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A Case Study: Implementation of Active Learning and Problem-Based Learning Pedagogies in Freshman Undergraduate Course

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Abstract—Globally, educational institutions have been forced to close and transition to online teaching due to the Covid-19 pandemic. From the last two and half years the student's attention span drastically reduced due to online teaching. The traditional teaching and learning practices will not grab the student attention. Hence, a novel teaching pedagogy is needed to enhance student's attention span and learning. To address this problem, this paper presented implementation of active learning and problem-based learning pedagogies in freshman under graduate course. The undergraduate freshman course is the smart system design. The course instruction methods are divided into two parts. In the first part, active learning methods such as flipped classroom, and Jigsaw are implemented. In the second part, problem-based learning is implemented. The implementation of these pedagogies results shows that the student attention span is increased, the students can work in teams and problem-solving skills are improved. Finally, these pedagogies make the students ready for next-generation engineers.

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1. Introduction

The field of education is always changing. Teaching policies with a greater emphasis on students' academic success have been discussed by many researchers. Consistent planning, analysing, and assessing what best equips learners in their academic lives is done, and this is done fiercely. As a result, instructors are continuously trained to provide excellent teaching and learning environments in the classrooms. (Adward, J. 2021, Gaikwad, P., et al, 2022). Cicekci, M. A., & Sadik, F. (2019) research study demonstrated theattention difficulties experienced by the instructors throughout course delivery based on the learners in the classroom. The indications of distracted attention in the classroom environment are viewed as reprimands, and the objective of interventions is to stop the learners' behaviour rather than regaining their focus. According to Cicekci, M. A., & Sadik, F. (2019) research study suggested the following points for improvement of the teaching and learning process.

- Instructors should interpret signs that the learner's concentration is preoccupied as a signal that the learning process should be altered.

- Instructors should schedule and plan instruction to grab the learner's concentration and during the course delivery provide hooking (role playing, puzzles educational games, etc.) frequently to minimize the cognitive load.

- Instructors keep in mind that the learners will have different requirements for self-regulation, and maintenance of attention.

- Instructors should enhance pedagogical skills on the creation effective classroom environment by implementing active, collaborative and problem based learning practices.

One of the most fundamental aspects of education that has undergone a paradigm shift is how lessons are presented to learners. In the past, instructors had complete autonomy within the classroom. The authors Gaikwad, P., et al., (2024) implemented a paradigm shift in the teaching and learning environment by adopting new teaching pedagogies. The pedagogies include experiential learning and project-based learning (PBL) and these pedagogies are implemented in the course named Mechatronics. The authors stated that experiential learning enhances learning ability using hands-on practice sessions. Whereas, the PBL improves the teamwork, critical thinking, and problem-solving skills of the learners. Finally, the authors concluded that the new paradigm shift in the teaching and learning process improves the technical and non-technical skills needed for next-generation engineers.

Kaushik, M. (2020) presented that PBL is viewed as a successful instructional strategy for two reasons.

- The millennial learning rhythm and attention span do not encourage teachers to employ traditional pedagogies.

- The National Board of Accreditation (NBA) defines graduate attribute 3 as the "ability to solve complex engineering problems" and it is exceedingly difficult to do with a series of theoretical courses and traditional pedagogies.

Both of the aforementioned factors motivate teachers to embrace PBL as a methodology to meet the needs of today's educational environment. According to Bayram-Jacobs and Hayirsever (2016), learner autonomy increases when they have opportunities to collaborate with their peers and take an active role in their education. Learner-centered pedagogical practices allow learners to become less reliant on their instructors for guidance and more capable of figuring out what they need to know on their own. In this way, they can become more involved in the material and maintain their attention and focus for the duration of the class. Peer learning is one student-centered strategy that promotes student autonomy and active participation in the learning process. In the peer learning framework, each student's perspective is valued equally. Knowledge and abilities can be gained through peer learning when people help and learn from one another (Wang, W. 2015). Compared to an instructor environment, group work enables learners to feel more at ease, connect, and ponder and explore concepts in greater depth (Hachad, T., Sadiq, A., & Ghanimi, F. 2020). Numerous studies have demonstrated the usefulness of learning from one's peers. Peer learning has been shown to boost student engagement, and its implementation has received widespread praise (Jeyamala, C., & Abirami, A. M. 2020). The purpose of this paper is to make first-year undergrad students more academically capable of becoming next-generation engineers.

2. Overview of The Freshman Undergraduate Course

The freshman undergraduate course used to implement active learning and problem-based learning pedagogies is the Smart System Design (SSD 2020). The SSD 2020 is a three-credit course offered to undergraduate freshman students. The course is planned for five hours per week which includes one lecture (L) hour, two practical/demonstration (P/D) hours, and two J component (J) hours. They are designed with active, collaborative, and platform-based learning pedagogy. Through the course, the learners experience learning with diverse active learning pedagogies. In addition, learners are exposed to problem-based learning to solve societal problems. In this course, student teams build and deploy intelligent microcontroller-based solutions. It is an emergent field that integrates existing engineering disciplines to produce system-level solutions. Students are accustomed to working in the high-tech industry, which flourishes in a multidisciplinary environment that synergistically combines organisations, stakeholder interests, and consumer requirements in an inventive manner.

A. SSD Syllabus

The SSD course syllabus is prepared in modules. Total 8 modules and one-course project. The modules of the course are as follows:

- Module 1: Introduction to Arduino boards
- Module 2: Arduino IDE and Basic Arduino Uno functions
- Module 3: Design of power supply unit (Demo)
- Module 4: Controlling of Light Emitting Diode (LED)s using switches
- Module 5: Liquid Crystal Display (LCD)
- Module 6: Sensors - Digital sensors (Infrared, Passive Infrared) and Analog sensors (Displacement, temperature, Light dependent register, Ultrasonic sensors)
- Module 7: Actuators – Relay and motors
- Module 8: Wireless connectivity to Arduino – Bluetooth, Wireless Fidelity and Global system for mobile communication.
- Course Project

B. Course Outcomes (CO)

The course outcomes of the SSD are as follows:

- CO1- Demonstrate the pin map and basic functions of Arduino.
- CO2 - Program the Arduino board
- CO3 - Select appropriate sensors and actuators based on the design requirements.
- CO4 - Analyze wireless connectivity to Arduino.
- CO5 - Develop a complete smart system using Arduino.

3. Methodology And Implementation

This paper presented the implementation of active learning and PBL pedagogies in a freshman undergraduate course named Smart System Design. As per the given syllabus in section 2.1 course instruction is delivered in the form of 8 modules and a course project. Out of 8 modules, module 1 and module 2 are demonstration sessions. Module 3, module 4, module 7, and module 8 are hands-on practice sessions. The module 5 to module 6 used the active learning techniques. For course projects PBL (Seibert, S. A. 2021, Foo, C. C., Cheung, B., & Chu, K. M. 2021, Tan, O. S. 2021) is used to solve engineering and societal problems. The instruction delivery methods and their corresponding schedules are shared with the students in the form of a lecture plan. Further, the complete implementation of active learning and PBL methodologies is discussed in the following subsections.

A. Implementation of Active Learning

Active learning methods such as flipped classroom (Barranquero-Herbosa et al., 2022; Chien, C. F. 2022; Golaki, S. P. et al., 2022, Shraddha, B et al., 2020), and Jigsaw activity (Chen, P., Liu, S., & Jia, J. 2021, Chang, W. L., & Benson, V. 2022, Sa'adiah, H., et al., 2021, Gosavi, C. S., et al., 2022). Are implemented to deliver module 5 and module 6.

Flipped classroom

LCD topic is selected for flipped class activity. The implementation procedure of flipped class is as follows

- Prior information about the activity (type of activity, procedure of condition, Topic and duration of the activity) and evaluation rubric are shared to the students two weeks before commencement of the activity.
- A video lecture (comprised of working of LCD, LCD pin diagram, LCD Commands, and Tinkercad simulation with one example) shared to the students.
- The students may interact instructor at the contact hours regarding any type of queries (contact hours are mentioned in the lecture plan)
- During the activity a problem is given to the students that is “Design a smart system to display your name and hall ticket number on the LCD. Constraints: Name in first line and Hall ticket number in second line” The time allotted for this activity is 2 hours.
- Then the student should draw the circuit, design it

in the tinkercad, and show the results within the stipulated time.

Jigsaw

The sensors topic is selected for Jigsaw. The implementation procedure of the jigsaw activity is as follows

1) Before the conduction (one week before)

- Activity is announced, learning teams are formed (based on the scores of flipped class activity) and individual student in the learning team is allocated sub topic in module 6.
- Students should read the allocated topic.

2) During the activity

- Dynamic learning teams are formed based on the subtopic. Then this dynamic learning team discusses the same sub-topic. (20 min)
- The individual learners return to their original learning team and explain their sub-topic to their teammates (60 min).
- Individual and group tests are conducted to analyse performance (10+10 min).

B. Implementation of PBL

In the proposed instruction model PBL is implemented for SSD course projects and 8 weeks are provided. In this approach, the students are grouped into teams and each team consists of 4 students (2 boys and 2 Girls). After teams are formed, the individual group must come up with at least four ideas that can address simple societal problems. The architecture of PBL used for SSD course projects is shown in Fig. 1.

The PBL architecture comprises of two phases namely idea generation and problem solving. The step-by-step framework of PBL is as follows

Step 1: Every team writes the need statements based on their day-to-day observation and experience of societal problems.

Step 2: Clear Understanding of these need statements by technical literature reviews and surveys. generate multiple ideas to solve the same problem.

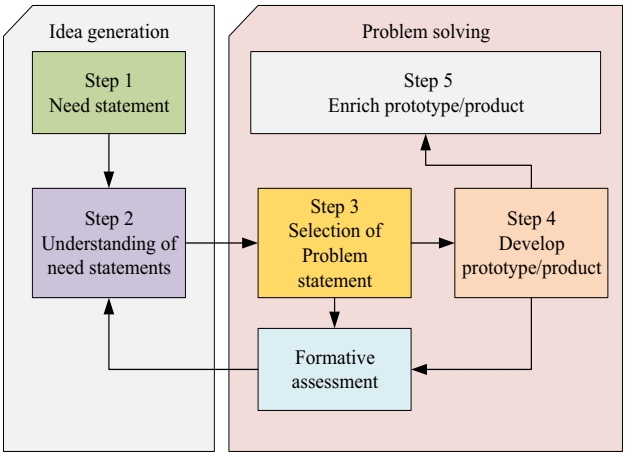

Fig. 1 : The Architecture of Pbl Used for SSD Course Projects

Step 3: Selection of best ideas using Pugh's matrix (Pugh, S. 1981). Pugh's matrix used for selecting the optimal solution is in Table 1. This matrix also gives the design specifications required for the selected idea.

Step 4: During this stage, students draw the schematic diagram, and simulate the circuit using Tinkercad. If simulation results are satisfied, then set up the hardware. Otherwise, modify the schematic diagram until it satisfies the design requirements. Once hardware is set up it is tested for design requirements and it matches with simulation results. If the design is satisfied continue with step 5, otherwise, repeat from step 2 or 3 based on the mentor/guide feedback.

Step 5: In the final stage, the students prepare casing for the final product/prototype. It should be attractive and user-friendly.

Table I :
Selection of Optimum Solution Using Pugh's Matrix

Section	Baseline solution	Idea 1	Idea 2	Idea 3	Idea 4
Safety	5	1	1	1	1
Time	4	-1	-1	0	0
Design	3	1	0	1	0
Cost	2	0	0	-1	-1
Portability	1	0	1	-1	-1
Sum of all neutrals		0	0	0	0
Sum of all negatives		4	4	3	3
Sum of all positives		8	6	8	5
Total		4	2	5	2

4. Outcomes And Reflections

This section presents the outcomes and reflections of pedagogies employed in a freshman undergraduate course. The outcomes and reflections are purely based on the student performance, observation, and feedback from the students. Further, the individual pedagogies outcomes and reflections are presented in the following sub-sections

A. Flipped classroom

After completion of the activity, the Tinkercad. simulations results of the given problem statement every student is evaluated on a 10-scale based on the rubric illustrated in Table 2.

Table II :
Rubric For Flipped Class Activity

Evaluation Criteria	Good	Average	Poor
Circuit	9-10	4-8	0-3
Program	9-10	4-8	0-3
Output	9-10	4-8	0-3

Based on the student performances in solving a given problem, the outcomes of the flipped classroom activity are modeled as shown in Figure 2. The total number of students participated in the flipped class activity was 63. Considering the circuit design for the given problem, 50 students completed it, 8 students completed it after receiving clues, and the remaining 5 students were unable to complete it. Considering the program for the given problem, 45 students completed it, 10 students completed it after receiving clues, and the remaining 8 students were unable to complete it. Considering the final output for the given problem, 38 students explained it clearly, 13 students completed it but they were unable to explain the output, and the remaining 5 students were unable to complete it.

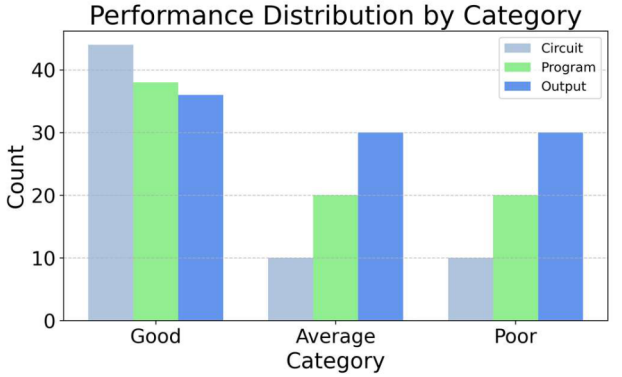

Fig. 2:The Outcomes of the Flipped Classroom Activity

After completion of the activity based on the observations and student scores the reflections of the activity are drafted as follows

- Engages the students on the given problem and increases their attention span.
- Enhance the Self-learning ability of the students.
- Slow learner needs more motivation before conducting the activity.

B. Jigsaw

After the jigsaw activity, two tests are conducted with Bloom's level 3 and level 4 questions. Test 1 is conducted for individual students with a duration of 10 minutes. Test 2 is conducted for the learner group with a duration of 10 minutes. The results of test 1 and test 2 are shown in Fig. 3 and fig. 4 respectively.

After completion of the activity based on the observations and test scores the reflections of the activity are drafted as follows

- Enhance the self-learning and collaborative learning abilities of the students.
- Slow learner involvement in the learning process is also increased due to the learner team.
- Enhance Confidence among the students on the topic.
- The instructor needs extra effort and plan for the conduction of the jigsaw activity.

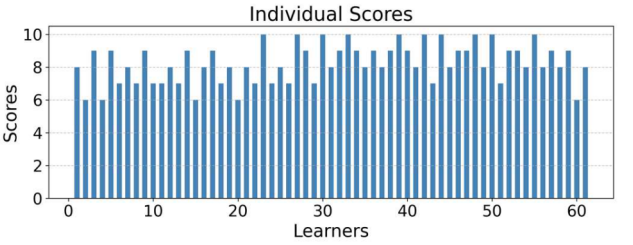

Fig. 3 : Test 1 scores

From the test 1 and test 2 scores, the correlation between individual and group performance in the Jigsaw activity provides valuable insights into the relationship between personal understanding and collaborative learning. A robust positive association indicates that students who achieve individually also contribute to the overall success of the group by

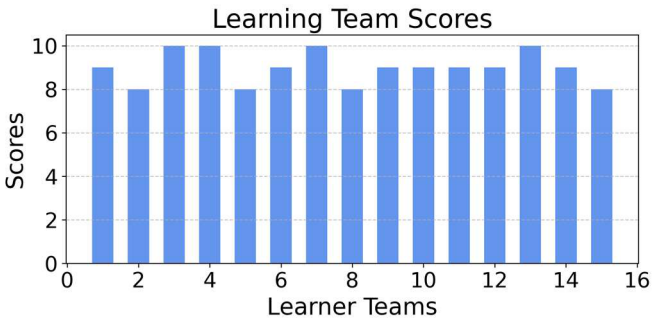

Fig. 4 : Test 2 scores

effectively sharing and integrating their knowledge within the team. On the other hand, a weak or negative correlation might suggest difficulties in group dynamics or collaboration, when individual strengths do not lead to collective achievement. This research emphasizes the significance of both personal responsibility and the efficacy of cooperative learning, indicating that improving group engagement can enhance overall educational results. Gaining insight into this connection helps guide teaching approaches, guaranteeing that the Jigsaw technique promotes both independent learning and collaboration.

C. PBL

The PBL pedagogy is implemented for course projects of SSD a freshman undergraduate course. The outcome of PBL pedagogy is 15-course projects. The students developed the course projects in four diverse domains of problems such as robotics, agriculture, smart city, and medical applications.

The diverse domains and corresponding course projects implemented by the students are represented in Fig. 5. Moreover, it is identified the students

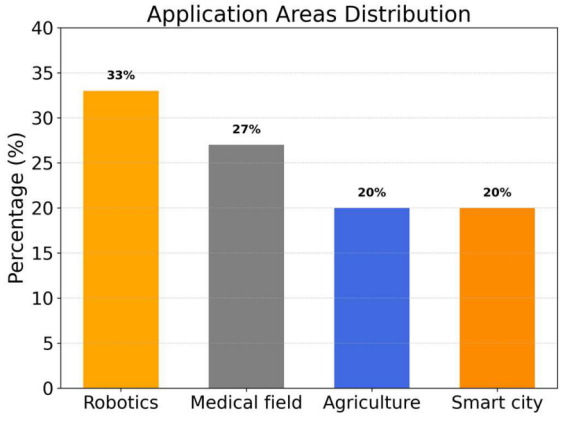

Fig. 5 : The Diverse Domains and Corresponding Course Projects Percentages

motivated to enhance their current implemented system for future applications, so that they can support sustainable development goal 9 to some extent. The course projects are mostly integrated with sensing and communication technology for real-time and remote monitoring through internet connectivity. Indeed, this method has assisted the students to understand the current technology and its significance in implementing smart systems for resolving pressing societal challenges. The course projects implemented by the students prove that PBL is the most suitable pedagogy for design-oriented courses in the curriculum.

Finally, the success of flipped classroom, jigsaw, and PBL was observed through student feedback and instructor observation. The student feedback on flipped classroom, jigsaw, and PBL are illustrated in Table 3. A total of 60 students participated in the filled the feedback form. The feedback form has the following questions.

- Is your attention span improved? (Yes/No)
- Is teamwork improves your performance? (Yes/No)
- Is your overall performance improved? (Yes/No)

The student feedback evident that the attention span and overall performance of the students are improved with active learning and PBL.

After completion of the course, based on my observations and student feedback the reflections on the flipped classroom, jigsaw, and PBL are as follows

- Enhance problem-solving skills
- Able to work within the teams

Table III :
Student Feedback on Flipped Classroom, Jigsaw, Pbl

Activity/ Parameter	Is your attention span improved? (Yes/No)	Is teamwork improves your performance? (Yes/No)	Is your overall performance improved? (Yes/No)
flipped classroom	45 -Yes 15 - No	55 -Yes 5 - No	50 -Yes 10 - No
jigsaw	50 -Yes 10 - No	50 -Yes 10 - No	50 -Yes 10 - No
PBL	58 -Yes 2 - No	58 -Yes 2 - No	58 -Yes 2- No

- Work within teams
- Critical thinking and decision making

These skills are useful for the students for their mini and major projects during graduation. In addition, these skills may be useful in their career and make them ready for next-generation engineers.

Conclusion

The paper presented two teaching learning pedagogies active learning and PBL were implemented in freshman undergraduate course. During first part of the course students experience the learning with hands-on practice, and active learning pedagogies flip class and Jigsaw. These pedagogies enhance the attention span, focus, self-learning ability and confidence in the students. During second part of the course PBL is implemented for the course project. Total 15-course projects are developed in four domains healthcare, agriculture, smart city and robotics. The PBL enhance problem-solving, critical thinking, decision making, team-based learning skills of the students. The novel paradigm shift in the teaching and learning process inculcate the quality required for the next generation engineers. Finally, it is suggested that a new paradigm shift is need in teaching and learning process in the current scenario. But, the instructor needs to put an extra efforts and time for planning and implementation of new pedagogies in the teaching and learning process.

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