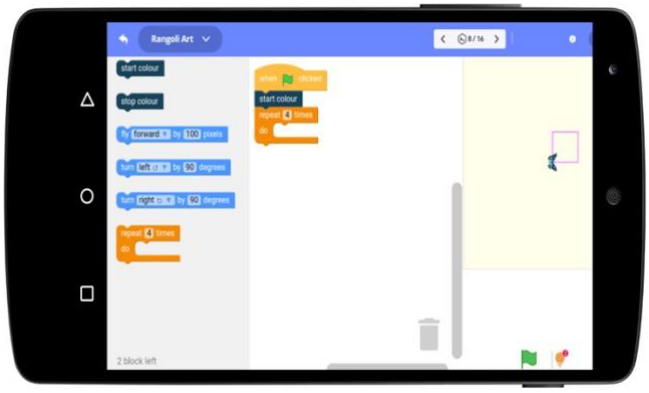

Figure 1: Rangoli Art lesson in Programming with Blocks

- Open lab: A personalized learning space where students create projects of self expression, stories, animations or solve any open-ended problem using block-based programming (and)
- Hour of Code: An hour of immersive, guided and exploratory problem solving across different contexts including maths, arts etc

The app captures user-level data such as completed tasks and number of attempts of activities to inform what concepts students are struggling with.

IV. Impact on Student Learning

A 10.25% increase in students' problem-solving skills were observed among 11000 students and 550 teachers after using Codemitra (The Yuwaah-UNICEF YoungWarriorNXT report 2021) and 70% of 50+ school teachers from rural India (with no prior background in computer science), exhibited one or more computational thinking skills after one hour of learning experience with the app.

V. Conclusion and Future Research

Code Mitra is a free, open-source, contextualized and interactive mobile-app to build 21st-century future skills especially among underserved communities. We are looking forward to incorporating AI and learning science research to make the tool more engaging for novice learners and are open to working with collaborators working in this area.

Think Out of the Box – An affordable and holistic computing tool to enable problem solving and creativity

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I. Introduction

Computing education in India has been taking a back seat at the K-12 level owing to several reasons such as unavailability of low-cost computing devices and lack of access to computer labs and computer science offerings especially in rural settings. Besides the cost barriers, several foundational courses teaching computer science report high cognitive load on novice students especially while learning topics like programming and problem solving that involves complex text-based coding and interpreting syntax. While several introductory computing courses have moved towards a block-based programming approach, only few of these programming environments are able to deliver the holistic objectives of the subject involving hardware and software to interact with the real world in real-time and even if they do, they come with a higher cost, leaving them in-accessible for the under-privileged yet deserving communities. To address this challenge, Pi Jam Foundation, working with its team of industry professionals, curriculum authors, teacher trainers, instructors and student leaders developed an equitable computing tool, **T**hink-**O**ut-of-**T**he-**B**ox (TOTB) to reduce the cognitive overload and entry barriers while fostering collaborative problem solving, creative and computational thinking abilities for students in under-privileged and marginalised communities.

II. Tool Description

The *think-out-of-the-box* tool aims to reduce access and entry barriers to computing by offering

- a DIY mobile-based modular electronics toolkit with wide variety of sensors and actuators and an embedded micro-controller board, that enables kids (3 to 4 at a time) to learn programming and problem solving collaboratively at a radically lower cost (cost in vicinity 10-12 dollar per kit excluding the cost of mobile device)
- a block-based programming environment that works in conjunction with tangible paper blocks (that resemble jigsaw puzzles). Paper blocks allow for tangible collaborative play and have the potential to motivate even novice learners to learn computing. There are tutorial videos embedded within the app to guide students with possible problem statements, solutions and circuit connections

Figure 1: (Left) Arduino Uno microcontroller connected to an Android smartphone (Right) The TOTB block based programming interface currently supporting microcontroller boards Arduino Uno, Nano and Raspberry-Pi Pico RP2040

III. Results

We have currently reached 250 middle students across our nation, including a pilot in Kenya. Evaluating the impact on 165 learners across pilots in India, we found that 88% found this approach most accessible using it every day or week. 61.2% report programming an Arduino Uno with a smartphone to be least difficult, signifying reduced cognitive load for novices. The number of girl students who responded that they are most confident with electronics increased by 35% after the intervention. Number of students who were able to express themselves creatively using technology improved by 50%. Over 70% of female students and more than 50% of male students were able to identify community-related problems after the intervention.

Figure 2. Think out of the box pilots in India (Top) and Kenya (Bottom)

IV. Conclusion and Future Research:

Think Out of the Box" (TOTB) is an affordable computing tool which reduces the cognitive load of learners and empowers students to move beyond their fear of learning computing to take agency in being creative thinkers and solve community related problems. We are currently evaluating our pilot in Kenya to investigate our potential for scaling across contexts.

Mixed-Signal Simulation Marathon for Education and Employment

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Abstract—Electronic Circuit Design is a difficult but an impor tant area. We demonstrate a Free and Open Source Electronic Design Automation software that is capable of training masses.

Index Terms—eSim, SKY130, Process Design Kit, Verilog, SPICE, Circuit Design, Mixed-Signal Simulation, ASIC Simula tion, PCB Design, Open-Source, EDA tools, Education, Massive Training

I. INTRODUCTION

Circuit Design is a niche area and difficult to understand. Visualizing the behavior of the electronic systems makes it more difficult. Simulation software could be helpful in solving this problem. There is software available for learning circuit design. However, these software are proprietary and not affordable by common people. The paper discusses a Free/Libre and Open-Source Software(FLOSS) Electronic De sign Automation(EDA) tool called eSim which can facilitate training masses.

II. WHY TO USE A FLOSS EDA TOOL FOR LEARNING ELECTRONICS

• Cost of developing prototype is high
• Potential damage risk is low
• Cost of Proprietary software is high
• Reducing the number of mistakes in Circuit Design • Experimentation would take time while simulation time is less

III. OVERVIEW OF ESIM

eSim is a Free and Open-Source EDA tool capable of Mixed-Signal Simulation Software developed by FOSSEE, IIT Bombay [1] [2]. eSim is created by integrating various other Free and Open Source software such as KiCad [3], Ngspice [4], GHDL, OpenModelica [5], Verilator [6], Makerchip [7], and SKY130 PDK [8]. eSim is released under GNU General Public License.

IV. FEATURES OF ESIM

The following are the features of eSim:
• Schematic Editor using KiCad: The Schematic Editor is used for drawing the circuits in the graphical format. The students can draw the required circuit as given in the book, reference papers, etc., and try it out themselves. • Ngspice Simulation: SPICE simulation is very popular for circuit simulation. This is achieved by Open Source Software called Ngspice [4].
• Mixed Signal Simulation: Mixed Signal Simulation is a niche area that includes a combination of both Analog and Digital Circuits. The involvement of both Analog and Digital circuits makes things much more complicated. The software eSim is also capable of Mixed Signal Simulation where the students can write code in HDL languages, draw schematics, and simulate using Ngspice [1] [2].
• PCB Design using KiCad: Printed Circuit Board De sign(PCB) forms an important step in fabricating the circuit. Learning through software makes it easy for students to fabricate the circuits themselves and try them out.
• SkyWater PDK: Process Design Kits contain foundry specific model files for simulation. eSim is interfaced with the Open Source SkyWater PDK primitive libraries [8] to facilitate students to make foundry-specific circuits that can be fabricated later on a real chip!
• Schematic converters: eSim Team has also developed Schematic Converters through which one can convert already available schematics in proprietary software to eSim. After the conversion is successful, one may run them in eSim.
• Miscellaneous Features: These include the interface of eSim with other Open Source tools like OpenModelica(a powerful Modelling software) and Makerchip(a powerful digital simulation software).

V. LEARNING THROUGH SPOKEN TUTORIALS

Spoken Tutorials [9] are self-learning-based videos for learning FLOSS. There are Spoken Tutorial Videos available for learning the software eSim. This makes learning the software easy without any manual assistance.

VI. ESIM ACTIVITES

The eSim team conducts marathons [10], workshops, Fel lowships [11], internships and the Circuit Simulation Project activity for effective learning of people throughout the country and abroad.

ACKNOWLEDGEMENT

This work could not have been carried out without the help of FOSSEE and Spoken Tutorial teams. The authors gratefully acknowledge the funding given by the Ministry of Education, Government of India to the FOSSEE project through the National Mission on Education through ICT.

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CLASS – The Cognitive Learning Ability Screening Score – A Performance Based Tool to Address Individual Learning Needs

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I. Overview

India's National Educational Policy or NEP 2020 prioritizes universal foundational literacy and numeracy in primary schools by 2025. Section 6.13 of the NEP thus emphasizes continuous assessment and early identification of learning strengths and weaknesses to achieve this goal. However, assessing learning in Indian schoolchildren is challenging for various reasons.

Four major challenges in learning assessment in the Indian context are:

1. heterogeneity of curricula across states, regions and educational boards
2. expense of traditional, paper-and-pencil testing
3. error-proneness of manual data collection and data entry
4. difficulty of identifying and appraising learning milestones for all ages and grades

A comprehensive screening tool designed to assess foundational learning, must evaluate core cognitive competencies in addition to acquired academic skills.

Only by adopting a two-pronged approach that measures innate cognitive potential alongside classroom learning can any assessment tool for foundational learning effectively map a child's learning potential and progress.

II. Rising to the Indian Challenge: CLASS as a Tool for Digital Assessment

In this technology for education conference, we present a potential solution to the challenges of assessing learning in the Indian context, namely CLASS. CLASS, or the Cognitive Learning Ability Screening Score is a tool for assessing foundational literacy and numeracy in Indian schoolchildren.

The five-point CLASS advantage includes:

1. curriculum-agnostic – implementable across educational boards and regions of India 2. completely digital – may be administered on PC, laptop or tablet
3. automated data synchronization – uploads data to a secure, centralized database
4. wide-ranging – age-, grade-, language-appropriate, covers ages 6 – 18 (grades 1 – 12) 5. two-pronged evaluation – targets both classroom learning and cognitive potential

III. Workshop Objectives

CLASS represents an ideal tool for the kind of continuous learning assessment emphasized by the NEP. In this workshop session, our aim is to share with fellow researchers, educators and technologists the rationale and methodology behind the construction of CLASS, as well as to offer glimpses of insights emerging through CLASS piloting. Specifically, the major objectives include:

1. Provide a quick walk-through of the CLASS literacy and numeracy modules 2. Demonstrate the role of working memory as a core cognitive competency in literacy and numeracy tasks
3. Share samples of CLASS individual- and school-level reports
4. Show how CLASS assessments can identify distinct learning needs in rural and urban schools.

IV. Workshop Participant Engagement: Interactive Components

Participant engagement during this session will be ensured through the following activities that will also promote active learning:

1. Fun Quiz (10 minutes) – an online quiz will be used to provide participants with a hands-on feel for the types of literacy and numeracy skills assessed by CLASS
2. WM Challenge (15 minutes) – participants will work in pairs to administer tasks that assess either visual or auditory working memory (WM), as well as advanced language and math processing tasks; through identifying the correlations between WM and language/ math performance, participants will be enabled to see how core cognitive competencies influence academic skills
3. CLASS Report Reading (15 minutes) – teams of 4 to 5 participants will work together to interpret the data provided in a sample CLASS report for an individual child, as well as a sample CLASS report for a school, identifying salient patterns and brainstorming to find the most appropriate recommendations for learning interventions

V. Key Take-aways

Through this session, workshop participants will be enabled to:

1. Gain an understanding of the principles underlying foundational literacy and numeracy assessment
2. Appreciate how underlying/ core cognitive competencies shape, direct and limit learning 3. Develop familiarity with the nature of foundational learning assessment reports and their interpretations
4. Acquire a basic grasp of how learning strengths and weaknesses are identified, and how recommendations for learning remediation are formulated

Teaching Tools for the Future: PictoBlox and Quarky

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I. Introduction

In the rapidly evolving educational landscape, it's essential to weave technology into the fabric of teaching and learning. This paper spotlights two groundbreaking educational tools: PictoBlox and Quarky. They are specifically crafted to merge technology with education, filling any existing gaps seamlessly. The core aim of this discussion is to equip educators with an in-depth grasp of these tools, highlighting their transformative potential in the EdTech sector. Our exploration is rooted in sound research and educational theories, demonstrating that hands-on and engaging learning experiences promote deep understanding and memory retention.

II. Description of the Tool

PictoBlox: PictoBlox is a block-based and Python coding

platform for students It offers a dual approach, allowing students to start with drag-and-drop blocks and transition to Python as they advance. With features supporting 3D, AR, VR, AI, and ML, it provides a holistic platform for students to experiment, create, and learn by doing.

Quarky: Quarky, an electronic robot, offers a tactile way to

grasp AI and robotics. It's a versatile tool with sensors, LEDs, and connectivity options. Quarky is not just a piece of hardware; it's a learning experience, allowing students to transform theoretical knowledge into tangible projects, from AI delivery bots to home automation systems.

III. Discussion of the Benefits

Both PictoBlox and Quarky offer a plethora of benefits:

- Engagement: PictoBlox is used globally in schools and workshops, with over 1.3 million users, and 170,000+ monthly active users.
- Skill Development: Beyond coding, students develop 21st-century skills like critical thinking, problem-solving, and creativity.
- Accessible Artificial Intelligence: Students get to experience creating and implementing Machine Learning and Deep Learning models without excessive coding knowledge.

PictoBlox and Quarky are widely adopted in education,

with PictoBlox boasting **100,000+ downloads** and **5,000+ reviews** on the Play Store. Its global recognition is a testament to its utility and impact in the educational sphere. However, like all pioneering tools, it comes with challenges. The initial learning curve and meshing it with traditional curriculums can be daunting. But with the right training and support, these hurdles are effortlessly tackled.

Many educators view it as a prime tool for cultivating 21st-century

skills in youth. Globally recognized, it's praised by educators like US

Technology Specialist Laura Reasoner Jones, who has provided insightful reviews, underscoring its value in modern education.

IV. Recommendations

For educators eager to weave PictoBlox and Quarky into their teaching methods:

1. **Training:** Dedicate time to grasp the intricacies of these tools. This will ensure their smooth integration into your lessons.

2. **Start simple:** Kick off with basic projects. This will help students get acquainted with the platforms, paving the way for more intricate assignments later.

3. **Collaborative learning:** Connect with a wider community of educators harnessing these tools. Sharing experiences and insights can be invaluable.

Future studies should probe the long-term impacts of these tools on student outcomes and their adaptability in diverse educational settings.

V. Conclusion

PictoBlox and Quarky are not just tools; they represent the future of education. They encapsulate the essence of what modern-day teaching tools should be - interactive, engaging, and effective. As we navigate the challenges of the 21st century, tools like these will play a pivotal role in shaping learners who are not just consumers but creators of technology. We urge educators to explore these tools and experience firsthand the transformation they can bring to classrooms.

Gatuvit

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I. Introduction

Gatuvit is a unique blend of Technology, Pedagogy & Andragogy that has educators autonomy at its core. It's a single platform that has all the components of an LMS, many components of an ERP and also a central repository for educators to publish their content for use by other educators and organizations. For many educational organizations it is acting as a single software they need to use for all their needs.

In this paper we want to put forward an example of how meaningful solutions can be co-created by educators and technocrats by carefully studying on-ground needs and usecases that will benefit the most from the use of technology and by iterating it based on its testing in various scenarios.

II. Description of the Tool

Gatuvit has 4 user roles - Author, Planner, Mentor & Learner. It provides frameworks and ways for authors to create, deliver & test their content. It helps them create and configure Bloom's taxonomy & more than 10 types of questions, such as Fill in the blanks, Match the pairs, Rearrange, Crossword, Text Highlight, Multiple Choice, etc. to make objective assessments more robust. It allows them to conduct subjective assessments where learners can submit their work, receive feedback from mentors and iterate over it based on the feedback before the mentors can grade their submissions based on custom rubrics. It also has a facility to conduct forum discussions among learners which are moderated and graded by mentors.

Gatuvit is a cloud based platform but since it is built considering on-ground constraints, it also works completely offline, syncing the data to the cloud whenever internet connection is available. Apart from web apps, Gatuvit has android apps for learner & mentor roles. The learner app has 2 variants based on the age-group of the learners. One mobile based variant for a higher age-group & one tablet based, bit more interactive variant for younger age-group. Gatuvit also has a WhatsApp based interface which makes it very easy for its learners to interact with the contents of the course/program they are going through.

Gatuvit is being used in wide variety of use-cases such as -

- Level based learning - For designing & conducting diagnostic tests, analyzing student levels based on various configurable parameters and providing remedial input ● Teacher training - For conducting blended mode courses with resources & hand-holding support provided via feedbacks on classroom recordings sent by teachers ● Classroom instruction - Standalone interactive apps which can provide on-the-fly help to the teachers for effective classroom instruction
- Activity planning - Choosing from activity bank for planning daywise & weekwise activities for Anganwadis and getting the plans reviewed by supervisor
- Conducting research - Collecting data using baseline, midline, endline assessments during an intervention to check its effectiveness.
- Parent assisted activities / at home interventions - Using whatsapp interface for sending parents the activities to be conducted with children at home, receiving the recordings of the activity and sending feedback.
- Blended mode interaction with parents - Using books with instructions for parents and worksheets for children + QR codes on every page to access learning materials and interactive resources when scanned through a dedicated app + whatsapp interface for receiving support.
- Public repository - An interface for educators to publish their courses/content/ assessments that they have made for their students for use by a wider audience ● Workshops & masterclasses - In-person/online workshops by educators on various topics that teachers can register for
- Operations - Attendance, timetable management, substitutions planning, fee management, entrance exams, etc.

III. Discussion of the Benefits

Apart from time efficiency & having all the content organized in an academically sound way at a single place, Gatuvit has been beneficial for improving & measuring student learning.

The following table shows the improvement in student scores after the teachers used Gatuvit connected apps for on-the-fly help in classroom instruction (sample size - 30 each)

Subject	Baseline	Endline
Fractions	24	66
Introduction to script	17	67

The following table shows the improvement in student scores when teachers implemented the inputs given to them through Gatuvit workshop after measuring student levels via baseline tests (sample size - 300)

Topic	***Baseline***	***Endline***
Word Problems	23	67

IV. Recommendations and Conclusion

We recommend the educators to try Gatuvit platform for maintaining their content in organized manner, distributing it within their own organization as well as to other organizations through it's

public repository. We also recommend them to use the assessment feature of Gatuvit to measure the impact of their interventions in a robust way and track the progress of the learners.

Gatuvit offers every stakeholder - parents, teachers, educators, supervisors, etc with the right tools & data that they need to make informed decisions about their programs and make the processes efficient. The team behind Gatuvit also seeks context specific inputs from educztors like you in order to customize Gatuvit for every educator's needs. In the crowded world of EdTech tools, Gatuvit proves to be a path-finding solution, which is exactly what the word Gatuvit means in Sanskrit.

Smart Paper - An AI tool for digitizing paper assessments at scale

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Objectives

Our demo aims to show how Paper Digital Integration can make learning data available at scale in low-tech classrooms. We will also show what type of research can happen by working with handwriting image data from paper assessments.

Description of the Tool

Smart Paper is an AI tool that leverages computer vision to digitize paper assessments. Smart Paper tool allows the collection of assessment data from paper worksheets. Test creators can define paper assessment templates in the Smart Paper system. When users (teachers/students/parents) scan the papers, the handwriting on the paper is digitized and evaluated as defined by the test creator. A large language model can also do the evaluation of digitized text to provide feedback on short answers. The worksheets can be printed on any standard paper on widely available papers. The scanning can be done using mobile phones, and there is no need for scanners. The photos can be taken using many types of devices, including phones 5-7 years old. Our vision algorithms work with various types of lighting conditions and capture poses.

Application for Learning & Teaching

Smart Paper reduces the evaluation workload of teachers and provides immediate data insights into learning in low-tech classrooms. A large percentage of classrooms worldwide do not have 1-1 technology access. This is especially true in India's government schools. Smart Paper aims to make low-tech classrooms data-rich and provide teachers with the capability to do personalized teaching. In the academic year 2022-23, the Rajasthan government used Smart Paper to assess 45 lakh children across 65,000 government schools. Nearly 2.37 lakh teachers used Smart Paper for assessment scanning through the government's teacher app RKSMBK. 4 crore papers were scanned across three state assessments, and the government collected competency-aligned longitudinal data for Maths, English, and Hindi for all students. The data was used in classrooms to give personalized group instruction to students and aided policy decision-making. The massive child-level population-scale data was used to produce report cards that reached nearly 25 lakh parents and involved them more in children's learning through public school guidance.

Application for Education Research

Every child in the world learns using pencil and paper. The enormous amount of educational data produced daily on paper never reaches digital systems. The data from the paper provides a window into how students think when they solve assessment problems on paper. We can discern diverse methods students employ to tackle problems by utilizing handwriting data. The handwriting image data can reveal patterns, including multiple solution paths and frequent student errors. Researchers can devise improved instructional strategies by identifying these common misconceptions and curate teacher guidebooks tailored to typical problem-solving techniques. Furthermore, we can use the known misconception data to create high-quality assessment questions that test for misconceptions. One public sample of the handwriting data for one question is available here: sample data link

Product Website: http://hellosmartpaper.com/
Demo Videos:
How to scan a Smart Worksheet using a Phone
Smart Test Authoring, LLM Grading

Empowering Educational and Research Societies through NoCode Tools: A Case Study of EdTech Society

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***Abstract*— This research paper presents a case study of EdTech Society, an educational and research society, and its innovative approach to streamlining society management, membership handling, and conference organization through the utilization of NoCode tools. The society has leveraged technology to enhance the learning, teaching, and research experiences of its members and stakeholders. This paper highlights the key features and functionalities of the society's website, offering valuable insights for educational institutions, research societies, and organizations seeking efficient management solutions. The research emphasizes the impact of technology on education and research societies and explores how NoCode tools can facilitate seamless operations and engagement within these organizations.**

Keywords*— *NoCode Tools, Educational Society, Research Society, Membership Management, Conference Organization.

I. Introduction

Educational and research societies play a pivotal role in fostering knowledge dissemination, academic excellence, and research collaboration. Effective management of these societies, including membership administration, event organization, and financial transactions, is crucial for their success [1]. Developing an online website that supports the management of such a society is a time-consuming task and requires a team of developers, but NoCode development has made the task easier and requires comparatively less time and human resources [2]. This paper presents an innovative approach to addressing these challenges through the development of a NoCode-based website for EdTech Society.

II. Objective

The primary objectives of this research paper are as follows

- To showcase the utilization of NoCode tools for creating a dynamic and user-friendly website tailored to the needs of an educational and research society.
- To demonstrate how the website facilitates efficient membership management, including the collection of member information, renewal notifications, and discount offerings.
- To explain how the society employs the eCommerce module to streamline the payment process for memberships, conference registrations, and online training sessions.
- To highlight the ability to conduct international conferences with complex payment calculations and multiple currency support.
- To illustrate the advantages of using NoCode tools in creating a multi-purpose website with customizable headers and footers for different events and conferences.

III. Description of the Tool/Product

The website of EdTech Society is a powerful NoCode-based platform that revolutionizes the management of educational and research societies. It offers the following key features:

A. Membership Management

The website offers a user-friendly and efficient membership management system with several key features. It simplifies the membership application process through an intuitive eCommerce form, ensuring a seamless onboarding experience. Members are prompted to complete their profile information during login, keeping their profiles up to date. Additionally, automated email notifications serve as timely reminders for members to renew their memberships. Furthermore, the website provides flexibility for the society to offer discounts to its members, whether on selected products or specific items, enhancing the overall membership experience and engagement.

B. Conference Organization

The website's advanced features empower authors by enabling them to select research papers for payment, including support for complex calculations like fees for additional papers. It ensures secure payment collection through multiple payment gateways, offering convenience and reliability. Notably, the website allows the society to define product prices in one currency while dynamically displaying prices in members' preferred currencies through real-time currency conversion. This feature greatly enhances accessibility for international users, making transactions more seamless and accommodating diverse currencies.

C. Customizable Headers and Footers

The website enables the creation of distinct headers and footers for various purposes, eliminating the need for separate microsites for different events.

IV. Benefits

The website offers a multitude of benefits, starting with streamlined society management. It simplifies membership

processing and renewal notifications, significantly enhancing administrative efficiency. The eCommerce module further streamlines payment collection and discount offerings. This leads to an enhanced user experience as members can seamlessly update their profiles and process payments within a unified platform. Real-time currency conversion adds to the international user experience's appeal. Additionally, the website enables efficient event management, eliminating the need for separate event-specific websites. It effortlessly handles complex payment calculations, making conference and event organization smoother and more efficient.

V. Conclusion

The case study of EdTech Society demonstrates the transformative power of NoCode tools in optimizing educational and research society management. By offering a user-friendly, feature-rich website, the society has simplified membership handling, conference organization, and financial transactions. This research paper underscores the potential for NoCode technology to empower educational and research societies, fostering improved learning, teaching, and research experiences.

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The following papers were also presented at the conference but are not included in these proceedings. Although these papers were shared during the event, they have not been compiled into this document.

Full Papers

Sign Buddy: An Innovative Sign Language App for Communication and Language Learning
Yash Petkar, Ritesh Bakare, Aarya Teli, Prerna Rawale, Kapil Kadam and Ashwin T S

Identification of influencing factors for new users in a online gamified learning environment: An Exploration study
Srimathi S and Anitha D

Blended Learning for Women's Business Development in Rural India: Enhancing Technology Adoption and Bridging the Gender Digital Divide
Bhanu Vr, Niksheeta Nayar, Amritha Natarajan, Reshma Ramesh, Aswathi Padmavilochanan and Srividya Sheshadri

Short Papers

An Analysis of Flipped Classroom Model for the course 'Analysis and Synthesis of Mechanisms'
Poonam Bhore, Rujuta Agavekar, Himani Kadam and Mrunal Moharir

Role of state ICTs in countering cyber-crimes against students of Kerala: An analysis
A G Krishnanunni and Dr Karthika C

Innovative Pedagogy for Experience-based Learning of Engineering Mathematics
Dr. Chaitra V, Dr. Deepthee M R and Dr. Madhukar K

Effectiveness of Game-Based Learning in Constructivist Classrooms
Sapna Iyer and Chandrang Pathak

Survey on Innovative Technology Integration in Teaching among Teachers of Higher Education in Kerala
Geethu T G and Dr. Sajna Jaleel

From Theory to Practice: Bridging the Gap in Traditional Computer Networks through Cisco Packet Tracer for Effective Conceptual Learning and Network Deployment
Shreya Devagiri, Vijayalakshmi M and Sneha Pamali

Pre-Service Teachers' Approaches to Quantitatively-Rich Mathematics Problems: Implications for Mathematical Knowledge for Teaching
Ajay Ramful, Ajeevsing Bholoa, Savila Thapermall-Ramasawmy, Asifa Salehmohamedand Narendra Dadarao Deshmukh

Reading between and beyond Cumulative Frequency Curves: Insights from In-Service Secondary School Mathematics Teachers
Savila Thapermall-Ramasawmy, Ajay Ramful, Ajeevsing Bholoa and Narendra D. Deshmukh

Unraveling the Factors Affecting Students' Success in an Online Introductory Programming Course: A Case Study
Shreya Singhal, Rishabh Balse and Swarnim Soni

Augmented Reality Based Intervention to Teach English Alphabets to a Moderate Intellectually Disabled Child: A Case Study Conducted in Kerala
Savitha K.K and Renumol V.G

Effectiveness of Virtual Flipped Classroom in Teaching of Science at Secondary Level
A.V. Jayalakshmi and Bhavisha Solanki

Unfolding Features of Gamification Pedagogy
Suja Jayachandran and Bharti Joshi

Design and Implementation of an Assessment Procedure to Combine Benefits of Collaborative Learning with 3-2-1 Strategy
Avani Sakhapara and Dipti Pawade

Inclusive learning model for technology-enhanced vocational education through culturally responsive pedagogy
Sithara G S, Reshma Ramesh, V R Bhanu, Niksheeta Nayar and Srividya Sheshadri

Evaluation of a Video Script Writing Tool Through Expert Testing
Ganesh Lokhande, Sushobhan Patankar and Sameer Sahasrabudhe

Strategies for effective monitoring of Short term decentralized Skill Development Programs (SDPs)
Parameswari Anitha, Lekha Shekar, Bhanu V R, Nisheetha Nayar, Balu M Menon, Srividya Sheshadri and Aswathi Padmavilochanan

Enhancing Aptitude Skills: Development and Expansion of the Apti-Trainer Android App
Mihir Patki, Dhanashri Nirmal, Shraddha Patil, Saira Sanadi, Aarya Teli and Kapil Kadam

SkillsGoGo: Empowering Education through a Mobile App for Seamless Learning, Collaboration, and Knowledge Sharing
Shraddha Jadhav, Girija Jadhav, Shravani Ghatage, Gayatri Bhagwat and Kapil Kadam

Step-by-Step Conduction of Online Laboratory Sessions using Simulators and Interactive Programming Platforms
Kartik Ramesh Patel

Smart Laboratories : Learning Data Structures through Games
Bhumika Shah and Jyoti Pareek

Qualitative Analysis of Metacognitive Knowledge generated through Cooperative Learning Strategies
Aakanksha Sharma and Jayashree Shinde

Notes Generation From Videos
Dipti Pawade, Avani Sakhapara, Mayank Kulkarni, Aditya Phatak, Divya Nair and Vedashree Joshi

AlgoComp: Visualization Tool for Path Finding Algorithms
Dipti Pawade, Avani Sakhapara, Abhijeet Pasi and Mishtee Gandhi

Mini-Games for Assessing Computational Thinking – A Usability Evaluation
Vinu Varghese V.V and Renumol V.G

Comparative Study of Engagement in Online Learning Environments with Competitive and Collaborative Elements of Gamification in Higher Education
Nidhi Shetty and Jayashree Shinde

Implementing a Student-Centric Free and Open-Source Virtual Laboratory in Bioinformatics and Computational Biology
Sreelekshmi Sreekumar, Rakhi Radhamani, Asha Vijayan, Krishnashree Achuthan and Shyam Diwakar

Enhancing student engagement in graduate level environmental awareness course using Google lens technology
Beena Anil

Glimpse of T4E 2023 conference participants at venue-IIT Bombay