

# Enhancing Machine Learning Skills Among Undergraduates Through Project -Based Learning: A Mixed Method Approach

Kaushik Mallibhat<sup>1</sup>, Satish Chikkamath<sup>2</sup>, Ramesh Ashok Tabib<sup>3</sup>, Suneeta V. Budihal<sup>4</sup>, Nalini C Iyer<sup>5</sup>, Uma Mudenagudi<sup>6</sup>, Indra R<sup>7</sup>

<sup>1,2,3,4,5,6</sup> Department of Electronics and Communication Engineering, KLE Technological University, Hubballi, India

<sup>7</sup>Indian Institute of Technology Bombay, India

<sup>1</sup>kaushik@Kletech.ac.in <sup>2</sup>chikkamath@kletech.ac.in <sup>3</sup>ramesh\_t@kletech.ac.in

<sup>4</sup>suneeta\_vb@kletech.ac.in <sup>5</sup>nalinic@kletech.ac.in <sup>6</sup>uma@kletech.ac.in <sup>7</sup>indra.r@iitb.ac.in

**Abstract**— Preparing engineering graduates with practical machine learning skills is crucial in the current era of artificial intelligence. To enhance practical machine learning skills among electronics engineering students, Project -Based Learning (PBL) pedagogy was implemented. To evaluate the effectiveness of the PBL pedagogy, the proposed study investigated the outcomes and experiences of the stakeholders. The study focused on two research questions “What is the impact of transitioning from traditional approach to PBL approach on Machine Learning skills among undergraduate engineering students?” and “What are the perceived benefits and challenges of implementing Project -Based Learning (PBL) in a machine learning course, as experienced by both undergraduate engineering students and faculty?” In the study participants were purposely sampled and twelve students participated in the Focus Group Discussion (FGD) and three faculty participated in the semi -structured interview. The data from FGD and semi -structured interview was used to arrive at the perceived benefits and challenges faced by the faculty and students by implementing Project -Based Learning (PBL) in a machine learning course through thematic analysis of the data. Further, to perform impact analysis, students’ scores and attendance were considered from control group and experimental group to determine the impact of PBL pedagogy. Student data from two academic years was considered to perform impact analysis. The students in the academic years without PBL as pedagogy is considered as ‘control group’ and students with PBL as pedagogy is considered as ‘experimental group’. The proposed study is an empirical and quasi-experimental study with mixed-methods design aiming at measuring the impact of PBL initiative on students and faculty. For the quantitative analysis, the data from three academic years is considered while for the qualitative analysis, data was collected through semi structured interviews from three faculty members, common across the three course deliveries were considered while six students from two academic years of PBL implementation were purposively sampled to participate in the FGD. Quantitative analysis shows that the transition from traditional mode of delivery to PBL mode of delivery helped students to improve their machine learning skills and the impact was evident through changes in the mark’s distribution range (score band range). The initiative helped the students to translate the machine learning skills into publications. The initiative resulted in 70 Scopus indexed publications and one Q1 journal publication. Qualitative analysis of data from FGDs

and interviews revealed the benefits and challenges experienced by students and teachers. The analysis highlighted the importance of processes, resources, scaffolding models, and the teacher’s

transition from lecturer to mentor within the PBL environment. Notably, the study found that course outcomes extended beyond the immediate course, impacting students’ subsequent projects and career interests.

**Keywords**— Machine Learning, Project Based Learning, Engineering Education, Mixed Methods

**JEET Category**—Research

## I. INTRODUCTION

**M**ACHINE learning is a three-credit course offered to third-year electronics and communication engineering students at the University. The course emphasizes on the concepts of supervised, unsupervised, and self-supervised learning methods. The course demands prerequisites of statistical methods, linear algebra, probabilistic theory, and Python programming. At the end of the course, students’ learning was evaluated through written exams and implementation assignments. The conventional black board teaching approach with assessments did not equip students with necessary machine learning skills. Thus, faculty team carried out SWOT analysis (Helms and Nixon, 2010) to introspect the course delivery and arrive at the list of changes to be made for the next delivery of the course. The action items from the SWOT analysis were to adopt a pedagogy to enhance the students’ machine learning skills, channelize the students’ learnings and skills through a project. The authors identified PBL as a pedagogical intervention to address the identified weakness and encash the opportunities in the machine learning course. So, a comprehensive review was carried out by author1 to understand the different PBL frameworks (Du et al., 2009; Guerra et al., 2021; Mendoza & Wagner, 2025; Kokotsaki et al., 2016; Thomas, 2000; Larmer & Mergendoller, 2010; DeFillippi, 2001 Krajcik & Blumenfeld, 2006); Morgan, 1983; Anazifa &

Kaushik Mallibhat

Department of Electronics and Communication Engineering, KLE Technological University, Hubballi, India  
kaushik@Kletech.ac.in

Djukri, 2017; Frank et al., 2003; Palmer & Hall, 2011) and choose an appropriate framework for the machine learning course. The authors identified 'PBL for critical contestability' [2] as the reference framework and initiated the course re-design process. The details of the PBL frameworks, and the justification for the choice of PBL for critical contestability model is discussed in the related works section of the paper.

#### *A. PBL as a New Pedagogy – Design and Delivery of the Course*

Transitioning from traditional approach to PBL approach demanded changes at course design, delivery and assessment levels. The authors carried out a comprehensive survey to understand the existing PBL models and frameworks. The gold standard PBL framework proposed by Buck Institute of Education (Mendoza & Wagner, 2025) and PBL model for critical contestability were found to be apt in our scenarios. The frameworks and models were selected by matching the objectives of the course with the aspirations of PBL models and frameworks. To adopt to the PBL for critical contestability framework (Du et al., 2009), there was a need for formulation of new course outcomes, designing input elements, process elements and output elements. The adaptations began with the formulation of new course outcome 'Design and develop end-to-end machine learning solutions, encompassing data preprocessing, selecting optimal models, model training and model deployment for practical applications' The design of process elements included emphasis on 'scaffolding methods' and 'nature of student engagement'. The authors used PBL scaffolding framework (Mallibhat, 2024) to design the process elements. The design began with the decision of early commencement of the course (during vacation) with emphasis on pre-requisites and python programming. Student engagement was planned in three phases, and phase-wise details are shown in Figure 1.

Phase I focused on the 'upskilling' of students and targeted addressing the identified weakness. Authors identified a need to upskill the students in terms of 'Python programming skills,' 'conceptual clarity of ML algorithms, and 'technical writing skills.' Phase I of the student engagement started during the summer vacation, and every day, students spent 90 minutes attending in-person lectures on machine learning concepts and 90 minutes upskilling in Python programming. A set of faculties delivered the machine learning course content for the initial 90 minutes, followed by a Python programming hands-on session. To scaffold students during hands-on sessions, the author 1 created a set of 51 videos on Python programming from scratch. Students were made to watch the videos in the laboratory in the presence of instructors and instructors helped students for troubleshooting and debugging. Customized videos were created to ensure shared learning among the students required to handle machine learning projects and avoid duplicating the efforts of faculty across six divisions of students.

Formative assessments were scheduled every Saturday for 90 minutes, focusing on ML concepts and programming skills.

During phase I, students were exposed to several online learning platforms, including 'W3 schools', 'Analytics Vidhya,' and Coursera' and encouraged students to complete online courses.

To address another identified weakness, there was a need to upskill students on technical writing skills, on every alternative Saturdays. Students participated in the technical writing workshops, during which students were introduced to how to find appropriate technical papers, how to read technical papers, how to perform literature review, how to synthesize the information from the literature. Identify gaps in the literature and formulate the objectives of the proposed study. While the students underwent the technical writing workshops, they were encouraged and motivated to translate their machine learning course project into a publication. Phase 1 spanned twenty-five days, and every student was engaged through in-person classes for 75 hours towards upskilling their Python programming skills, technical writing skills, and ML conceptual clarity. In addition, every student spent a minimum of 10 hours to complete the online courses and assignments. Phase -I, helped the course instructors to complete the prescribed course content thus helping both students and course instructors to focus on the projects.

Phase 1 helped the authors address the identified weakness, including upskilling the students towards Python programming, technical writing, and the time crunch.

Phase 2 focuses on the formulation and implementation of projects. Phase 2 began with student team formation, allotment of application area, and a mentor. The course is a core course and did not had flexibility to make multidisciplinary team and hence the team formation was made with in the division and mentor allotment was done based on the faculty expertise. Figure 3 shows eight application areas, or the broader themes of projects, and student teams selected the application areas for their projects based on their area of interest. Student teams were encouraged to explore other areas of their interest as well. Though there was no compulsion for the student teams to select the projects adhering only to the prescribed areas, course teachers observed that the list of areas helped students set directions for the literature survey.

Scaffolding during phase II was done through a set of three formative reviews. Review-I focused on scoping the problem, thorough literature review, identification of gaps and setting the objectives of the project. Review-II focused on conceptual framework of solution and proficiency of using EDA tools while review-III focused on presentation of results, comparison of obtained results with state of art methods. Rubrics based assessment was carried out during all the three reviews. Providing constructive feedback and tracking the team progress was the aim of the reviews. Access to computation facility for all the project teams to train the ML models was extremely challenging and University's central computing facility was used and computation facility was allotted to division wise student teams based on need and time-sharing basis. Though the authors were able to touch on the weakness 'resource crunch'

but could not completely address it.

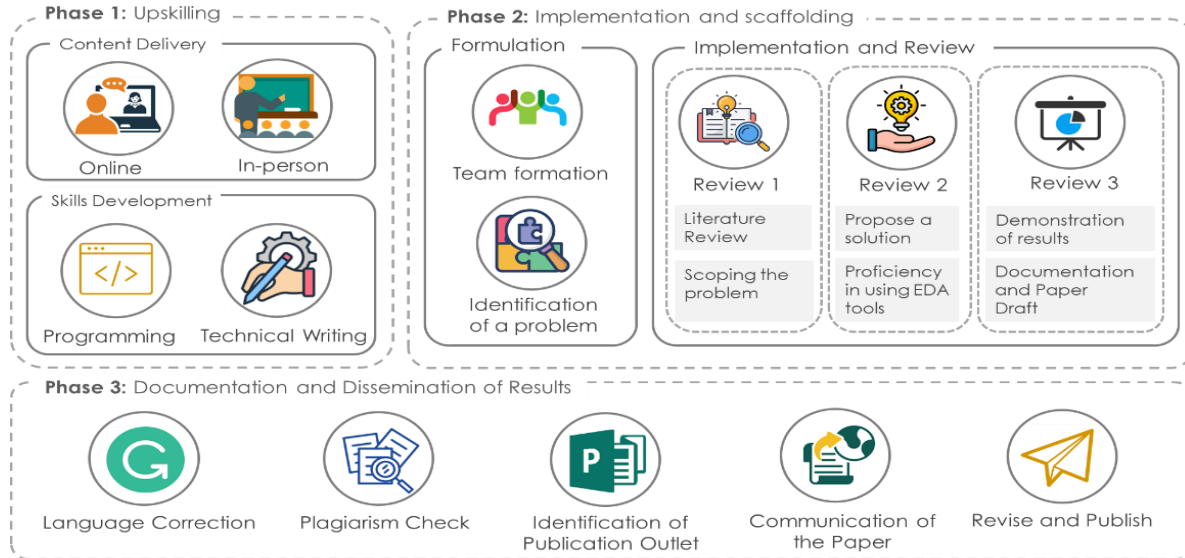


Fig. 1. Phase wise implementation details of machine learning course



Fig. 2. Application areas/ Themes of the project

TABLE I  
TOOLS AND TECHNOLOGIES USED DURING THE PEDAGOGICAL INTERVENTION

Phase	Name of the tools/technology	Purpose
I	Moodle based LMS	Content delivery through videos, Assignment submissions Tracking the student progress Collecting the surveys, feedback
	Google Colab	Handson for python programming Execution of ML algorithms Testing the ML models
	YouTube	Content delivery
	Citavi, Zotero	Literature review
II	Overleaf, Microsoft office	Presentations and paper writing
	DGx, Workstation	Computations and training the ML model
	GitHub	Data sharing and maintaining the repos
	Turnitin	Plagiarism check
III	Grammarly	Sentence level corrections
	Quill bot	Reframing the sentences
	ChatGPT	Restructuring the paragraphs
	Gemini	
	Conference Management tools including CMT, easy chair, EDAS	Paper submission

Phase- II spanned for a duration of 120 days and focused on technical contributions while providing feed to phase -III. The amount of time the team spent on the project was proportional to the complexity of the project. The Phase - 3 focused on the output elements of the PBL framework. The expected outcome from the students were in terms of building a ML model to perform the identified task.

Phase III provided an opportunity to translate the project outcomes into publications. The draft versions of the papers submitted during review III of phase II undergoes quality check process in terms of 'grammar' and 'plagiarism'. The papers not satisfying the quality checks will undergo major revisions and resubmit for the review. Course instructors played an important towards pushing the papers to suitable publication outlets. The list of publication outlets was chosen based on the theme of the conference and (Scopus/Web of Science). Unlike phase -I and II, the time spent by student teams was blurry since it was dependent on the timelines of the conference/journal. Phase -III emphasized on addressing the identified opportunities and threats mentioned in the figure 1. During all the three phases, scaffolding through technology was the backbone for the successful implementation of PBL framework. Table 1 shows the summary of various tools and technologies during each of the phases. Technology helped at every phase either to carry out the work or improvise the work. The next sections of the paper discuss about the research questions, findings and outcomes of the pedagogical interventions.

### B. Research questions

Despite the existing integration of PBL in engineering curricula, the proposed study examines the efficacy of adapting conventional courses to a PBL approach, with an emphasis on developing the skill sets necessary for engineers to thrive in an AI -centric world. Transition from conventional to PBL approach was an initiative and the authors want to investigate the effectiveness of the initiative through the following research questions

RQ1: What is the impact of transitioning from conventional approach of teaching to PBL approach on Machine Learning skills among undergraduate engineering students? RQ2: What are the perceived benefits and challenges of adopting Project-Based Learning (PBL) method in a machine learning course, as experienced by both undergraduate engineering students and faculty? The hypothesis was "The implementation of a Problem-Based Learning (PBL) approach in a machine learning course significantly enhances students' understanding and application of machine learning concepts and skills". So, research questions, hypothesis helped us to navigate through the investigations. The authors used quantitative methods to investigate the RQ1 and qualitative methods to investigate RQ2. The further sections of the paper discuss the related PBL frameworks in the related works section followed by sampling details, data collection methods, analysis method and our findings through quantitative and qualitative methods in the

subsequent sections of the paper.

## II. PBL ELEMENTS, MODELS AND FRAMEWORKS- A CONNECTION TO WHAT LITERATURE SAYS?

Project-Based Learning (PBL) is a well-accepted and promising pedagogy in indexing education. Literature describes various elements, models, and frameworks to be considered during the design of PBL courses. After a comprehensive literature review of different models and frameworks, authors identified a gap in terms of lack of empirical works on the adaptation of PBL for machine learning education at the undergraduate level PBL. Thus, authors made an evaluated decision to choose the gold standard PBL framework described by the Buck Institute of Education as a reference framework to design the course in the current study. This framework describes the design elements and teaching practices to be adopted for the design and delivery of the PBL course. Further, the literature, such as that described by authors (Thomas, 2000; Larmer & Mergendoller, 2010) categorizes PBL models into five types based on the expected outcomes or aspirations of the course. The five PBL models include 'PBL towards improving propositional knowledge' (focusing on factual understanding), 'PBL to improve disciplinary boundaries' (integrating knowledge within a course), 'PBL for transdisciplinary learning' (combining knowledge from multiple courses), 'PBL for professional action' (applying knowledge to real-world problems), and 'PBL for critical contestability' (encouraging analysis and debate). The selection of the 'PBL for professional action' model was a deliberate choice, driven by the specific learning objectives of the machine learning course. Machine learning, by its nature, is a practical and application-oriented field. Students are expected not only to understand theoretical concepts but also to apply them to solve real-world problems. For instance, a project requiring students to develop a predictive model for a real-world dataset, like predicting customer churn or analysing medical data, perfectly aligns with the 'PBL for professional action' model. This model emphasizes the development of skills needed to apply theoretical knowledge to solve real problems. It helps students to see the direct relevance of their learning to real-world scenarios. This approach, in turn, fosters a deeper understanding of machine learning principles and enhances students' ability to work effectively in professional settings. The alignment between the model's essence and the course outcomes ensures that students not only acquire theoretical knowledge but also develop the practical skills necessary to succeed in the field of machine learning. The study of various PBL frameworks, models helped the authors to design input, process and output elements in the course. The proposed framework illustrates the empirical advancement of the existing body of knowledge of various PBL models for adaptation towards AI based courses in undergraduate engineering. The comprehensive literature review helped the author 1 to arrive at detailed synthesis (Ref anonymized and will be added in CRC) as well curate PBL elements for the proposed ML course with PBL implementation and represented through Table II. Further section of the paper discusses about the adopted

methodology for research design, participant selection for the study, quantitative and qualitative analysis of the findings.

### III. METHODOLOGY

Conventional pedagogical approach was adopted in the machine learning course adopted till the academic year 2022 - 23 and PBL was initiated during the year 2023 -24. The authors aimed at evaluating the new approach through two research questions RQ1: What is the impact of transitioning from conventional approach of teaching to PBL approach on Machine Learning skills among undergraduate engineering students? RQ2: What are the perceived benefits and challenges of adopting Project -Based Learning (PBL) method in a machine learning course, as experienced by both undergraduate engineering students and faculty?

#### A. Research Design Overview

To investigate the research questions, the authors used mixed methods approach in the study. To investigate the impact of transition from conventional approach of teaching to PBL approach the authors used quantitative methods and qualitative experimental design. For the quantitative analysis, students' assessment data was considered. Students of the Academic Year (AY) 2021 -22 and 2022 -23 were considered as control group while students of AY 2023 -24 as experimental group. All cohorts were drawn from the same academic program with no changes in the admission criteria, curriculum framework across the selected years. Furthermore, institutional infrastructure, faculty expertise remained same across the batches. As a result, the observed differences in the learning can be attributed to the pedagogical intervention. Sample equivalence between the control and experimental groups was ensured to establish a valid baseline for comparison.

On the other hand, for qualitative analysis, Focused Group Discussion (Hennink, 2013; O. Nyumba et al., 2018; Tümen Akyıldız & Ahmed, 2021) was carried out with students while semi-structured interviews (Adams, 2015; Kallio et al., 2016; Adams, 2010) were carried out with faculty.

#### B. Participants

The data for the study was collected from two categories of stake holders: faculty and students. Three faculty participated in the semi-structured interviews and the faculty were sampled based on their experience of teaching machine learning course. Two faculty had prior experience of handling the machine learning course and were part of SWOT analysis while another faculty handled the Machine learning course for the first time. Semi structured interviews with the faculty were scheduled in an online mode and recorded using Microsoft teams. The recordings are preserved in the Google drive. The conduction of the interview with the faculty, drawing inferences was carried out by the last author of the paper. On the other hand, Focus Group Discussion (FGD) was conducted with the students. The students were purposely sampled considering the 'status of their publication' and 'division' as the criteria. Twelve students participated in the study and no incentives were given to the participants. The required permissions to conduct the study was obtained from the University's Institutional Review Board (IRB).

#### C. Researcher Description

All the authors (except the author 7) of the study were the course teachers who were part of design, delivery and assessment of machine learning course while the authors 7 is a researcher from outside the organization, who conducted faculty interviews to avoid the bias in the data. Formulation of questions for semi-structure faculty interview, interview scheduling, conduction, transcription, member checking and analysis of the semi- structure interview was carried out by author 1,7. Author1 is a qualitative researcher and had a previous experience of successful PBL implementation (anonymized for peer review) in a first-year course and also had an experience of handling the machine learning course. Author1 conducted FGD for the students.

TABLE II  
PBL ELEMENTS DESIGN AND OPERATIONALIZATION

Type of PBL element	Description of element	Operationalization in the current study through
Input	Student teams	1. Mono-disciplinary team (belonging to electronics and communication engineering and same division of class) 2. Team size=3 with gender diversity
	Teacher	Pair of teachers (A combination of ML and domain expert)
	Expected learning	1. Use python programming to implement ML algorithms 2. Apply ML algorithms to solve problems in the areas of health care, automotive, education, agriculture and manufacturing 3. Evaluate the performance of various ML models
Process elements	Type of project and problem scenario	1. Open ended 2. Exists multiple solutions
	Role of a teacher Scaffolding models	Reviewer, mentor, challenger, navigator 1. ST-Scaffolding through Single Teacher 2. MT-Scaffolding through Multiple Teachers 3. PE-Scaffolding through Project Exhibition 4. GR-Scaffolding through GIT Repositories 5. RL-Scaffolding through Reinforcement Learning 6. NM-Scaffolding through Novel Metrics of Learning 7. OP-Scaffolding through Online Platform
Output	Formative assessment	Written exams to test conceptual clarity
	Public product	Publication and presentation
	Summative assessment	Project demo

Formulation of questions, pilot study, sampling, scheduling, conduction, transcription and member checking was carried out by author1 while the analysis part including emerging codes and thematic analysis was carried out by other authors.

#### IV. FINDINGS

The study aimed to evaluate the impact of transitioning from a traditional teaching approach to a Project-Based Learning (PBL) model in a Machine Learning course offered to undergraduate engineering students. The authors used mixed methods in the study and to investigate the research questions. Quantitative methods are used to answer RQ1 and qualitative methods are used to answer RQ2.

*RQ1:* What is the impact of transitioning from conventional approach of teaching to PBL approach on Machine Learning skills among undergraduate engineering students?

The impact of transition from conventional approach to PBL approach was analyzed from two dimensions namely 'Student learning' and 'outcomes. To analyze the student learning, the authors compared the student summative assessment scores of control group with the experimental group. To compare the performance students were categorized into seven classes. Students with score >91 were considered as S grade, while 81 to 90 as A, 71 -80 as B, 61 to 70 as C, 51 to 60 as D, 41 to 50 as E and less than 40 as F grade. Figure 4 shows the students grade distribution across the control group and experimental groups. Following are the inferences drawn towards analyzing the impact.

##### 1. Significant shift toward higher grades in AY 2023 –24

A dramatic increase in the percentage of students receiving the 'S' grade (from 0% in 2021 –22 and 0.7% in 2022 –23 to 50.2% in 2023 –24).

##### 2. Decline in mid and lower grades in 2023 –24

Grades C, D, E, and F show a consistent decline, especially in 2023 –24. For example, 'C' dropped from 20.8% in 2021 –22 to just 5% in 2023 –24 and no students received an 'F' in 2022 –23 or 2023 –24.

##### 3. Improvement trend over time

The distribution line for each year shifts leftward over time, indicating a move toward higher academic achievement. The AY 2021 –22 and AY 2022 –23 distributions are more balanced across A to D grades, while 2023 –24 is heavily skewed toward excellence.

##### 4. Possible effectiveness of PBL implementation

The steep improvement in AY 2023 –24 coincides with the adoption of the PBL approach, suggesting a positive impact on learning outcomes.

This supports the hypothesis that PBL enhances conceptual understanding.

The second dimension of the impact analysis is through the outcomes of the initiative. The PBL approach helped students to apply the acquired machine learning skills to solve a real - world problem. Thus, the PBL approach resulted in the

outcomes in the form of publications. A total of 70 Scopus indexed publications were recorded in the AY 2023 –24 while there were no publications in the AY 2022 –23 and 2021 –22. Division wise details of publications in the AY 2023 –24 are shown in the Table III. 68% of the publications were part of Springer LNNS series, 30% of the publications were part of IEEE xplore and 1.4% was part of Q1 journal. The publication distribution graph is shown in the figure 5.

Following are the inferences drawn from the table III 1. The throughput of the PBL approach 54.2 % indicates that PBL pedagogy helped students to elevate their machine learning skills to the level of solving real world problems by applying machine learning algorithms. 2. There is a stark disparity in performance across divisions, ranging from 0% to 95% throughput in spite of using common facilitation and scaffolding techniques. 3. There is a need for detailed investigation towards arriving at concrete reasons for nonperformance divisions. Clear evidence in the students' grades moving to higher grades, number of publications in the conferences serves as support towards holding the hypothesis 'The implementation of a Project-Based Learning (PBL) approach in a machine learning course significantly enhances students machine learning skills ' holds true.

However, with reference to table III, it was observed that publication through put across the same were not in the same range. Thus, necessitating the identification of the root cause for the drop in the publication throughput in two of the divisions.

*RQ2:* What are the perceived benefits and challenges of adopting Project -Based Learning (PBL) method in a machine learning course, as experienced by both undergraduate engineering students and faculty?

In the proposed work, authors used qualitative methods to investigate the perceived benefits and challenges of the PBL initiative from both students and faculty perspective. The authors collected the student's perspective through Focus Group Discussion (FGD) and faculty perspective through semi structured interviews. To collect students' diverse perspectives about benefits and challenges, FGD was chosen as a data collection method while deeper insights through one -to -one faculty interviews

##### A. Focus Group Discussion (FGD) With Students

Focus Group Discussion was carried out with students after the summative assessment was completed. FGD was carried out in a well -lit laboratory by two faculty members. One of the faculty members played the role of a session moderator and the faculty played a role of scribe. FGD was scheduled for 60 minutes. The FGD data was audio recorded along with scribe data. The students were purposely sampled such that there was representation from every division, both students of both paper published and unpublished categories. Twelve students

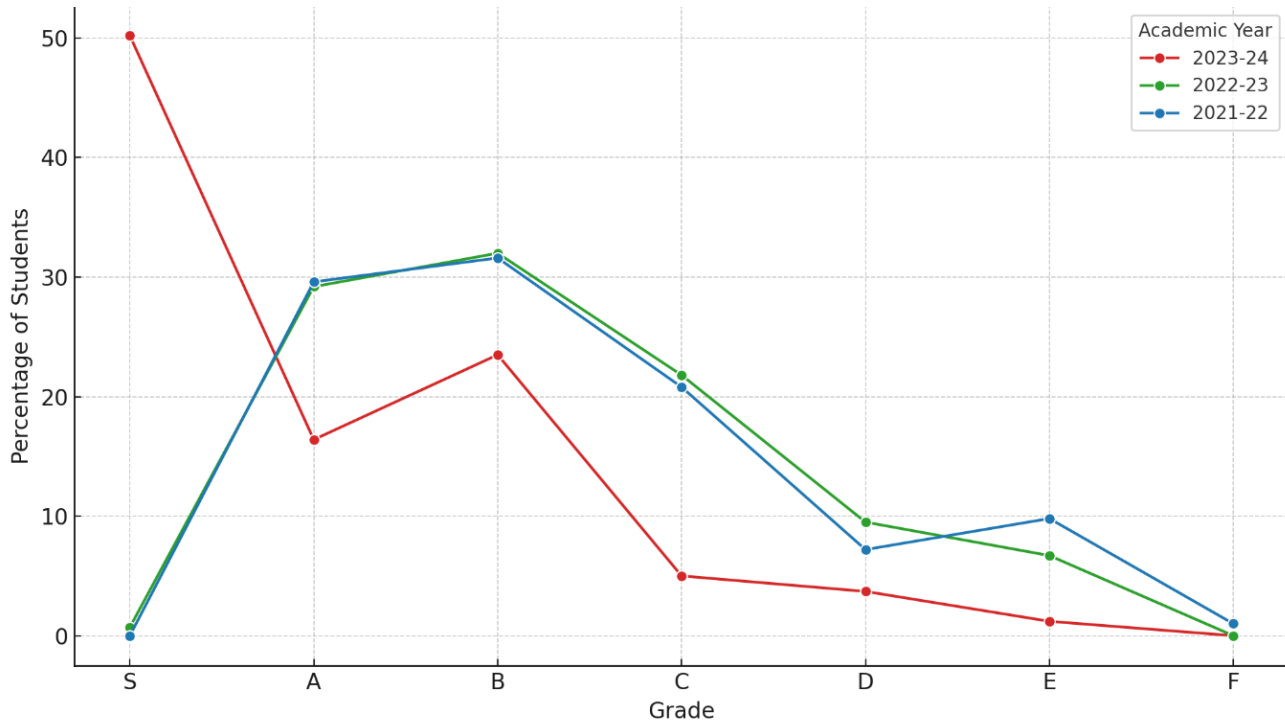


Fig. 3. Line graphs representing the grade distribution of students across academic years participated in the study and participation was voluntary, no

TABLE III  
DIVISION WISE PUBLICATION DISTRIBUTION DETAILS

Division	No. of student teams	No. of projects translated into papers	Non- translated papers	Throughput of the division in %
A	22	00	22	0
B	23	02	21	8
C	22	21	01	95
D	19	18	01	94
E	24	17	07	70.8
F	19	12	07	63
Total	129	70	59	54.2

incentives/perks were given for the participation. Informed consent was taken from the participants and the study was approved by Institution Review Board (IRB) at the University. The questions for the FGD had two introductory questions and six probing questions intended to extract details regarding benefits and eight questions to extract details regarding challenges and two wrap questions. Before the actual FGD, pilot study was carried out with two other students. The pilot study helps us to make modifications in few questions. The audio recorded data during FGD was transcribed using software and cleaning process was carried out. After transcribing the

FGD data, member checking process was carried out to ensure that intent of the participants is rightly captured. Inductive approach was used to arrive at the initial codes, themes and further refined the themes. Thematic analysis helped us to emerge two themes under the lens of benefits while the challenges faced by the students were categorized into three sub themes including time management, resource management and team work. The detailed themes, subthemes along with the student quotes are represented in the figure 5. Some of the student quotes where either they upvoted or intention was same, the authors have merged it.

The sub-themes emerged under ‘benefits theme’ further provides evidence that the proposed hypothesis holds true. However, the subthemes emerged under ‘challenges theme’ serve as feedback to our course re-design for the upcoming semester. The challenges identified are at operational level and needs action both at course level and department level.

**B. Focus Group Discussion (FGD) With Faculty**

To avoid bias in the data, author 7 who was not part of design and delivery of the ML course conducted semi -structured interviews with the faculty to record the responses. Interview questions had both introductory and probing questions that

align with the RQ2. Purposive sampling was done with the criteria of their experience in teaching the course and PBL pedagogy exposure. The interviews were conducted using Google Meet at the convenient time of interviewee with their consent. The videos were recorded followed by transcribing, data cleaning and member checking process. The themes, subthemes and supported faculty quotes are visually represented through thematic map in fig 6.

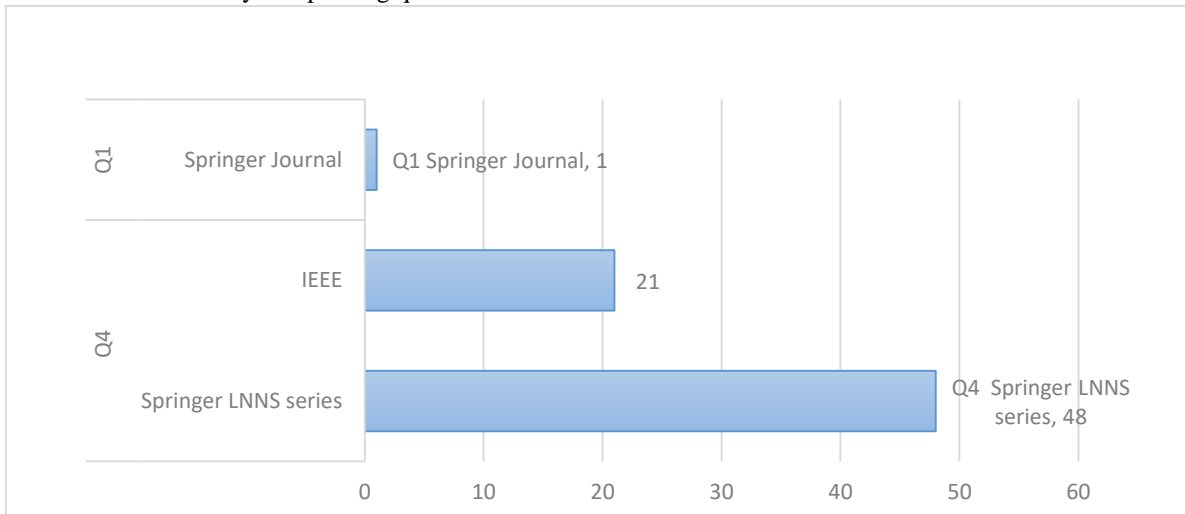


Fig. 4. Bar graphs representing the quartile wise distribution of publications from the ML course

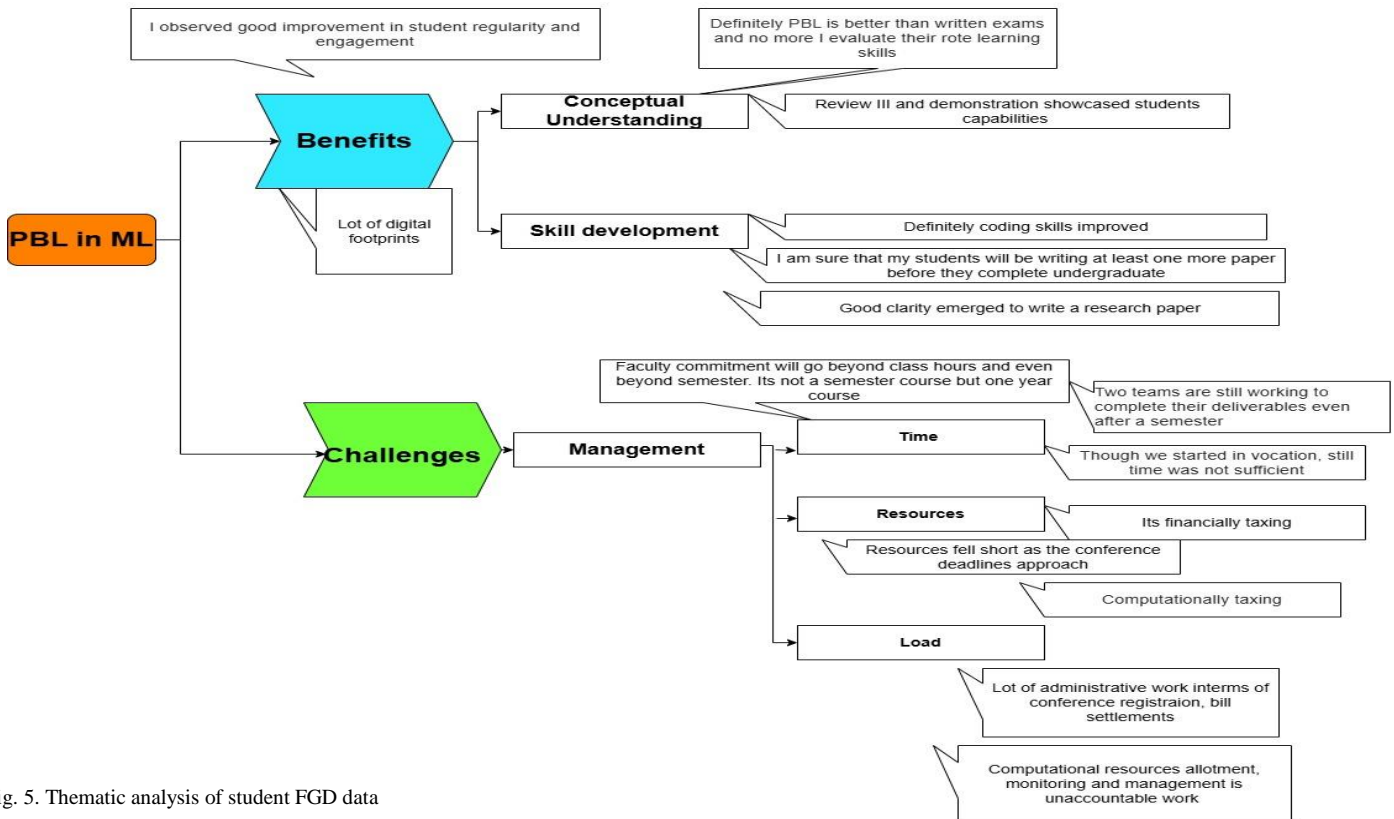


Fig. 5. Thematic analysis of student FGD data

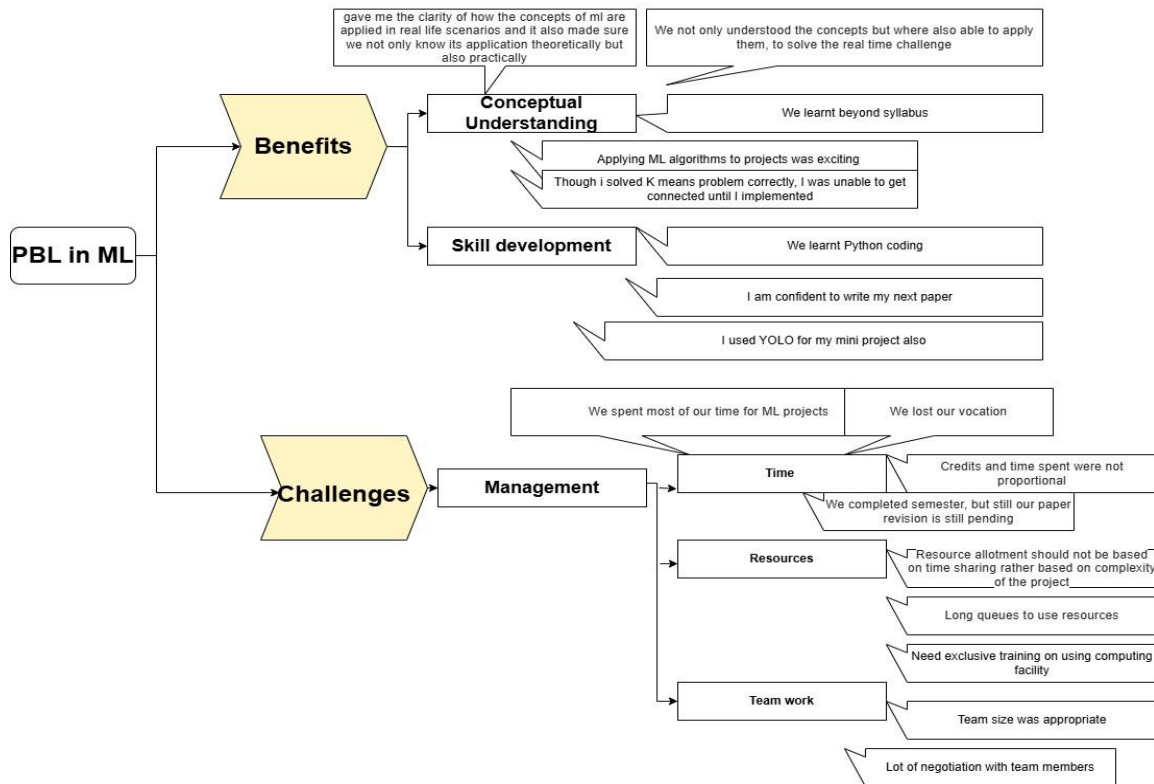


Fig. 6. Thematic analysis of faculty interview data

align with the RQ2. Purposive sampling was done with the criteria of their experience in teaching the course and PBL pedagogy exposure. The interviews were conducted using Google Meet at the convenient time of interviewee with their consent. The videos were recorded followed by transcribing, data cleaning and member checking process. The themes, subthemes and supported faculty quotes are visually represented through thematic map in fig 6.

## V. INFERENCES AND DISCUSSION

The proposed study used mixed methods to evaluate the effectiveness of PBL based machine learning course delivery for undergraduate engineering students. The effectiveness of the initiative was measured through student learnings, course outcomes, experiences of faculty and students. The evidences in the form of increase in the 'S' grades, skew towards higher grades, and number of student publications through the course holds the hypothesis true. Further the hypothesis was supported by qualitative methods through the quotes, sub themes, themes

emerged from the qualitative analysis. The proposed work demonstrates a replicable PBL framework to the educators and help students to prepare for contemporary AI world. In a nutshell, the initiative helped the students to take forward their projects to a publication level and demonstrate their machine learning practical skills at the cost of extra time, efforts for the students and financially taxing for the university. Further, the authors could not perform a direct comparison of the results with existing studies, as no prior work was identified that explicitly adopted a structured PBL framework for AI-related courses, despite an extensive literature review. The present study may therefore contribute preliminary insights toward the design of PBL frameworks for AI-focused courses. Future work may include detailed statistical analyses to explore learning patterns across different student cohorts. In addition, there is scope for conducting a longitudinal study to better understand the longer-term impact of the course on students' competencies and their preparedness to undertake machine learning-related projects in subsequent semesters. Further authors propose to include the problem statements from the industry partners (Nandi et.al, 2015) and demonstrate the projects during project exhibition (Mallibhat et.al, 2021) and consider to include 'public product' element of PBL framework.

## REFERENCES

- Adams, C. (2015). Conducting semi-structured interviews. In *Handbook of practical program evaluation* (pp. 492–505).
- Adams, E. (2010). The joys and challenges of semi-structured interviewing. In *Community Practitioner*, 83(7), 18–22.
- Anazifa, R. D., & Djukri, D. (2017). Project-based learning and problem-based learning: Are they effective to improve student's thinking skills? *Jurnal Pendidikan IPA Indonesia*, 6(2), 346–355.
- Baligar, P., Kavale, S., Joshi, G., & Shettar, A. (2018, November). Engineering exploration: A collaborative experience of designing and evolving a freshman course. In *2018 World Engineering Education Forum-Global Engineering Deans Council (WEEF-GEDC)* (pp. 1-5). IEEE.
- DeFillippi, R. J. (2001). Introduction: Project-based learning, reflective practices and learning. *Management learning*, 32(1), 5-10.
- Du, X., De Graaff, E., & Kolmos, A. (2009). PBL–Diversity in research questions and methodologies. In *Research on PBL practice in engineering education* (pp. 1-7). Brill.
- Frank, M., Lavy, I., & Elata, D. (2003). Implementing the project-based learning approach in an academic engineering course. *International Journal of Technology and Design Education*, 13, 273–288.
- Guerra, A., Chen, J., Winther, M., Kolmos, A., & Nielsen, S. R. (2021). *Educate for the future: PBL, Sustainability and Digitalisation 2021*.
- Helms, M. M., & Nixon, J. (2010). Exploring SWOT analysis—where are we now? A review of academic research from the last decade. *Journal of strategy and management*, 3(3), 215-251.
- Hennink, M. M. (2013). *Focus group discussions*. Oxford University Press.
- Kallio, H., Pietilä, A. M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing*, 72(12), 2954–2965.
- Kaushik, M. (2020). Evaluating a first-year engineering course for project based learning (PBL) essentials. *Procedia Computer Science*, 172, 364-369.
- Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving schools*, 19(3), 267-277.
- Thomas, John W. "A review of research on project-based learning." (2000).
- Larmer, J., & Mergendoller, J. R. (2010). Seven essentials for project-based learning. *Educational leadership*, 68(1), 34-37.
- Mallibhat, K. (2024). Scaffolding Models in a Project-Based Learning Course-A Case Study. *Journal of Engineering Education Transformations*, 37.
- Mallibhat, K., & Joshi, G. (2020). A systematic review on frameworks of project-based learning. In *Educate for the future: PBL, sustainability and digitalisation 2020* (pp. 538–550). Aalborg University Press. [https://vbn.aau.dk/ws/portalfiles/portal/357965178/AU\\_8th\\_PBL\\_2020\\_interaktiv\\_2.pdf](https://vbn.aau.dk/ws/portalfiles/portal/357965178/AU_8th_PBL_2020_interaktiv_2.pdf)
- Mallibhat, K., Chikkamath, S., Tabib, R., Nirmala, S. R., & Mudenagudi, U. (2022). Project-based learning in machine learning course: experience and outcomes. In *EDULEARN22 Proceedings* (pp. 1545-1551). IATED.
- Mallibhat, K., Humbi, N., Marebal, D., Joshi, G., & Kolhar, M. (2021, July). Project Exhibition In Engineering: A Case Study Of Design and Implementation Of Virtual Exhibition In First-Year Project-Based Learning Course. In *2021 International Conference on Advanced Learning Technologies (ICALT)* (pp. 416-418). IEEE.
- Mendoza, J., and K. Wagner. "Gold Standard Project Based Learning Designed as HQIM." *PBL Evidence Matters*, vol. 4, no. 1, Buck Institute for Education, 2025.
- Morgan, A. (1983). Theoretical aspects of project-based learning in higher education. *British Journal of Educational Technology*, 14(1), 66–78.
- Nandi, A., Bali, J., Kaushik, M., & Shirol, S. (2015). Industry-Institute interaction: An important step towards empowering skills of engineering students. *Journal of Engineering Education Transformations*, 103-107.
- O. Nyumba, T., Wilson, K., Derrick, C. J., & Mukherjee, N. (2018). The use of focus group discussion methodology: Insights from two decades of application in conservation. *Methods in Ecology and Evolution*, 9(1), 20–32.
- Palmer, S., & Hall, W. (2011). An evaluation of a project-based learning initiative in engineering education. *European Journal of Engineering Education*, 36(4), 357–365.
- Tümen Akyıldız, S., & Ahmed, K. H. (2021). An overview of qualitative research and focus group discussion. *International Journal of Academic Research in Education*, 7(1), 1–15.