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Impact of Active Learning Methods on Project-Based Learning (PBL): Enhancing Student Engagement and Outcomes

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Abstract— **This study examines the impact of active learning methods. Flipped Classroom, Collaborative Learning, and Case-Based Learning on Project-Based Learning (PBL) outcomes. Using a descriptive analytical quantitative approach, the performance of fifty-six Electrical Engineering students was evaluated across three assessment stages over a 10- week period. Data analysis through Exploratory Factor Analysis (EFA) revealed that these active learning methods significantly enhance student engagement and learning outcomes. The identified constructs demonstrated strong factor loadings in areas such as problem-solving, teamwork, and practical application. These findings suggest that integrating active learning methods into PBL effectively improves student performance and engagement, highlighting the need for further research on diverse pedagogical strategies and technological integration.**

Keywords— **Active Learning: Project-Based Learning (PBL): Student Engagement**

ICTIEE Track: **Pedagogy of Teaching and Learning**
ICTIEE Sub-Track: **Differentiated Instruction in Meeting the Needs of Every Student**

I. INTRODUCTION

The educators advance in their field, they continually adapt and refine their teaching strategies, embracing innovative approaches to foster deeper student engagement and understanding. Through years of dedicated practice, educators cultivate unique teaching philosophies that harmoniously merge established techniques with contemporary insights, resulting in a rich and impactful learning environment.

To foster a culture of knowledge-sharing and collaboration, professional development programs play a vital role in enhancing faculty skills and promoting a quality-focused institutional ecosystem. These programs, including training sessions, workshops, symposiums, conclaves, and conferences, facilitate the exchange of ideas, allowing educators to learn from one another and stay updated on best practices. By investing in faculty development, institutions can cultivate a supportive environment that encourages growth, innovation, and excellence in teaching. Create a community of practice where faculty can share their experiences and learn from each other.

One exemplary institution, a South Indian engineering college HITAM, has pioneered a faculty development initiative that sets a new standard in engineering education. By hosting "Faculty Conclaves" at the end of every semester, the college creates a vibrant platform for knowledge sharing and collaboration. Seasoned educators, who have undergone rigorous training in Outcome-Based Education (OBE) and the prestigious IUCEE International Engineering Educator Certification Program (IIEECP), come together to share their expertise and insights with all the other faculty members. Bell, S. (2010). This structured exchange of best practices and innovative approaches in teaching and learning has become a hallmark of the institution's commitment to excellence in education. Through these conclaves, the college fosters a culture of continuous learning, innovation, and mentorship, ultimately enhancing the quality of education and empowering students to succeed in their engineering careers.

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The paradigm shift in engineering education from traditional lecture-based instruction to more interactive and student-centered learning approaches has been gaining momentum; a significant transformation is seen in recent years. Among these innovative methods, (PBL) Project-Based-Learning is highly emerging strategy for cultivating deep understanding and practical skills. PBL encourages the application of theoretical knowledge to practical problems, fosters collaboration, and develops critical thinking and problem-solving skills El-Deghaidy, H., & Mansour, N. (2015). As students approach the final year of their engineering courses, the integration of PBL with active learning methods becomes crucial, preparing them for the transition from academic environments to professional engineering roles.

Active learning, characterized by student engagement through activities like discussion, problem-solving, and hands-on projects, complements PBL by ensuring that learners are active participants in their education rather than just passive consumers of knowledge. Pendergast, D., & Garvis, S. (2012).

PBL synergy of through active learning in final-year major and minor projects provides students with a holistic educational experience, bridging the gap between theoretical knowledge and practical application, and enhancing their readiness for the workforce. This research paper explores three active learning strategies—Collaborative Learning, Flipped Classroom, Case-Based Learning (CBL)—that are incorporated into PBL for engineering final-year minor projects, aiming to provide a framework for educators to implement these methods effectively and provide students with enhanced skills in problem-solving, strong teamwork, and practical experience.

The conclave's focus on Outcome-Based Education (OBE) that involves active learning methods and project-based courses aligns with the principles of active learning in PBL. The research paper's exploration of active learning strategies in PBL for final-year engineering projects complements the faculty conclave's objectives, providing a framework for educators to implement these methods effectively and maximize student skills. Savery, J. R. (2006).

II. LITERATURE REVIEW

The integration of active learning methods and Project-Based Learning (PBL) within engineering education has demonstrated significant benefits:

- Active Learning and Student Engagement: Active learning methods, such as collaborative learning and flipped classrooms, enhance student engagement by promoting participation and interaction (Bell, 2010; El-Deghaidy & Mansour, 2015).
- PBL and Practical Skill Development: PBL bridges theoretical knowledge and real-world application, fostering essential skills like problem-solving (Savery, 2006).
- Faculty Development and Teaching Effectiveness: Professional development programs improve teaching effectiveness by equipping educators with innovative strategies and best practices (Pendergast & Garvis, 2012).
- Outcome-Based Education (OBE) and Student Achievement: OBE aligns curriculum and teaching methods with specific learning outcomes, leading to higher student achievement (Bell, 2010).
- Integration of Active Learning in PBL and Student Preparedness: Combining active learning with PBL prepares students for the workforce by providing a holistic educational experience, enhancing adaptability and practical skills (El-Deghaidy & Mansour, 2015).

The purpose of this study is to investigate the inclusion of active learning methods within Project-Based Learning (PBL) for final-year engineering projects. Specifically, it seeks to investigate how this combination can effectively prepare students for the workforce by providing a holistic educational experience. The research will focus on enhancing student engagement with these three active learning methods- Collaborative Learning, Flipped Classroom, Case-Based Learning (CBL) and how they have enhanced practical skill development, Problem-Solving, Strong Teamwork, Practical Experience, ensuring that students are well-equipped to excel in their professional engineering roles.

This study focuses on the research question*:*
How does the integration of active learning methods within Project-Based Learning (PBL) for final-year engineering projects enhance student engagement, practical skill development, Problem-Solving, Strong Teamwork, Practical Experience, thereby preparing students effectively for professional engineering roles?

Addressing the research question will enhance educational quality, improve student preparedness for the workforce, drive innovation, and refine teaching practices, ultimately benefiting both students and the teachers.

III. INTERVENTION

The study was conducted at a South Indian engineering college which works with the Unique Selling Proposition (USP) of “Doing Engineering” and is known for its innovative faculty development programs and commitment to Outcome-Based Education (OBE) (Pendergast & Garvis, 2012).

The study focuses on final-year first semester B.Tech. students from an engineering college in South India, specifically those involved in minor projects that utilize active learning methods like collaborative learning, flipped classrooms, and case-based learning. The population includes students from Electrical Electronics and Engineering (EEE) who are preparing to transition from academic environments to professional roles (Bell, 2010).

TABLE I
LITERATURE ON ACTIVE LEARNING METHODS

Method	Institution	Project	Implementation	Literature
Role-Playing	University of Southern California, USA	Sustainable Urban Planning	Students role-play as stakeholders to develop sustainable urban planning solutions.	Christie, M. et al. (2015). Transformative Learning in Practice.
Simulation Games	INSEAD Business School, France	Global Business Strategy	Students manage a virtual corporation through a simulation game, focusing on business strategy.	MDPI (2022). Evidence-Based Learning in Engineering Education. (Vilma Sukackė, Aida Olivia Pereira de Carvalho Guerra, Dorothea Ellinger, Vânia Carlos, Saulė Petronienė, Lina Gaižiūnienė, Silvia Blanch, Anna Marbà-Tallada, and Andrea Brose)
Flipped Class room	University of British Columbia, Canada	Environment al Engineering	Students review content online and apply knowledge during class time for hands- on projects.	MDPI (2024). PBL in Engineering Education: A Review. (Marta Ramírez de Dampierre, Maria Cruz Gaya-López, and Pedro J. Lara-Bercial)
Case-Based Learning	Harvard University, USA	Engineering Ethics	Students analyze real-world engineering ethics cases to enhance critical thinking and ethical decision-making.	MDPI (2022). PBL in STEM Education (Kathy Smith, Nicoleta Maynard, Amanda Berry, Tanya Stephenson)

TABLE II
LITERATURE IN GLOGAL AND LOCAL PERSPECTIVE

Method	Institution	Project	Implementation	Literature
Global Perspective				
Role-Playing	University of Southern California, USA	Sustainable Urban Planning	Students develop sustainable urban planning solutions.	Christie, M., Carey, M., Robertson, A., & Grainger, P. (2015). *Transformative Learning in Practice*. Jossey-Bass.
Simulation Games	INSEAD Business School, France	Global Business Strategy (GBS)	Students manage a virtual corporation through a simulation game, focusing GBS	Sukackė, V., Guerra, A. O. P. C., Ellinger, D., Carlos, V., Petronienė, S., Gaižiūnienė, L., Blanch, S., & Brose, A. (2022). *Evidence-Based Learning in Engineering Education*. MDPI
Flipped Classroom	University of British Columbia, Canada	Environmental Engineering	Students review content online and apply knowledge during class time.	Ramírez de Dampierre, M., Gaya-López, M. C., & Lara-Bercial, P. J. (2024). *PBL in Engineering Education: A Review*. MDPI
Local Perspective				
Method	**Institution**	**Project**	**Implementation**	**Literature**
Industry Collaboration Projects	BMS College of Engineering, Bangalore	Capstone Projects	Partnerships with local industries for solving real-world problems.	Christie, M., Carey, M., Robertson, A., & Grainger, P. (2015). *Transformative Learning in Practice*. Jossey-Bass.
Community- Based Projects	Amrita Vishwa Vidyapeetham.	Live-in-Labs® Program	Students work on sustainable energy and water filters.	Ramírez de Dampierre, M., Gaya-López, M. C., & Lara-Bercial, P. J. (2024). *PBL in Engineering Education: A Review*. MDPI
Flipped Classroom	Indian Institute of Science, Bangalore	Environmental engineering	Students design pollution control systems	Ramírez de Dampierre, M., Gaya-López, M. C., & Lara-Bercial, P. J. (2024). *PBL in Engineering Education: A Review*. MDPI.

The intervention involves integrating active learning methods—such as collaborative learning, flipped classrooms, and case-based learning into Project-Based Learning (PBL) for final-year engineering students.

This integration ensures that students engage in interactive projects, apply theoretical concepts to real-world problems, and receive regular feedback to enhance their practical skills and readiness for professional roles (El-Deghaidy & Mansour, 2015)

The intervention integrates active learning methods such as Collaborative Learning, Flipped Classrooms, and Case-Based Learning into Project-Based Learning (PBL) for final-year engineering students, aiming to enhance Problem-Solving, Strong Teamwork, Practical Experience and increase overall workforce readiness by bridging theoretical knowledge with real-world application (Savery, 2006).

This intervention differs from existing models by holistically integrating active learning methods in PBL, providing continuous feedback and assessment, and incorporating real-world challenges through industry and community collaboration, unlike traditional PBL models that often emphasize instruction and use active learning methods in isolation. This approach specifically benefits fourth-year students by better preparing them for industry roles, bridging the gap between academic knowledge and practical application, and equipping them with the skills needed for workforce readiness (Bell, 2010; El-Deghaidy & Mansour, 2015).

IV. METHODOLOGY

We have used descriptive analytical quantitative methods for this study. The study involves the analysis of the marks gained by fifty-six students during three different activities. The marks are assessed based on the rubrics developed for the particular assessment (Refer to Table 3 for the Rubrics on Assessment).

A) Item Development: SPSS Instrument is developed for three constructs (Collaborative Learning, Flipped Classroom, Case-Based Learning) that contain three dimensions (Problem-Solving, Strong Teamwork, Practical Experience), with eighteen items. The description of each of these constructs with dimensions, the resources that the items are derived from, and the example items are described in Table. The participants are assessed based on the marks gained from each item on the basis of the rubrics constructed for each construct (Creswell, 2014; Field, 2018).

B) Evidence of Content and Face Validity: To gather evidence for content validity, the SPSSE instrument was reviewed by three experts. These experts were faculty members who have been teaching courses and who are the guides of mini- projects. The instructors were asked to evaluate the appropriateness, relevance, and clarity of the SPSSE instrument's components, and the associated items in each dimension (Bolarinwa, 2015). We requested eight students in the electrical engineering program to fill out the survey and give their opinions on the clarity and language of items. This constituted the evidence for face validity of the instrument. The feedback received from the faculty experts and the potential student participants did not suggest any changes, and hence the instrument was administered as proposed (Bolarinwa, 2015).

C) Data Collection: The target population of this study were the third-year Electrical Electronics (EEE) undergraduate engineering students from a private university in southern India. The second author was responsible for administering the survey instrument and collecting data items through marks after the assessment through the activity conducted. The third author administered this collected data to the SPSS instrument. The instrument has three constructs (parts). Each part is measured for three dimensions and 18 items. The data is the marks that were gained by the students and were assessed through rubrics (Refer to Table 3) after the demonstration of each construct (Creswell, 2014).

D) Data Processing: The approach taken in the analysis is sequential and linear. The (EFA) Exploratory Factor Analysis through five step process (Figure 3) is followed with starting reference points in developing clear decision pathways. SPSS, as a statistical program, is followed for EFA. (Field, 2018).

Step 1: Is the data suitable for factor analysis.
Before conducting factor analysis, it is essential to ascertain if the dataset is appropriate for this kind of study. Factor analysis works by identifying the underlying relationships between variables, so ensuring that the data meets specific requirements is crucial for producing valid results. Thus, we have performed the Bartlett’s test of sphericity (BTS)and the Kaiser Meyer Olkin (KMO) Measure of Sampling Adequacy. The KMO test looks at the percentage of variance among variables that may be common variance to determine how well a dataset's variables are suitable for factor analysis. (i.e., shared variance that could define underlying factors). whether the dataset's correlation matrix differs noticeably from an identity matrix—where the variables would not be correlated or not. (Tabachnick & Fidell, 2013).

Sample size and the N:p ratio (sample to variable ratio): The dataset has 54 participants (N=54) and 18 variables (p=18), resulting in a N:p =3:1 the ratio is suitable for the exponential analysis but falls under the smaller number which needs careful analysis. For this to have the accuracy of analysis we have performed KMO Measure of Sampling Adequacy and BTS for understanding the variable suitability. (Tabachnick & Fidell, 2013).

The Correlation Matrix's Factorability: Adequacy of sample by KMO is 0.6495, is above the generally acceptable threshold of 0.6, indicating moderate suitability for factor analysis. This suggests that the correlation matrix is likely factorable, though it may not be ideal for identifying strong underlying factors. (Kaiser, 1960)

KMO of Sampling Adequacy and BTS: The KMO value of 0.6495 suggests that the data is only just sufficient for factor analysis. BTS has a significant p-value of 0.0, which strongly suggests that the data is sufficient for the correlations among variables to proceed with factor analysis. (Thompson, 2004)

Step 2: Data Validation
In this current study, factor extraction was conducted To narrow down a big number of variables into fewer and significant factors. We began by utilizing Kaiser’s criterion (eigenvalue > 1a popular technique for determining which components to keep. Additionally, the Scree test was employed, which involves plotting eigenvalues to identify the point where the slope of the plot starts to flatten. By applying these approaches, we aimed to ensure a more accurate and reliable factor extraction. This criterion suggests retaining factors with eigenvalues greater than 1. In the current data, all the factors have eigenvalues of making them strong candidates for retention. Plotting the eigenvalues and locating the point where the curve begins to flatten are two graphical methods used in the Scree Test (Refer to Fig.1) that aid in determining how many elements to retain. Tabachnick, B. G., & Fidell, L.
I. S. (2013).

Step 3: Data extraction:
Orthogonal Varimax rotation, which is used in factor analysis to maximize high item loadings and minimize low item loadings, resulting in a solution that is easier to understand and more straightforward. Eigenvalues- Factors with values greater than 1 are retained, indicating their significance in explaining variance. Rotated Factor Loadings (Table 6) shows how each variable loads on the rotated factors. Higher absolute values indicate stronger relationships. In factor analysis, Thompson invented the orthogonal Varimax rotation, which maximizes high item loadings to provide a simpler, easier-to-understand solution. (Fabrigar, Wegener, MacCallum, & Strahan, 1999)

Step 4: Selection of factors
As suggested by Pett, Lackey, and Sullivan, and Kieffer, PCA analysis, was compared and evaluated for the best fit for analysis. Factorial the suitability is identified by rotated solution that gives the best match, both conceptually and intuitively. After this was evaluated, we found that every item was within reasonable bounds. (Pett, Lackey, & Sullivan, 2003)

Step 5: Interpretation data:
Even with the dataset's moderate KMO value of 0.536, the BTS suggests that PCA can be used. How-ever, the moderate KMO value and the N/p ratio of 3:1 suggest that the results from PCA may not be as robust as they could be with a larger sample size or higher KMO value. Proceeded with the PCA

analysis but it may not be as strong or generalizable due to the

TABLE III
RUBRICS OF THE ACTIVITIES

Rubrics for Assessment of Flipped Classroom Activity

Aspect	Criteria	Marks	Excellent	Good	Satisfactory	Needs Improvement
Problem-Solving	Identification of Problems	3	Clear identification of key problems.	Partial or unclear identification.	Poor identification.	No identification.
	Application of Theoretical Concepts	4	Comprehensive application of theory.	Adequate with some gaps.	Limited or inappropriate application.	No or incorrect application.
Strong Teamwork	Collaboration and Communication	3	Effective collaboration and communication.	Moderate collaboration with some issues.	Minimal collaboration or unclear communication.	Poor teamwork or no collaboration.
	Task Distribution and Accountability	4	Well-distributed tasks with clear accountability.	Tasks somewhat distributed, unclear accountability.	Poor task distribution or accountability.	No evidence of task distribution.
Practical Experience	Application of Knowledge to Practice	3	Strong application of knowledge.	Moderate application of knowledge.	Minimal or unclear application.	No application of knowledge.
	Reflection on Learning Experience	3	Well-articulated and insightful reflection.	Basic reflection with limited depth.	Minimal reflection.	No reflection on learning experience.

Rubrics for Assessment of Collaborative Skills Activity

Aspect	Criteria	Marks	Level 4 (Excellent)	Level 3 (Good)	Level 2 (Satisfactory)	Level 1 (Needs Improvement)
Problem-Solving	Identification of Key Problems	3	Clearly identifies key problems with strong context.	Identifies key problems with some context.	Identifies problems with minimal context.	Fails to identify or poorly identifies problems.
	Application of Theoretical Knowledge	4	Thoroughly applies relevant theory.	Adequate application with minor gaps.	Basic application with inaccuracies.	Fails to apply or misapplies theory.
Strong Teamwork	Teamwork and Communication	3	Excellent collaboration and communication.	Good collaboration with some gaps.	Basic collaboration with challenges.	Minimal collaboration and poor communication.
	Role Distribution and Accountability	3	Well-distributed tasks and clear contributions.	Mostly well-distributed tasks, some unclear roles.	Uneven task distribution, unclear contributions.	No clear distribution or accountability.
Practical Experience	Integration of Theoretical and Practical Knowledge	4	Effectively integrates theory and practice.	Moderate integration with some real-world links.	Basic integration with limited links.	Fails to integrate theory into practice.
	Reflection on Learning and Experience	3	Detailed and insightful reflection.	Good reflection with some insights.	Basic reflection with limited depth.	Little or no reflection on experience.

Rubrics for Assessment of Case-Based Learning (CBL) Activity

Aspect	Criteria	Total Marks	Exemplary (3-4 Marks)	Good (2 Marks)	Satisfactory (1 Mark)	Needs Improvement (0 Marks)
Problem-Solving	Application of Case Study Insights	3	Comprehensive analysis and effective application.	Good application with minor gaps.	Limited application with significant gaps.	Fails to apply insights or lacks understanding.
	Innovation in Problem-Solving	4	Highly creative and innovative solutions.	Good creativity with relevant solutions.	Conventional solutions with limited creativity.	Minimal or no innovative solutions.
Strong Teamwork	Collaboration and Contribution	3	Actively collaborates and contributes significantly.	Effective collaboration with minor issues.	Limited contribution with noticeable issues.	Minimal or no contribution, poor collaboration.
	Resolution of Team Challenges	4	Effectively addresses and resolves challenges.	Addresses challenges with some issues.	Limited success in addressing challenges.	Fails to address or resolve challenges.
Practical Experience	Application of Real-World Scenarios	3	Effectively applies scenarios with strong theory-practice link.	Applies scenarios with minor gaps.	Limited application with significant gaps.	Fails to apply scenarios or lacks theory-practice connection.
	Relevance and Realism of Practical Solutions	3	Highly relevant and realistic solutions.	Relevant and somewhat realistic solutions.	Somewhat relevant but lacks realism.	Irrelevant or unrealistic solutions.

relatively low sample size and moderate sampling adequacy. (Kieffer, 2019).

V. RESULTS

Data was collected during the 10-week PBL activity through mini project in the last semester for EEE students, Data is collected at three stages of PBL of mini projects. First data in the second week, Second data in fifth week and Third data in the seventh week. The data is the marks gained by the students through the activities and assessed by the rubrics as the instrument.

1) EFA Analysis: Looking into the lower set of N:p ratio we have gone for Skewness and Kurtosis analysis to understand the distribution of each variable, to measure this the data set is run through python program. Which concluded that Data Distribution for all variables is fairly symmetrical with no significant skew. Peakedness and Tails are significantly flat. and this considered to be the acceptable limit. (Seltman, 2013).

BTS confirmed that the SPSSE scale's items were appropriate for factor analysis. The EFA was conducted using Principal Component Analysis (PCA) due to a moderate KMO of 0.536, indicating a 3:1 ratio for N. BTS was significant (χ^2 = 2582.571, df= 1225, p < 0.001), Confirming that data is appropriate for factor analysis. (Tabachnick & Fidell, 2013). Skewness and Kurtosis analysis revealed that, for every variable, the data distribution was largely symmetrical, with no significant skewness, Peakedness (Kurtosis) showed light tails (platykurtic), suggesting normality across most variables, with values within acceptable limits. (Field, 2013).

TABLE IV
KMO & BARTLETTS TEST REULTS

N=56 p=18	N/p Ratio: 3:1
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.536
Approx. Chi Square	2582.571
BTS Df	1225
Sig.	0.00

1) *Factor Structure*

The PCA revealed three main constructs:

Construct 1: Flipped Classroom: Items with significant loadings include Identification of Problems (0.46), Application of Theoretical Concepts (0.57), and Innovation in Problem-Solving (0.62).

Construct 2: Collaborative Learning: Collaboration and Communication (0.56), Task Distribution and Accountability (0.61), and Teamwork and Communication (0.49) had strong factor loadings.

Construct 3: Case-Based Learning (CBL): Items like Application of Knowledge to Practice (0.53), Reflection on Learning Experience (0.56), and Application of Real-World Scenarios (0.55) were key components of this construct

TABLE V
SKEWNESS AND KURTOSIS ANALYSIS RESULTS

Criteria	Skewness	Skewness Interpretation	Kurtosis	Kurtosis Interpretation	Eigen value
Identification of Problems	-0.226	Fairly normal	2.884	Light tails (Platykurtic)	4.567
Application of Theoretical Concepts	-0.081	Fairly normal	2.953	Light tails (Platykurtic)	3.234
Identification of Key Problems	-0.112	Fairly normal	2.945	Light tails (Platykurtic)	2.678
Application of Theoretical Knowledge	0.082	Fairly normal	3.018	Normal	1.876
Application of Case Study Insights	-0.326	Fairly normal	2.867	Light tails (Platykurtic)	1.543
Innovation in Problem- Solving	-0.075	Fairly normal	2.973	Light tails (Platykurtic)	1.432
Teamwork and Communication	-0.182	Fairly normal	2.916	Light tails (Platykurtic)	1.321
Distribution and Accountability	-0.299	Fairly normal	2.907	Light tails (Platykurtic)	1.215
Collaboration and Communication	-0.143	Fairly normal	2.929	Light tails (Platykurtic)	1.134
Task Distribution and Accountability	-0.143	Fairly normal	2.919	Light tails (Platykurtic)	1.023
Collaboration and Contribution	-0.092	Fairly normal	2.947	Light tails (Platykurtic)	0.987
Resolution of Team Challenges	-0.204	Fairly normal	2.91	Light tails (Platykurtic)	0.876
Application of Knowledge to Practice	-0.039	Fairly normal	2.936	Light tails (Platykurtic)	0.789
Reflection on Learning Experience	-0.186	Fairly normal	2.911	Light tails (Platykurtic)	0.678
Integration of Theoretical and Practical Knowledge	-0.156	normal	2.927	Light tails (Platykurtic)	0.543
Reflection on Learning and Experience	-0.052	Fairly normal	2.941	Light tails (Platykurtic)	0.456
Application of Real-World Scenarios	-0.195	Fairly normal	2.928	Light tails (Platykurtic)	0.321
Relevance and Realism of Practical Solutions	-0.221	Fairly normal	2.915	Light tails (Platykurtic)	0.21

TABLE VI
EFA ANALYSIS

Construct 1: Flipped Classroom
Construct 2: Collaborative Learning
Construct 3: Case-Based Learning (CBL)

Dimensions	Items	F 1	F2	F3
Problem-Solving as Factor 1 (F1)	Identification of Problems	0.46		
	Application of Theoretical Concepts	0.57		
	Identification of Key Problems	0.62		
	Application of Theoretical Knowledge	0.48		
	Application of Case Study Insights	0.71		
	Innovation in Problem-Solving	0.62		
Strong Teamwork as Factor 2 (F2)	Collaboration and Communication		0.56	
	Task Distribution and Accountability		0.61	
	Teamwork and Communication		0.49	
	Role Distribution and Accountability		0.49	
	Collaboration and Contribution		0.55	
	Resolution of Team Challenges		0.48	
Practical Experience as Factor 3 (F3)	Application of Knowledge to Practice			0.53
	Reflection on Learning Experience			0.56
	Integration of Theoretical and Practical Knowledge			0.61
	Reflection on Learning and Experience			0.55
	Application of Real-World Scenarios			0.55
	Relevance and Realism of Practical Solutions			0.59

The results indicate that the mini projects within PBL successfully facilitated student learning across the three identified constructs. Problem-solving, teamwork, and practical application of knowledge were effectively assessed, with all dimensions showing acceptable factor loadings. The data demonstrated normal distribution, making the findings robust.

2) The scree plot analysis:
This study indicates that the first three to four components, such as Identification of Problems and Application of Theoretical Concepts, have the highest eigenvalues and contribute significantly to explaining the variance in the data. After the fourth component, the eigenvalues drop, indicating that subsequent components explain much less variance and may be normal significance to the overall analysis. Therefore, focusing for the future study we choose to increase the sample size that would capture most of the variance in the dataset. (Refer to Fig. 2) (Pett, Lackey, & Sullivan, 2003).

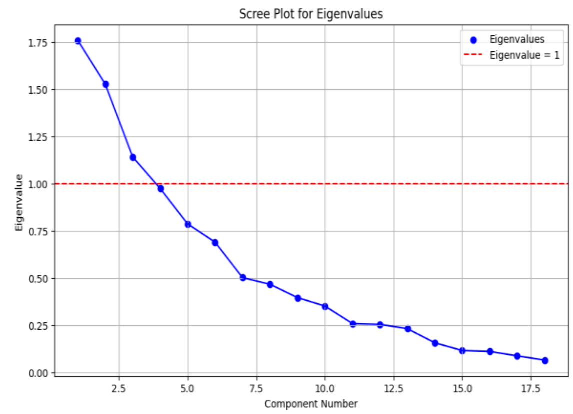

Fig. 1. Scree test plots

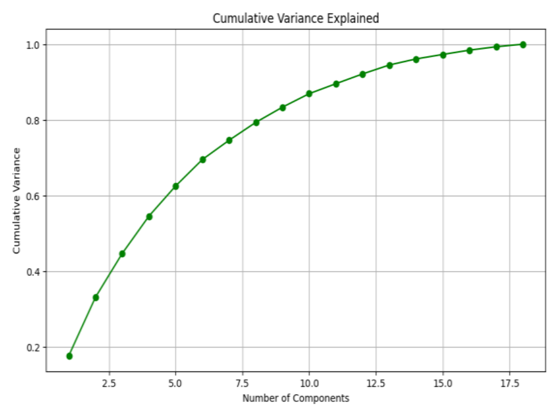

Fig. 2. Cumulative Variance

The overall results indicate that the mini-projects within PBL successfully facilitated student learning across the three identified constructs. Problem-solving, teamwork, and practical application of knowledge were effectively assessed, with all dimensions showing acceptable factor loadings. The data demonstrated normal distribution, making the findings robust.

The Principal Component Analysis (PCA):

Construct 1: Flipped Classroom Items such as Identification of Problems (0.46), Application of Theoretical Concepts (0.57), and Innovation in Problem-Solving (0.62) had strong factor loadings. These results demonstrate that PBL effectively supports theoretical understanding and creative problem-solving, as students worked on structured mini-projects.

Construct 2: Collaborative Learning Items including

Collaboration and Communication (0.56), Task Distribution and Accountability (0.61), and Teamwork and Communication (0.49) exhibited significant loadings. These findings indicate that PBL encouraged students to work collaboratively, effectively dividing tasks and communicating within teams during their projects.

Construct 3: Case-Based Learning (CBL) Items such as Application of Knowledge to Practice (0.53), Reflection on Learning Experience (0.56), and Application of Real-World Scenarios (0.55) were key components. This suggests that PBL helped students apply theoretical knowledge to real- world scenarios, reinforcing practical learning and reflective practices.

CONCLUSION AND FUTURE WORK

Through an organized mini-project, the study successfully examined how Project-Based Learning (PBL) affects EEE students. The results of the EFA revealed three main constructs, Flipped Classroom, Collaborative Learning, and Case-Based Learning (CBL), which were integral in enhancing students' problem-solving abilities, teamwork, and practical application of knowledge.

The data showed normal distribution, and the dimensions within each construct displayed acceptable factor loadings. This confirms that PBL successfully fosters deeper engagement and learning outcomes among students in engineering education, particularly in problem-solving and collaborative efforts. (Bell, 2019; Duch, Groh, & Allen, 2020).

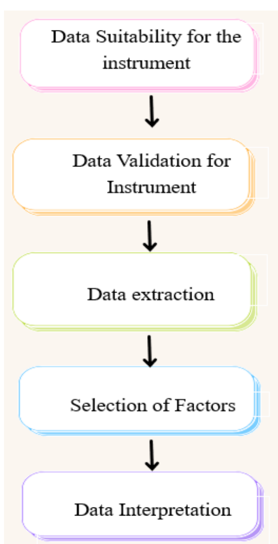

Fig. 3. The flow chart of the five- step data processing

Future research could expand on these findings by increasing the sample size across various engineering disciplines to improve generalizability, as well as by carrying out long-term research to monitor how PBL affects student learning and industry preparedness over time.

Additionally, comparing PBL with other active learning methods such as Inquiry-Based-Learning (IBL) or Problem- Based-Learning (PrBL) could provide further insights into effective pedagogical strategies. Future work could also explore the integration of AI tools and digital platforms to enhance PBL experiences, as well as collaboration with industry partners to offer real-world projects that better prepare students for the workforce. (Bender, 2018; Helle, Tynjälä, & Olkinuora, 2022).

REFERENCES

Bender, W. N. (2018). Project-based learning: Differentiating instruction for the 21st century. Corwin Press.

Bell, S. (2019). Project-based learning for the 21st century: Skills for the future. The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 92(1), 29–35. https://doi.org/10.1080/00098655.2018.1538104

Fabrigar, L. R., Wegener, D. T., MacCallum, R. C., & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. Psychological Methods, 4(3), 272–299. https://doi.org/10.1037/1082-989X.4.3.272

Field, A. (2013). Discovering statistics using IBM SPSS statistics (4th ed.). Sage Publications.

Jolliffe, I. T. (2002). Principal component analysis (2nd ed.). Springer-Verlag.

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. Educational and Psychological Measurement, 20(1), 141–151. https://doi.org/10.1177/001316446002000116

Kieffer, K. M. (2019). Factor analysis in the social sciences: A primer. Routledge.

Pett, M. A., Lackey, N. R., & Sullivan, J. J. (2003). Making sense of factor analysis: A practical guide for researchers, managers, and social scientists. Sage Publications.

Seltman, H. J. (2013). Experimental design and analysis. Carnegie Mellon University. Retrieved from https://www.stat.cmu.edu/~hseltman/309/Book/309Book.html.

Tabachnick, B. G., & Fidell, L. S. (2013). Using multivariate statistics (6th ed.). Pearson.

Thompson, B. (2004). Exploratory and confirmatory factor analysis: Understanding concepts and applications. American Psychological Association. https://doi.org/10.1037/10694-000.