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"Assessing the Need for Project-Based Learning: Student Engagement and Outcomes in Engineering Disciplines"

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Abstract: In traditional education system the focus is on content based learning. There was a shift to outcome-based education as a philosophy of teaching and learning in engineering education. But the, challenge of active student engagement could not be resolved. This study evaluates student engagement and academic outcomes in traditional outcome-based education within the engineering departments of Computer Science & Engineering, Artificial Intelligence & Machine Learning, Artificial Intelligence & Data Science, Mechanical Engineering, Aeronautical Engineering and Civil Engineering. The goal is to determine the necessity of implementing a Project-Based Learning (PBL) system in these disciplines. A comprehensive survey assessed students' learning experiences, engagement levels, and educational outcomes. The results will guide the development of a customized PBL system aimed at improving educational effectiveness and student satisfaction in these evolving fields.

Keywords: *Outcome-Based Education, Student Engagement, Academic Outcomes, Engineering Education, Project-Based Learning (PBL), Learning Experience, Educational Effectiveness, Student Satisfaction*

Introduction:

Background and Context

Overview of Traditional Education

Traditional lecture-based education has long been the cornerstone of higher education, including engineering disciplines. This approach typically involves a professor delivering content through lectures while students passively receive information (Chickering & Gamson, 1987). In engineering programs, lectures often focus on theoretical knowledge and problem-solving techniques, with students expected to apply this knowledge through problem sets and exams (Prince, 2004). This model emphasizes a top-down transmission of knowledge, where students are generally assessed through written examinations and quizzes.

Current Challenges

Despite its widespread use, traditional lecture-based learning faces several challenges. One significant issue is the lack of student engagement; research shows that passive learning environments can lead to lower levels of motivation and participation (Freeman et al., 2014). Additionally, the traditional approach often limits real-world application, as it may not adequately prepare students for practical problem-solving in professional settings (Fink, 2013). This disconnect can result in graduates who are less equipped to meet industry demands and adapt to rapidly changing technological landscapes (Boud & Feletti, 1997).

Importance of Student Engagement and Outcomes

Definition and Relevance

Student engagement refers to the level of interest, enthusiasm, and commitment students exhibit towards their learning activities (Kuh, 2009). Academic outcomes encompass various indicators of student success, such as grades, retention rates, and the ability to apply learned knowledge effectively. Engaged students are more likely to achieve better academic outcomes, demonstrating that engagement is a critical component of educational success (Astin, 1999).

Impact on Learning

Student engagement significantly impacts learning effectiveness and long-term success. Research indicates that active engagement in learning processes leads to deeper understanding and better retention of material (Carini, Kuh, & Klein, 2006). High levels of engagement also correlate with

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improved problem-solving abilities and higher academic achievement (Tinto, 1997). Therefore, enhancing engagement can foster a more effective and rewarding learning experience, particularly in fields requiring complex and adaptive skills.

Introduction to Project-Based Learning (PBL)

Concept of PBL

Project-Based Learning (PBL) is an instructional approach that emphasizes learning through engaging with complex, real-world problems (Thomas, 2000). In PBL, students work on projects that require critical thinking, collaboration, and the application of knowledge to solve problems (Barrows, 1996). This method contrasts with traditional lecture-based approaches by focusing on hands-on, student-centered activities that promote deeper learning and practical skill development (Hmelo-Silver, 2004).

Benefits of PBL

The benefits of PBL are well-documented. It fosters enhanced student engagement by involving students in meaningful, real-world tasks that are relevant to their interests and career goals (Bell, 2010). PBL also supports the development of critical thinking and problem-solving skills by challenging students to apply their knowledge in practical contexts (Gijbels, Dochy, Van den Bossche, & Segers, 2005). Moreover, PBL prepares students for real-world challenges by simulating professional scenarios and encouraging collaborative work (Thomas, 2000).

Relevance to Engineering Disciplines

Field-Specific Needs

In engineering disciplines such as Computer Science & Engineering, Artificial Intelligence, Data Science, and Machine Learning, PBL offers particular advantages. These fields demand not only theoretical understanding but also practical skills and problem-solving abilities that PBL can effectively develop (Mills & Treagust, 2003). PBL aligns well with the need for students to work on complex projects, integrating knowledge from various areas and applying it to real-world problems (Cunningham & Duffy, 1996).

Alignment with Industry Trends

The rapid evolution of technology and industry practices further underscores the relevance of PBL. As the engineering sector faces increasing demands for innovation and adaptability, PBL prepares students to meet these challenges by fostering skills that are crucial in the professional environment, such as teamwork, project management, and adaptive problem-solving (Boud & Feletti, 1997). Aligning educational practices with industry trends ensures that graduates are well-equipped to contribute effectively in their fields (Boud & Feletti, 1997).

Literature Review

The implementation of Project-Based Learning (PBL) in engineering education has been a subject of increasing interest over the past few decades. The study contributes to this growing body of research by evaluating the need for PBL in specific engineering disciplines, focusing on student engagement and academic outcomes.

Historical Context of Engineering Education

Traditionally, engineering education has relied heavily on lecture-based instruction, a method that has been criticized for its limitations in developing practical skills and maintaining student engagement (Felder & Brent, 2005). Seely (2005) traced the evolution of engineering education, noting that the emphasis on theoretical knowledge often came at the expense of hands-on experience. This disconnect between academic preparation and industry needs has been a persistent concern in the field (Sheppard et al., 2008).

Student Engagement in Higher Education

The importance of student engagement in higher education has been well-established in the literature. Kuh (2009) emphasized that engagement is a critical factor in academic success and retention. Specifically in STEM fields, Gasiewski et al. (2012) found that active learning environments significantly improved student engagement and performance. The study builds upon the research by examining engagement levels in traditional lecture-based engineering courses.

Project-Based Learning in Engineering

PBL has emerged as a promising approach to address the challenges of traditional engineering education. Mills and Treagust (2003) argued that PBL provides students with practical, hands-on experience that bridges the gap between theoretical knowledge and real-world application. Kolmos et al. (2013) conducted a comprehensive review of PBL in engineering education, highlighting its potential to develop not only technical skills but also soft skills such as teamwork and communication.The effectiveness of PBL in engineering has been demonstrated in various studies. For instance, Fernandes et al. (2014) reported improved student motivation and problem-solving skills in a PBL-based software engineering course. Similarly, Helle et al. (2006) found that PBL enhanced students' professional identity and self-efficacy in information systems design.

Discipline-Specific Considerations

The focus on Computer Science & Engineering, Artificial Intelligence and Data Science, and Artificial Intelligence and Machine Learning is particularly relevant given the rapid evolution of these fields. Li et al. (2020) emphasized the importance of project-based approaches in developing students' digital skills in data science and AI. Similarly, Marques (2016) argued for the integration of real-world projects in computer science education to keep pace with industry demands.In the field of AI and Machine Learning, Balaji et al. (2021) reported on the successful implementation of a PBL approach, noting improvements in students' ability to apply theoretical concepts to practical problems. This aligns with the goals in assessing the potential benefits of PBL in these specialized disciplines.

Assessment and Implementation of PBL

The comprehensive survey approach used reflects a growing emphasis on evidence-based practices in engineering education. Borrego et al. (2014) advocated for such data-driven decision-making processes in curriculum development. However, implementing PBL is not without challenges. Hung (2011) identified several obstacles, including faculty resistance and resource constraints, which need to be considered in any PBL implementation plan.Chen et al. (2021) conducted a review of PBL implementation in engineering education, highlighting various models and their effectiveness. They emphasized the importance of tailoring PBL approaches to specific institutional and disciplinary contexts, a consideration that aligns with the goals in developing a customized PBL system.

Future Directions

The research contributes to an ongoing dialogue about the future of engineering education. As noted by Graham (2018) in a global state-of-the-art report, there is a growing trend towards more integrated and experiential learning in engineering programs worldwide. The findings will inform the broader conversation and contribute to the development of more effective educational strategies in rapidly evolving technical fields.In conclusion, the study addresses a critical need in engineering education by evaluating the potential benefits of PBL in specialized fields. By assessing student engagement and outcomes in traditional lecture-based courses, this research provides a foundation for evidence-based curriculum reform. The results will contribute to the ongoing efforts to align engineering education with the needs of a rapidly changing technological landscape.

Methodology

Participants

This study utilized a survey to assess the necessity of implementing Project-Based Learning (PBL) in engineering education. A total of 816 students from six engineering branches participated in the survey: Computer Science & Engineering (CSE) (n=180), Artificial Intelligence and Machine Learning (AIML) (n=140), and Artificial Intelligence and Data Science (AIDS) (n = 140), Mechanical Engineering (ME) (n =150), Aeronautical Engineering (AE) (n =70) and Civil Engineering (CE) (n =136)A pie chart in Fig. 1 showing the distribution of students across the six departments. CSE has the largest share at 22%, followed by ME, AIML, AIDS, CE and AE.

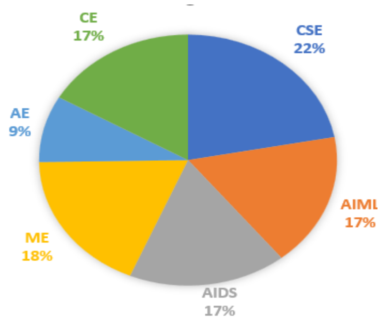

Fig. 1 Students Distribution across Departments

Survey Instrument

A Google Form survey was designed to gather data on student engagement and satisfaction with the traditional lecture-based teaching approach. The survey consisted of ten questions, each rated on a scale from 1 to 10, where 1 represented the lowest level of satisfaction or engagement, and 10 represented the highest. The questionnaire included the following items:

1. **Engagement During Lectures**: How engaged do you feel during traditional lecture-based classes?
2. **Understanding of Course Material**: To what extent do you feel that the traditional lectures help you understand the course material?
3. **Relevance to Real-World Applications**: How well do you think the content delivered in traditional lectures relates to real-world applications?
4. **Interaction with Instructors**: How effective do you find the level of interaction with instructors in traditional classes?
5. **Opportunities for Hands-on Learning**: How satisfied are you with the opportunities for hands-on learning in the current traditional setup?
6. **Retention of Knowledge**: How well do you retain the knowledge from traditional lecture-based teaching?
7. **Ability to Apply Theoretical Concepts**: How confident are you in applying the theoretical concepts learned in traditional classes to practical problems?
8. **Classroom Participation**: How often do you actively participate in discussions during traditional lectures?
9. **Preparation for Future Career**: To what extent do you believe that traditional lectures prepare you for your future career in your field of study?
10. **Overall Satisfaction with Traditional Teaching**: How satisfied are you with the overall experience of traditional lecture-based teaching in your department?

Data Analysis

The collected survey data were analyzed using various Machine Learning techniques to visualize and interpret student responses. The analysis included the following steps:

1. **Box Plot Rating**: Box plots were used to display the distribution of ratings for each survey question, highlighting the median, quartiles, and potential outliers in student responses.
2. **Average Rating**: The mean rating for each survey question was calculated to provide an overview of general student satisfaction and engagement levels.
3. **Correlation Heatmap**: A correlation heatmap was generated to examine the relationships between different survey questions, revealing patterns and potential correlations in student responses.
4. **Distribution Charts**: Distribution charts were created to show the frequency of ratings for each question, providing insight into the overall distribution of student responses.
5. **Pie Chart**: Pie charts were used to illustrate the proportion of different satisfaction levels across various survey questions.
6. **Violin Plot Rating**: Violin plots were employed to visualize the distribution of ratings and the density of responses for each question, allowing for a detailed view of the data's spread.

Software and Tools

The data visualization and analysis were conducted using Python with libraries such as Matplotlib, Seaborn, and Scikit-learn. These tools facilitated the creation of various plots and charts to effectively interpret and present the survey results.

Results

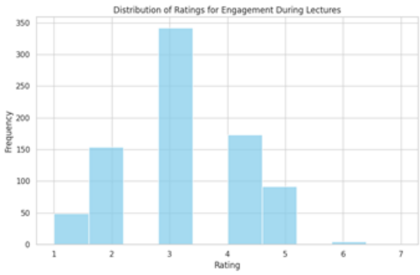

Fig.2 Engagement During Lectures distribution

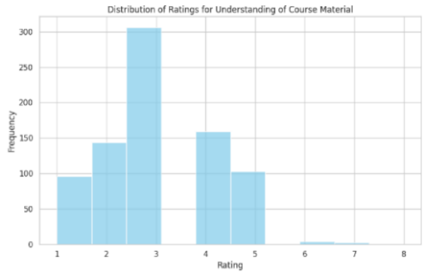

Fig.3 Understanding of Course Material distribution

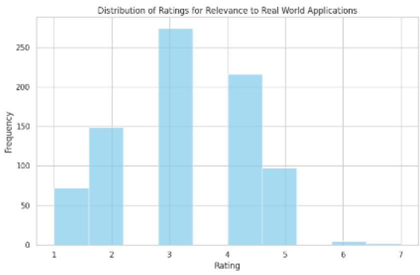

Fig.4 Relevance to Real World Applications distribution

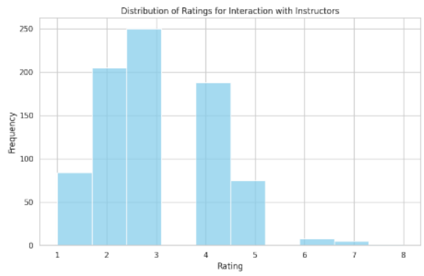

Fig.5 Interaction with Instructors distribution

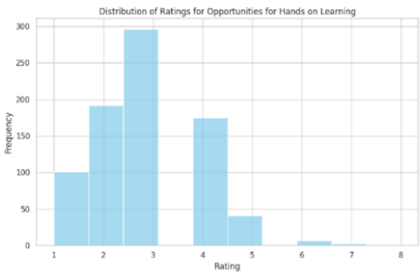

Fig. 6 Opportunities for Hands on Learning distribution

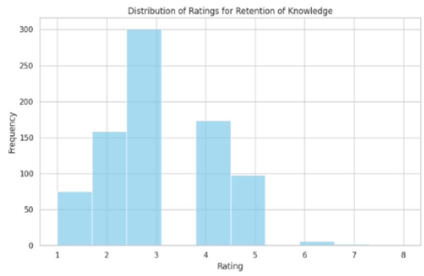

Fig. 7 Retention of Knowledge distribution

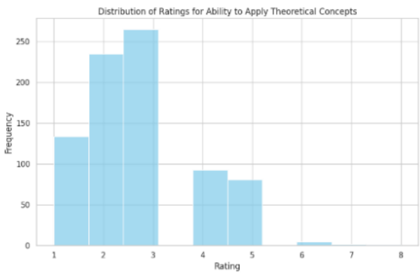

Fig.8 Ability to Apply Theoretical Concepts distribution

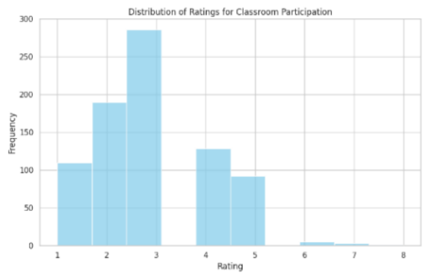

Fig. 9 Classroom Participation distribution

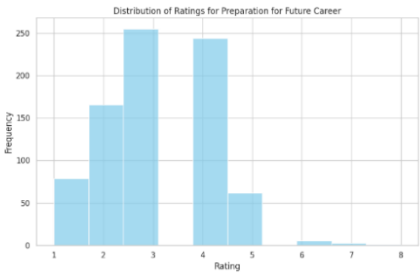

Fig. 10 Preparation for Future Career distribution

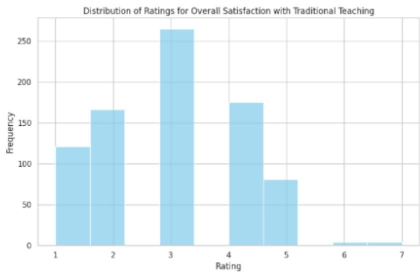

Fig. 11 Overall Satisfaction with Traditional Teaching distribution

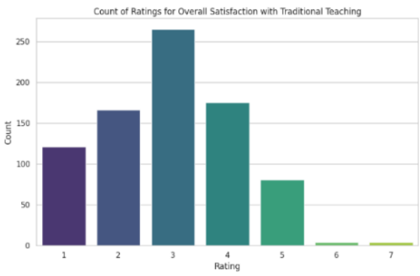

Fig.12 count plot overall satisfaction

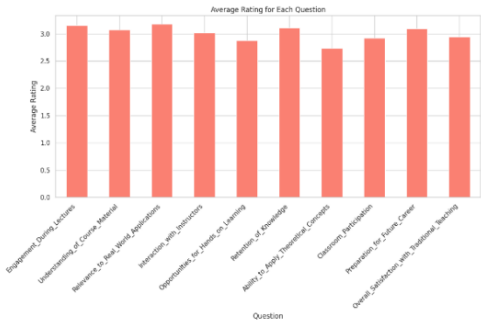

Fig. 13 Average Ratings

These figures in Fig.2 to Fig. 11 represent distribution charts for each of the ten survey questions. Each chart shows the frequency of ratings from 1 to 10 for its respective question, providing a visual representation of how students responded to each aspect of their educational experience.

A count plot in Fig.12 showing the overall satisfaction levels across all respondents, providing a summary view of student sentiment towards traditional teaching methods.

A bar chart in Fig. 13 displaying the average ratings for each of the ten survey questions, allowing for quick comparison of student responses across different aspects of their educational experience.

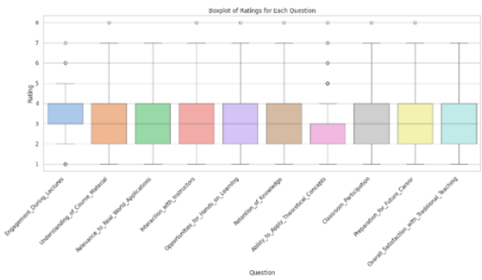

Fig. 14 Boxplot Ratings

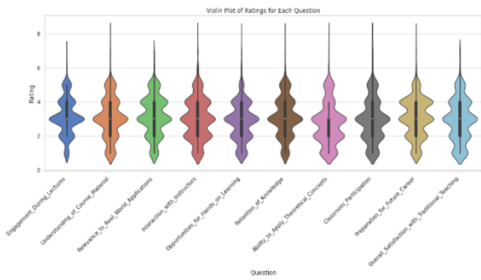

Fig. 15 Violin Plot Rating

A box plot in Fig. 14 showing the distribution of ratings for each survey question, including median, quartiles, and potential outliers, providing a comprehensive view of response patterns.

A violin plot in Fig. 15 illustrating the distribution and density of ratings for each survey question, offering a detailed view of response patterns and concentrations.

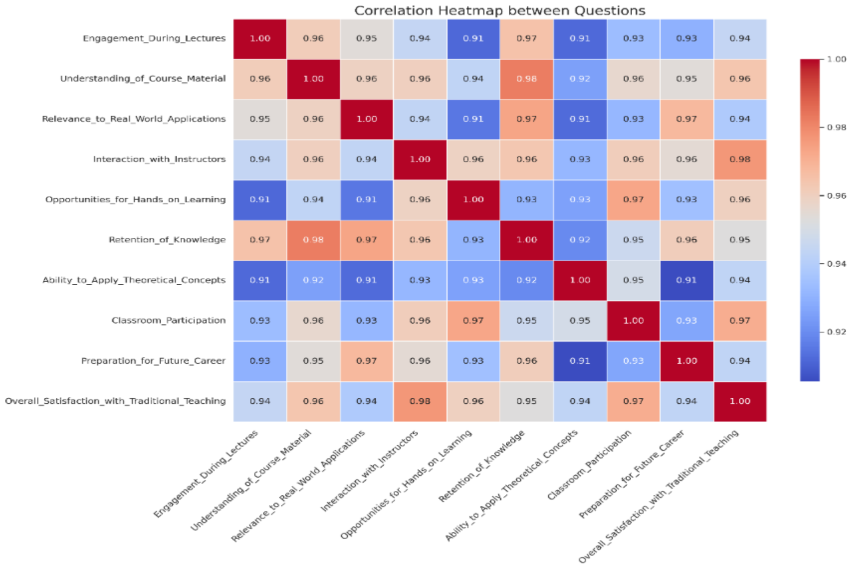

Fig. 16 Correlation Heat map

A correlation heat map in Fig. 16 displaying the relationships between responses to different survey questions, helping identify patterns and potential correlations in student feedback.

Discussion

This study, involving 816 students from the engineering departments of Computer Science & Engineering, Artificial Intelligence & Machine Learning, Artificial Intelligence & Data Science, Mechanical Engineering, Aeronautical Engineering and Civil Engineering provides valuable insights into the effectiveness of traditional lecture-based education and the potential need for Project-Based Learning (PBL) in these disciplines.

1. Student Engagement During Lectures: The survey reveals a wide range of engagement levels, with responses spanning from 1 to 7. While some students report high engagement (ratings 5-7), a significant number indicate low to moderate engagement (ratings 1-4). This variability suggests that traditional lectures may not consistently capture students' attention and involvement, highlighting a potential area for improvement through PBL approaches.
2. Understanding of Course Material: Responses regarding understanding of course material also vary widely. While some students report high levels of understanding (ratings 5-8), others indicate struggles (ratings 1-4). This disparity suggests that traditional lectures may not be equally effective for all students, and alternative methods like PBL could help address these learning gaps.
3. Relevance to Real-World Applications: The perception of real-world relevance shows a similar spread, with ratings from 1 to 7. This indicates that while some students can connect lecture content to practical applications, others struggle to see this relevance. PBL could potentially bridge this gap by providing more concrete, real-world contexts for learning.
4. Interaction with Instructors: Ratings for instructor interaction range from 1 to 8, suggesting significant variability in student-teacher engagement. Lower ratings indicate a need for more interactive learning environments, which PBL could provide through its collaborative nature.
5. Opportunities for Hands-on Learning: This aspect shows some of the lowest overall ratings (mostly 1-5), indicating a critical shortfall in traditional lecture-based teaching. The lack of hands-on learning opportunities in rapidly evolving fields like AI and ML underscores a pressing need for more practical, experiential learning approaches like PBL.
6. Retention of Knowledge: Knowledge retention ratings vary widely (1-8), suggesting that traditional lectures have

mixed effectiveness in helping students retain information. PBL's emphasis on active learning and application could potentially enhance knowledge retention across the student body.

7. Ability to Apply Theoretical Concepts: The generally lower ratings (mostly 1-5) in this category highlight a crucial weakness in traditional teaching methods, especially for engineering disciplines where practical application is vital. This finding strongly supports the need for PBL to help students bridge the gap between theory and practice.
8. Classroom Participation: The varied responses (ratings 1-8) in classroom participation suggest that traditional lectures may not consistently encourage active student involvement. PBL's collaborative nature could foster more uniform and higher levels of participation.
9. Preparation for Future Career: Ratings ranging from 1 to 8 indicate diverse perceptions of career preparedness. Lower ratings suggest that traditional lectures may not adequately prepare all students for their future careers in rapidly evolving fields like AI and ML. PBL's focus on real-world problems and teamwork could enhance career readiness.
10. Overall Satisfaction with Traditional Teaching: The wide range of satisfaction levels (ratings 1-7) indicates that traditional teaching methods do not uniformly meet student needs and expectations in these cutting-edge fields.

In conclusion, this comprehensive survey reveals significant variability in student experiences with traditional lecture-based education in Computer Science & Engineering, Artificial Intelligence & Machine Learning, Artificial Intelligence & Data Science, Mechanical Engineering, Aeronautical Engineering and Civil Engineering. The data highlights several areas where traditional methods may fall short, particularly in providing hands-on learning experiences, fostering the application of theoretical concepts, and consistently engaging all students.

Conclusion:

These findings strongly support the need for implementing a Project-Based Learning system in these disciplines. PBL's emphasis on practical application, collaborative problem-solving, and real-world relevance could address many of the shortcomings identified in the current traditional approach. By integrating PBL, these engineering departments could potentially enhance student engagement, improve the application of theoretical knowledge, and better prepare students for their future careers in these rapidly evolving fields. The next step would be to design and implement a customized PBL system that addresses the specific needs and challenges identified in this study, with the goal of improving educational effectiveness and student satisfaction in these cutting-edge engineering disciplines.

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