Integrating project-based learning for enhancing higher education within an outcome-based education framework

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ABSTRACT

Project-based learning (PBL) has emerged as a powerful pedagogical approach within the outcome-based education (OBE) framework that is designed to align educational outcomes with the evolving demands of the 21st century. This research investigates the integration of PBL into an engineering course and focuses on its impact on the overall development of the students. Project-based approach was adapted in the artificial intelligence (AI) course, where 56 and 58 students applied AI concepts to real-world challenges in academic year 21-22 and 22-23, respectively. A structured PBL framework was implemented, systematically dividing the project into stages ensuring progressive learning. Feedback and statistical analysis, including a paired t-test, were conducted to evaluate students' academic and interpersonal skill improvements. The statistical analysis proved a remarkable improvement in the course assessment marks. Students demonstrated improved problem-solving ability, algorithmic thinking and expertise in AI techniques. The findings exhibited enhanced communication skills, effective presentations, articulation of ideas and peer collaboration. These outcomes indicate the significance of PBL on the holistic development of higher education students, within technical disciplines by equipping students with the necessary skills, mindset, and experience to excel in their professional practice. PBL provides a comprehensive assessment of student's abilities and fosters collaboration with industry partners thus strengthening ties between academia and industry.

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1. INTRODUCTION

Outcome-based education (OBE) has gained importance in engineering education as a transformative framework that focuses on defined learning outcomes over traditional content-centric instruction. The traditional teaching learning methods are teacher-led lectures where the knowledge imparted to students is in a passive way and there are no activities that keep the students engaged resulting in lack of enthusiasm and interest. Studies show that the student's attention in the classroom starts to decline within 10 minutes if the lectures are not effective in engaging the students [1]. OBE emphasizes the alignment of curriculum, assessment, and teaching methodologies with predetermined program outcomes (PO). This paradigm shift emphasizes the need for student centric active learning strategies, where the educator's role is of a facilitator, guiding students towards competency attainment, and real-world application of knowledge.

Central to the OBE framework are the PO, which serve as benchmarks for curriculum design and assessment. The PO articulate the desired competencies and qualities expected from graduates, thereby ensuring alignment with industry requirements and societal needs [2]. OBE empowers educators to design learning experiences, using active learning approaches to promote critical thinking, problem-solving abilities, and interdisciplinary perspectives among students. Moreover, OBE cultivates a self-directed learning, empowering students to become lifelong learners for solving complex, open ended problems, and are also equipped to thrive in dynamic professional environments [3].

Active learning process is an effort of fully engaging students in the learning procedure and help in developing the student's overall personality. These techniques provide an opportunity for every student in the class to engage with the course content. This helps in fostering leadership qualities, innovative and creative thinking, and also emphasizes sustainability. The active learning practices for higher education can range from simple interactive lectures and classroom discussions to case study, role play, think-pair-share [4], flipped classroom [5], [6], collaborative learning [7], problem/project-based learning, gamification [8], [9], and peer teaching [10], [11]. Figure 1 shows some of the active learning strategies for higher education.

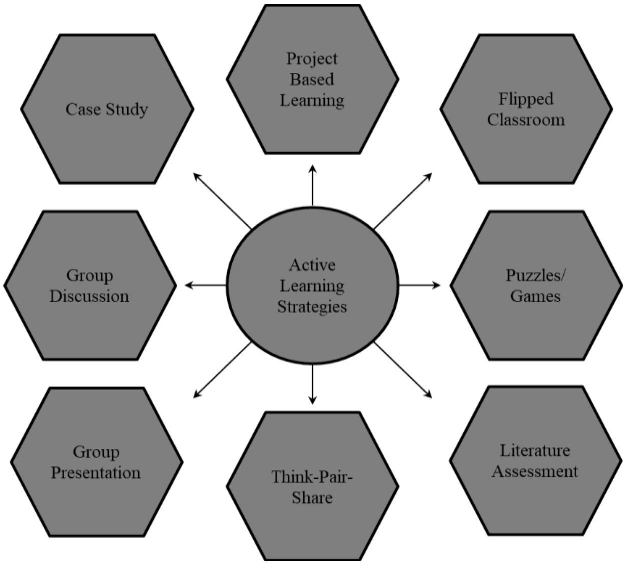


Figure 1. Active learning strategies for higher education

Among the various pedagogical approaches, project-based learning (PBL) has sprung out as a powerful method for fostering active engagement and promoting deeper learning experiences among students. PBL engages students in legitimate, real-world projects, encouraging them to explore complex problems, team up with peers, and utilize theoretical knowledge to practical problems. Thus, the incorporation of PBL in an OBE framework holds immense promise for strengthening the quality and effectiveness of higher education, particularly in the field of engineering. This technique not only helps in improving the technical proficiency but also enhances the non-technical expertise in the students.

This research explored the integration of PBL in the OBE system to improve higher education. The authors implemented PBL for the artificial intelligence (AI) course, for the third-year information technology (IT) engineering students. The PBL was divided into three phases to have systematic progress. The three phases were topic identification, case study and learning by doing. The results were evaluated using students' feedback and statistical methods. The research aimed to answer the following questions:

i) How does PBL align with modern pedagogical frameworks like OBE?
ii) Can a structured PBL activity ensure effective learning?
iii) What is the impact of integrating PBL on the technical and non-technical skills of the students?

This research introduces a systematic, structured, and theme-based approach to PBL. This approach introduces a structured, multi-stage PBL framework spread across the semester that allows students to gradually engage with AI concepts. Students were required to formulate their problem statements based on a predefined theme. These projects required an interdisciplinary knowledge base, integrating concepts from computer vision, machine learning, data analytics, and domain-specific expertise. By working on projects that demanded knowledge from multiple disciplines, students developed a holistic understanding of AI applications, enhancing their ability to tackle complex, real-world problems effectively. A structured mentorship pattern was adopted where the PBL process was closely monitored and guided by the instructor, ensuring students receive timely feedback and necessary direction. Use of quantitative analysis with paired t-test was conducted to measure the impact of PBL on students' curricular improvement providing empirical evidence of learning outcomes. Student feedback was collected using a structured questionnaire covering two major aspects: knowledge enrichment in AI and growth in interpersonal skills. This dual-perspective assessment provided insights into both technical competency and soft skills enhancement, making the study more comprehensive than conventional evaluations. Incorporating these novelties in the PBL implementation resulted in enhanced technical learning, problem-solving skills, and teamwork, making education more engaging, structured, and outcome-oriented within an OBE framework.

The primary contribution of this research is the technique used for implementing collaborative learning in AI course. The further contribution is in the assessment method used to evaluate the impact of integrating PBL on the technical as well as non-technical skills of the students. The aim is to bridge the gap between the theoretical concepts (algorithms students' study in theory class) and the real-world applications (usage of the algorithms for real world solutions). This activity not only enhanced the student's technical abilities but also improved their non-technical skills.

2. LITERATURE REVIEW

In recent years, a huge transformation in the learning paradigm and mode of learning among students has been observed [12]. Several studies have highlighted the efficacy of PBL in developing students' abilities in various domains. The usage of PBL for mechatronics subject of mechanical engineering students is presented in Patange *et al.* [13]. The authors highlight the efficacy of PBL as an efficient pedagogy technique to help improve the cognitive skills, sustainability, and ethics among students leading to lifelong learning. PBL is used for summative assessment of undergraduate students [14]. The author adapted PBL for the third-year engineering students to make them identify real life digital signal processing applications. Student's feedback was analyzed based on the course outcomes and skills developed by students.

The study by Teixeira *et al.* [2] reveals the efficacy of PBL done in collaboration with industry professionals for the comprehensive growth of the students. Similarly, Kulkarni and Ramdasi [15] used the undergraduate project course to check its effect on the attainment of PO. The results indicate satisfactory achievement of almost all the PO thus indicating the holistic development and growth among students. In study by Shpeizer [16], the author reviewed the features of PBL with its advantages in higher education and the challenges during implementation. The author has demonstrated ways for integrating PBL with the use of available communication technologies. The benefits and experiences of PBL are focused in Guo *et al.* [17]. The authors measured the cognitive and behavioral outcomes using questionnaires, interviews, observations, and self-reflection journals. Research by Granado-Alcón *et al.* [18] examined the impact of PBL on competency acquisition, and knowledge transfer, while study done by Chen and Yang [19] conducted a meta-analysis to compare the impact of PBL and traditional instruction on student academic achievement. Various phases required for implementation of PBL and their pedagogical values are discussed in the previous study by Žerovnik and Šerbec [20]. The authors also explored the integration of technology using various frameworks. Rio and Rodriguez [21] presented the use of PBL in the labs of mechanical and chemical engineering degrees. The students were asked to watch online video before the lab session to increase their motivation. The survey results indicated that PBL helped in improving the knowledge and students' skills like team work, decision making, and applying the knowledge to practice.

Study by Costello *et al.* [22] focused on the efficacy of collaborative models in mixed-methods of study and research and publication highlighting the value of hands-on experiences under PBL. Work done by Nazarov and Jumayev [23] illustrated the transformational potential of project-based laboratory assignments, to foster digital competencies and problem-solving skills. Similarly, the study carried out by Almulla [24] examined the PBL's impact on student engagement. The authors used structural equation modeling on 124 teachers' data. The results confirms that PBL enhances students' engagement by fostering knowledge sharing and discussions. Collaborative PBL was implemented for students, learning the training method course for managing training programs for older adults [7]. The result of this collaborative learning technique showed improved knowledge, attitude, and skill indicating overall growth. Previous studies [25], [26] showed the effectiveness of OBE in empowering student performance, by integrating PBL within OBE frameworks to enhance educational outcomes. Moreover, several studies [27]–[29] focused on PBL's implementation in engineering higher education, emphasizing its role in promoting professional project management skills, and enriching teaching experiences. Thus, the literature review highlights the utilization of PBL within the OBE framework that helps in fostering experiential learning, critical thinking, and holistic skill development among students.

3. METHOD

The AI course is offered as a program elective to the third-year IT students. The 56 and 58 students from the IT program opted for this subject in academic year (AY) 21-22 and 22-23, respectively. Currently, AI is the most rapidly growing technology and is revolutionizing the way in which we are living and working. This course gives the students the knowledge and skills to create innovative solutions for societal benefits. The students learn to apply AI techniques for problem solving. Use of various active learning techniques, while teaching this course, benefits the students in understanding the core concepts. Different pedagogy techniques were used for the active participation of the students in the theory as well as laboratory exercises. At the beginning of the semester, the students were informed about the active learning techniques that would be used for the course. To study the effect of active learning, techniques like case study, expert lecture by industry person, flipped classroom were implemented for the theory content of the course while PBL was adapted for the laboratory. The AI course has a separate theory and laboratory section. For the laboratory course, PBL was adapted that is divided into three phases: topic identification, case study, and learning by doing. Figure 2 shows the PBL framework used in the AI course.

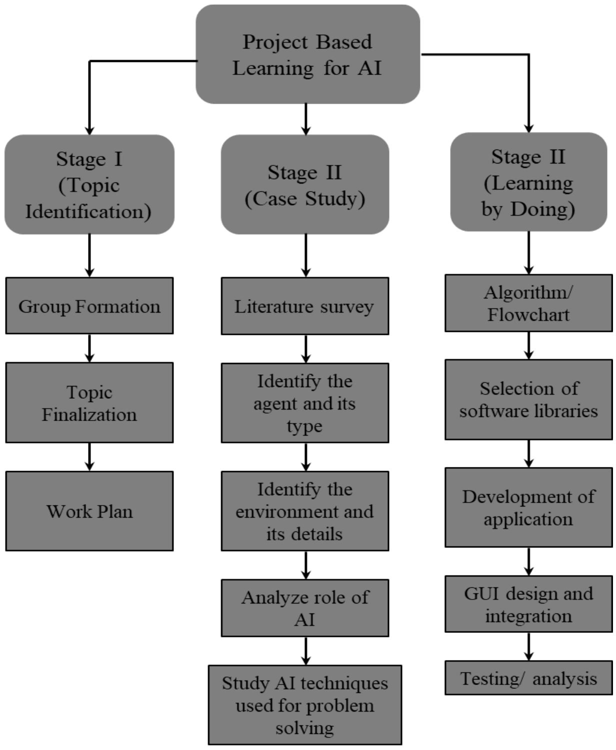


Figure 2. PBL framework used in the AI course

3.1. Case study

Case study is a wonderful tool for active learning in higher education [25], [26]. The students can comprehend and analyze real world examples. This helps them in critical thinking and promotes collaborative thinking. It helps students understand how the concepts they learn in the theory course can be applied in practical real-life examples, thus making the learning more relevant. It makes students gather additional information in order to thoroughly understand the case.

Before starting the case study phase of PBL, real life AI applications were identified. Group formation was done with 3-4 students in one group and the work plan was prepared for streamlined execution. Working in groups was done to promote collaborative learning. The students were asked to study different real-life applications that use AI, and come up with one such case that they can present and discuss. The case study was thoroughly based on the AI concepts taught in the classroom during content delivery. The case study was presented to the teacher by the students in the form of a PowerPoint presentation. Few of the case studies the students selected for their presentation are listed in Table 1. Most of the students were fascinated with the gaming sector, hence in the AY 21-22 the theme for topic selection was decided as 'AI in gaming industry' while for the AY 22-23 the theme was 'AI trends in various sectors.'

Table 1. List of applications

Topics	
2021-2022	2022-2023
Missionaries and cannibals	Face recognition
Maze path finder	ChatGPT for cognitive behavioral therapy (CBT)
Sudoku solver	Emotion detection using AI
Pacman	AI virtual assistance
Checkers game	Speech recognition

3.2. Learning by doing

The next phase was implementation that involved learning by doing, where the students implemented the application that was studied in the previous phase. PBL is amongst the most effectual active learning techniques for higher education that takes learning to the next level. It provides a platform to the students in enhancing their skills for developing real life applications. This helps the students apply their learned knowledge and broaden their scope of knowledge. This is learning by doing. This technique ensures comprehensive development, critical thinking, collaborative learning, communication, and higher order cognitive skills.

Moreover, executing these projects required an interdisciplinary knowledge base, integrating concepts from computer vision, machine learning, data analytics, and domain-specific expertise. By working on projects that demanded knowledge from multiple disciplines, students developed a holistic understanding of AI applications, enhancing their ability to tackle complex, real-world problems effectively. The students used python programming with libraries like NumPy, pygame, and Tkinter. for developing the application. The rubric used for evaluating the PBL technique is given in Table 2. The students were informed about the assessment criteria at the start of the semester to ensure their readiness.

Table 2. Rubrics for assessment

Criteria	Needs improvement	Satisfactory	Good
Findings from the literature review with proper understanding	Did not refer research articles and no understanding	Referred research articles but limited understanding	Referred multiple research articles with clear understanding
Identify the type of agent and environment	Not able to identify	Able to identify without reasoning	Able to identify with reasoning
Algorithm used and the results obtained	Algorithm and results not explained explicitly	Algorithm and results explained partially	Algorithm and results very well explained
Developed application	Not up to the mark	Very limited features present in the application	Fully developed application
Analyze role of AI in application	Not able to analyze	Partial analysis	Complete analysis

4. RESULTS AND DISCUSSION

This research aims to examine the effect of incorporating PBL in the OBE system to improve higher education. PBL was carried out for the AI course, for the third year IT students. Its impact on the academic growth as well as overall personality growth of the students was validated using a statistical analysis approach and student feedback method. The results indicate that along with improved academic performance, the students also learned the importance of mutual support and collaboration which are key attributes of project management. Along with technical skill development other attributes like getting engaged in discussions, taking responsibilities, and developing social skills and teamwork were also cultivated.

4.1. Statistical analysis

A pre-test and a post-test were carried out to evaluate the impact of PBL on the technical concepts of the course. The marks obtained were used to study any notable differences regarding the academic performance of the students for the given course. The mean of the pre-test and post-test marks are shown in Table 3. A positive difference between the mean test marks signifies the improvement in the course knowledge and understanding of the student. To verify the obtained results, a paired t-test was used for the statistical analysis. Paired t-test was employed to ascertain if there was a substantial difference between the two means. Testing is done on the following null hypothesis (H_0): there is no substantial difference between the mean marks of the students. The alternate hypothesis (H_a) is: there is a substantial difference between the mean marks of the students. Hypothesis testing was done using the statistical data of the pre-test marks and post-test marks. Table 4 shows the result of the analysis. The calculated paired t-test value is greater than the table value. Hence, we reject the null hypothesis claiming that there is a significant difference between the mean marks of the students.

Table 3. Mean values of the pre-test and post-test marks

Year	Pre-test mean (%)	Post-test mean (%)	Difference (%)
21-22	63.34	71.3	7.96
22-23	72.88	81.5	8.62

Table 4. T-test outcomes of the pre-test and post-test marks

Parameters	AY 21-22	AY 22-23
Mean	4.76	5.103
Standard deviation	2.76	4.59
Standard error	0.37	0.60
Calculated paired t-test value	12.88	8.46

(Two tailed 95% confidence interval)

4.2. Student feedback and impact analysis

Along with testing the students' academic achievements, their overall growth was also studied. Student feedback was taken based on their learning. The feedback was collected for two academic years 21-22 and 22-23. AI is a program elective for third year IT students. A total of 56 and 58 students opted for the AI course in AY 21-22 and 22-23 respectively. Out of these 48 and 51 students responded to the feedback questions in AY 21-22 and 22-23 respectively. The questionnaire was based on two perspectives: enrich the course knowledge and growth in interpersonal skills after completion of PBL. Figure 3 shows the student responses related to enrichment of the course knowledge in form of ratings: excellent, good, and satisfactory.

Figure 3(a) shows the enhancement in the practical knowledge of the students after the PBL experience. Figure 3(b) indicates the enhanced self-learning capability of the students. Figure 3(c) shows the improvement in students for applying the studied knowledge to the practical problems. Figure 3(d) indicates the upgraded ability of the students to design solutions to practical applications. Figures 3(e) and 3(f) shows the refinement in graphical user interface (GUI) development and integration and improvement in testing and analyzing the results achieved respectively. Overall, Figure 3 indicates how implementation of PBL, helped strengthen the course knowledge, and also helped the students to map the concepts learned in theory classes with the real-life applications. Table 5 shows the questions related to interpersonal skills development in the questionnaire answered by students and Figure 4 shows the student's responses for interpersonal questionnaire. Figures 4(a) and (b) shows the responses for AY 21-22 and 22-23, respectively.

4.3. Discussion

The validation results indicate the importance of introducing PBL on the holistic development of higher education students, particularly within technical disciplines. The results obtained implies the following: i) PBL leads to enhanced student engagement as it involves real-world problems that can motivate students. This higher engagement can induce better retention rates and deeper learning; ii) PBL helps in making education more relevant to industry needs as it bridges the gaps between theoretical knowledge and practical application. This helps the students understand the applicability of their learnings; iii) PBL encourages students to take charge of their own learnings, leading to a mindset of lifelong learning; iv) Engineering projects often require knowledge from multiple disciplines. PBL encourages the integration of concepts from various fields, promoting a holistic approach to problem-solving; and v) Introducing PBL in technical disciplines like engineering promotes the demonstration of students' capabilities and readiness for professional challenges.

In general, PBL aligns well with the demands of engineering education, equipping students with the necessary skills, mindset, and experience to excel in their professional practice. PBL may require collaboration with industry partners to provide students with real world problems to solve. Such collaborations help in strengthening the ties between academia and industry leading to more opportunities for internships, job placements, and joint research projects. It also ensures that the curriculum remains relevant to current industry practices and technologies.

Educators should continue to explore innovative approaches to accommodate diverse learning styles and leverage technology to facilitate collaborative learning experiences through effective teachers professional development programs [30], [31]. Such development programs can significantly enhance teaching quality and overall educational outcomes by introducing teachers to modern assessment methods, including formative and summative evaluations, rubrics, and peer assessments. This ensures more effective measurement of student progress and learning outcomes.

Integrating PBL can be done at different levels of curriculum starting with small scale projects in the first or second year, increasing complexity of projects in the third year and a comprehensive capstone project in the final year. Thus, incorporating PBL in engineering curriculum, fosters a hands-on, student-centered approach that not only reinforces technical competencies but also nurtures critical non-technical skills such as teamwork, communication, and lifelong learning giving them deeper understanding of engineering principles.

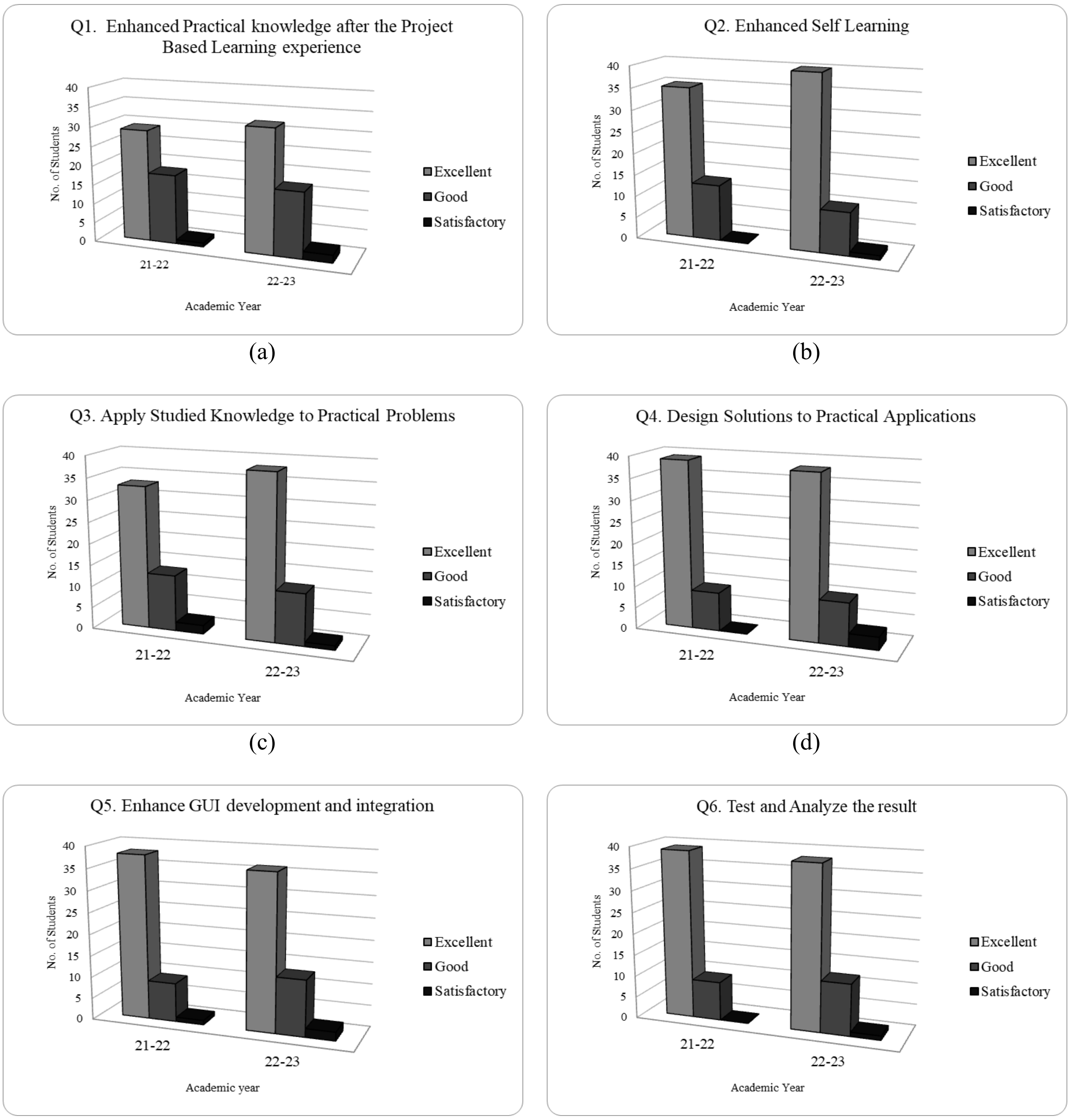
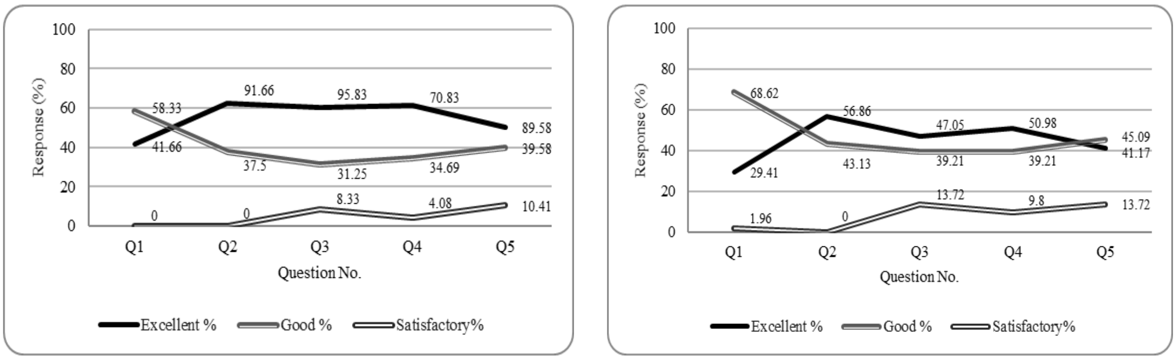


Figure 3. Student's responses to enrichment in course knowledge: (a) enhancement in practical knowledge, (b) enhanced self-study, (c) application of studied knowledge, (d) design solutions for practical applications, (e) enhancement in GUI development and integration, and (f) enhancement in testing and analyzing results

Table 5. Feedback questionnaire

Question no.	Interpersonal skills
Q1.	Improve the documentation and presentation skills
Q2.	Promote collaborative learning
Q3.	Improve communication skills
Q4.	Strengthen project planning and meeting submission deadlines
Q5.	Upgrade programming skills



(a) (b)

Figure 4. Student's responses for interpersonal questionnaire: (a) AY 21-22 and (b) 22-23

5. CONCLUSION

This research reports a structured PBL framework that involves case study and learning by doing pedagogy techniques. This active learning strategy was implemented for the AI course for the third year IT students. The study focused on evaluating the enhancement of technical expertise, including problem-solving and algorithmic thinking, as well as non-technical competencies, including effective communication, teamwork, and a disposition towards lifelong learning. The statistical analysis done indicates improved course knowledge and basic concepts while the feedback taken from the students at the end of the course reflects the comprehensive growth of the learners' that include both technical and non-technical skills like project enhanced course knowledge, management skills, increased cooperation, leadership, and improved interpersonal skills. The results signify that the PBL technique stimulates critical thinking and higher cognitive level thinking in the learners. It helps to bridge the disparity between theoretical concepts and its real-world implementations. It also promotes self-learning, collaborative learning, time and resource management, perseverance, and self confidence that are a part of project management skills. The integration of PBL in an OBE framework holds immense promise for enhancing the quality and effectiveness of higher education, particularly in the field of engineering. In the future, PBL can drive innovation in curriculum design, pushing educators to create more interdisciplinary and integrative learning experiences and strengthen the ties between academia and industry.

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Anagha Kulkarni	✓								✓					

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author [RB], upon reasonable request.

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