Journal of Engineering Education Transformations,
Volume No. 37, January 2024 Special Issue, eISSN 2394-1707

Enhancing Learning in Biology for Engineers: A Problem Based Case Study

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***Abstract*— Problem-Based Learning (PBL) is acknowledged as an effective pedagogical approach that facilitates a deeper understanding of concepts, surpassing a 90% comprehension rate. Renowned as a dynamic and student-centered activity, PBL fosters out-of-the-box thinking, thereby supporting the enhancement of students' skills and creativity. This paper specifically delves into the application of problem-based learning in the context of the third-year undergraduate Biology for Engineers course. PBL activities tailored for the Biology for Engineers curriculum are meticulously crafted to provide students with a progressive and comprehensive grasp of biological concepts, coupled with their practical applications in the realm of engineering. By adopting a creative, applied, and design thinking approach, PBL enables students to traverse the intricacies of the biology course effectively.**

In the Biology for Engineers course, PBL activities are strategically designed to facilitate a step-by-step acquisition of in-depth knowledge and a nuanced understanding of the real-life applications of biology in engineering contexts. This deliberate approach not only augments students' experiential learning of biology but also nurtures their creativity. Significantly, the PBL methodology empowers students by instilling a sense of ownership over the course, thereby contributing to their overall academic and professional development.

Keywords—Learning, Course, Problem based Learning, Activity, Biology.

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I. INTRODUCTION

Numerous researchers have substantiated that Problem-Based Learning (PBL) facilitates experiential learning by guiding students through structured pathways. The application of Project-Based Learning in the third-year undergraduate course is characterized by a well-organized and strategic learning approach. PBL serves to empower students by honing the essential skills requisite for the course, a fact corroborated by several researchers who have demonstrated that a meticulously designed PBL significantly enhances students' proficiency in the relevant subject matter. Notably, PBL excels in addressing intricate real-world problems, positioning itself as a student-centered learning method. Within this framework, the teacher's role undergoes a transformation from content delivery to that of a facilitator. Specifically, the Biology for Engineers B. Tech course has integrated problem-based learning activities, marking a proactive shift toward collaborative teaching tools for third-year B. Tech students in the second semester.

In the realm of problem-based learning, students engage in the design, development, and hands-on provision of solutions to the posed problems. This approach provides undergraduate students with the opportunity to confront open-ended challenges, thereby diversifying their learning experiences. Consequently, PBL emerges not only as a collaborative teaching method but also as an effective and dynamic learning activity.

Problem-Based Learning (PBL) has proven to be a valuable approach in teaching Biology for Engineers. This method helps students learn through experience and carefully guided paths as they interact with the course material. It equips students with essential skills, allowing them not only to understand biology deeply but also to handle complex real-world problems. PBL brings about a significant change in the teacher's role, shifting from simply delivering content to becoming a facilitator. This change enhances the student-centered aspect of learning, encouraging collaboration and active involvement. Implementing problem-based learning in the third year, second semester of the Biology for Engineers B. Tech course has shown to be effective in creating a dynamic and collaborative environment for students to apply their knowledge and skills. Undergraduate students, through problem-based learning, are presented with unique challenges that have no fixed solutions. This promotes creative problem-solving and offers various learning approaches. The collaborative nature of PBL not only boosts students' skills but also enriches their overall learning experience, providing diverse perspectives and fostering a deeper engagement with the subject matter.

II. LITERATURE REVIEW

Davies, John et. al. reported that PBL is a very effective method of learning. They introduced two models one is project based which involves engineering students and others is case oriented model in the medical field. PBL involved project approach and case approach. A case-based study used in the social and medical field and analysed both the methods to meet the learning and teaching aspects.

Critical thinking and soft skills of students were improved by involving the students in team formation, solving real time problem formation. In PBL, author suggested a project for students to explore various foods and the nutritional value of the food, in the magazine. Project based learning involves a crossover between two or three subject areas. Definitely it is beneficial than learning different subjects.

Authors reported that Project based learning or PBL involves learning activities and real-time problem-solving task. PBL is nothing but a teamwork, which is done to achieve a common goal. The teacher is just a facilitator and who just shows the way to solve the problems rather than teaching everything. A teacher who previously provides the knowledge will change the role, now they are mentors and coach the students, students share the projects on a web page and communicate with the outside world.

The researchers explored the application of Problem-Based Learning (PBL) and Outcome-Based Education (OBE) in enhancing students' knowledge and skills in a manufacturing technology laboratory setting. The authors discussed how the integration of PBL and OBE methodologies can lead to more effective learning outcomes for students. By providing a practical example in a specific domain, they emphasized the potential of PBL in promoting a deeper understanding of course material, fostering critical thinking, and improving practical skills. Their study adds valuable insights into the broader effectiveness of PBL and OBE approaches in engineering education.

The authors delved into the theoretical foundations that underpin the effectiveness of Problem-Based Learning (PBL). The authors examined the pedagogical aspects and principles of PBL, shedding light on why this approach yields positive results in promoting student engagement, critical thinking, and skill development. By exploring the theoretical framework of PBL, they contributed to a deeper understanding of the mechanisms behind its success in various educational contexts. Their study is significant in providing a comprehensive theoretical perspective on PBL, which can inform educators and researchers about the rationale behind its effectiveness.

The researchers investigated the fundamental characteristics of Problem-Based Learning (PBL). The researchers outlined key elements that define PBL, such as its learner-centred approach, collaborative nature, and emphasized on real-world problem-solving. By analyzing

the core attributes of PBL, their study offered valuable insights into the distinctive features that make PBL an effective instructional method. Their paper helped to establish a foundational understanding of PBL, which is essential for educators seeking to implement this approach successfully in engineering education.[2]

III. PROBLEM IDENTIFIED

- The Biology for Engineers course was delivered by the instructors in a theoretical format, following a generic course structure.
- There is a hesitancy among students and faculty to engage with this course.
- Faculty members lack specialized training in the field of biology.
- The following factors affect the Biology for Engineers course:
- Why biology in engineering?
- Lack of interest and awareness in Biology domain.

IV. OBJECTIVES

- Implement PBL activity for Biology for Engineers course.
- Evaluate students' PBL activity with designed rubrics.
- Analyze the students' performance.
- Develop creativity and skills of students
- Reduce resistance of course with different case studies.

V. BIOLOGY FOR ENGINEERS

Implemented Problem Based Learning in under graduate Class for Biology for Engineers Course. To overcome the problems identified in Biology for Engineers course effectiveness problem-based learning is finalized through literature review. The Problem based learning was conducted at the institute for under graduate students of Electronics and Telecommunication department. Total 76 under graduate students are implemented problem-based learning. Students' evaluation test was conducted through continuous evaluation as well as through feedback process. The feedback had conducted at the beginning of the course, middle of the course and at the end of the course. The statistical analysis is used to evaluate the students' performance in Biology for Engineers course. The final evaluation was done by rubrics method to analyze the students 'publications and real time applications. The seven-step PBL process involved problem identification, theory application, design simulation, variable selection, emulation, design interpretation, and a concluding presentation.

VI. PROBLEM BASED LEARNING TO BIOLOGY FOR ENGINEERS COURSE

Problem based Learning had applied for the UG course Biology for Engineers. PBL Steps of Biology for Engineers course are as follows:

Step 1: Problem identification:
Every student had identified the problems. After identification the problems, had discussed the problems with peers and faculty. After peer and faculty discussion had fixed and finalized the problem. Students had formulated the research problem and write problem statements.
Case study name are Blind stick, Paste maker antenna, low cost wheel chair, pain analysis, thermometer, oximeter, etc.

Step 2: Biology for Engineers theory:
Students select sensors, controller, design the system.

Step 3: Simulate the Design:
Students simulate the design.

Step 4: Selecting I/O variables:
Select variables of input and output variables as well as test points.

Step 5: Emulate the Design:
Students run the design on emulator.

Step 6: Interpreting the design:
Evaluate the design in all aspects with biology constraints.

Step 7: Conclusion:
Present the work to other students. Students write conclusion. Sample Case studies uploaded on Moodle server snap is shown in figure 1.

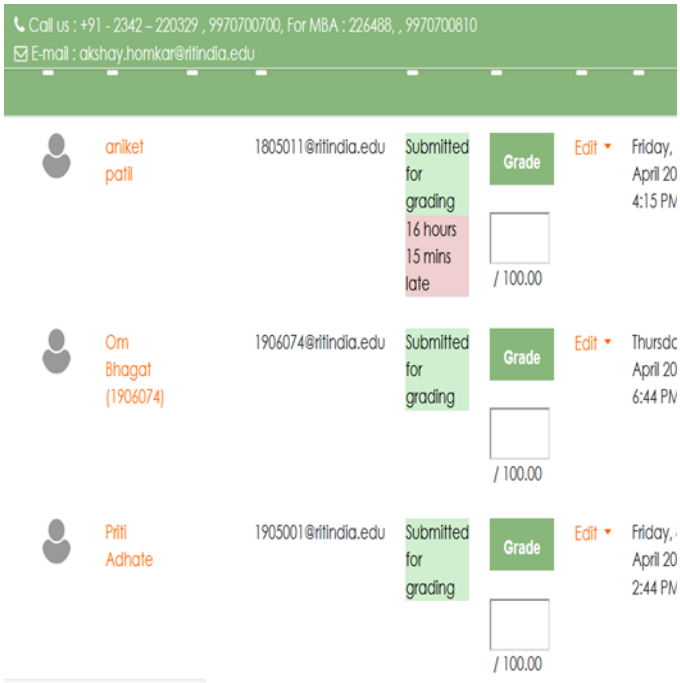

Figure1. Sample case studies snap

VII. RESULTS AND DISCUSSION

Continuous assessment using rubrics revealed improvements in student performance. Clear evaluation criteria provided students with feedback, making them better judges of their work. The course outcomes were achieved, as reflected in the graphical representation of student attainment.

Table1: PBL evaluation rubrics

Criteria	Exemplary (Marks)	Proficient (Marks)	Developing (Marks)	Unacceptable (Marks)
Participation	Student proactively participated in preparing PBL, implementation, observations, analysis conclusion and/or asks questions more than once. (8.1-10)	Student committed few mistakes while implementing PBL which he could correct after guidance from course teacher. (7.1-8)	Student committed few mistakes while implementing PBL which he could not correct after guidance from course teacher. (4.1-7)	Student never participated in preparing PBL implementation. observations, analysis, conclusions and asking questions. (0-4)
Implementation Skills	All content points of PBL are systematically implemented (8.1-10)	71%-80% content points of PBL are systematically implemented. (7.1-8)	61%-70% content points of PBL are systematically implemented. (4.1-7)	Below 60% content points of PBL are systematically implemented. (0-4)
Inferring by Q-A	Shows a superior understanding of the PBL. (16.1-20)	Shows 71%-80% understanding of the PBL. (14.1-16)	Shows 61%-70% understanding of the PBL. (8.1-14)	Shows Below 60% understanding of the PBL. (0-8)
Timely Submission	Completely organized submission of PBL (8.1-10)	Completely organized submission of PBL after one day deadline. (7.1-8)	Completely organized submission of PBL report after two-to-three-day deadline. (4.1-7)	Completely organized submission of PBL report after one week. (0-4)

Student performance had improved by clearly showing them how their work is assessed and what is expected.

- Students become better judges of the quality of their own work.
- Students have more informative feedback about their strengths and areas in need of improvement
- Assessment is more objective and consistent
- Criteria are determined in specific terms.
- Effectiveness of instruction is examined using multiple methods.
- Students become aware of the criteria to use in providing peer feedback.
- Amount of time spent assessing student work is reduced.

The course attainment is given in table. All the course outcomes are achieved. The graphical representation of course outcome is shown in figure 2.

Table2: CO statement and Attainment

Sl. No	**CO Code**	**CO Statement**	**Level based Attainment**
1	CO1	Apply biological engineering principles, procedures needed to solve real-world problems	2.31
2	CO2	Demonstrate the functions of biological systems	2.58
3	CO3	Analyze biological phenomena with math and physics to gain important insights	2.37

4	CO4	Explain working of different biomedical instruments	2.52
5	CO5	Select the sensors for given biological applications	2.29
6	CO6	Explain relevant aspect of movement control process	2.17

Feedback from 65 students indicated a positive response to PBL, with all students recommending it for other courses. Direct feedback highlighted the effectiveness of the PBL activity in enhancing learning experiences.

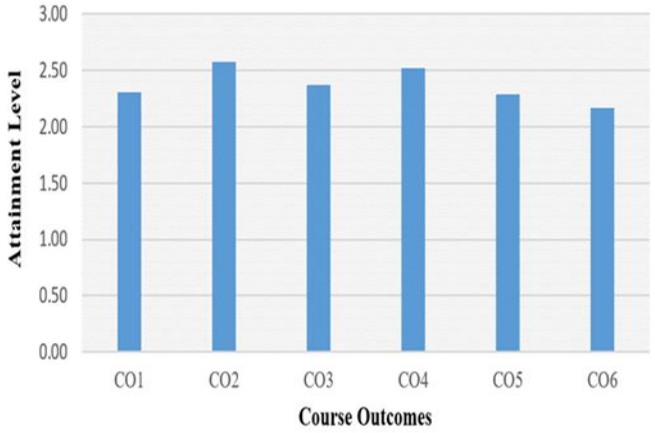

Figure 2. CO Attainment of Course

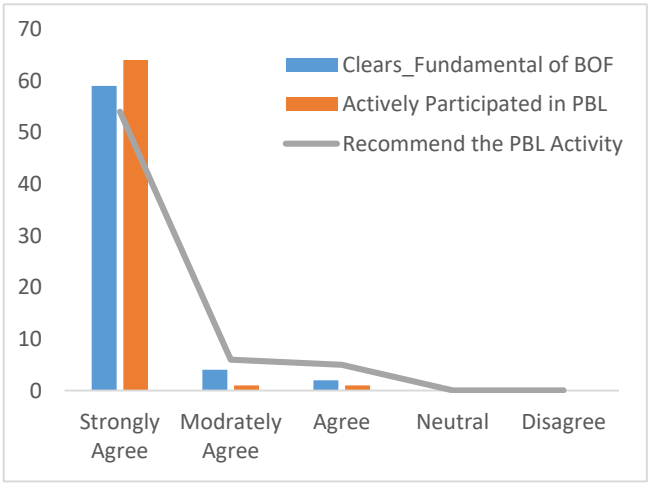

Figure 3. Direct Feedback for PBL activity

All course students agreed to recommend the PBL activity to other courses. Figure 3 represents the feedback of students on PBL activity.

VIII. STATISTICAL ANALYSIS

The course activity had analyzed using statistical tools. For statistical analysis the data had collected by questionnaire method.

Table3: ANOVA testing

Clears Fundamental of BOF	Between Groups	10.187	3	0.027	0.198	0.672
	Within Groups	11.538	62	0.198		
	Total	10.862	65			
Actively Participated in PBL	Between Groups	10.002	2	0.001	0.077	0.901
	Within Groups	10.977	64	0.019		
	Total	10.489	65			
Recommend the PBL Activity for BOF	Between Groups	10.057	4	0.088	0.161	0.862
	Within Groups	11.034	61	0.248		
	Total	10.545	65			

The significance value of one-way ANOVA testing is greater than 0.05, therefore there is no difference in variables of PBL activity implementation. The table shows that PBL activity is more suitable to students.

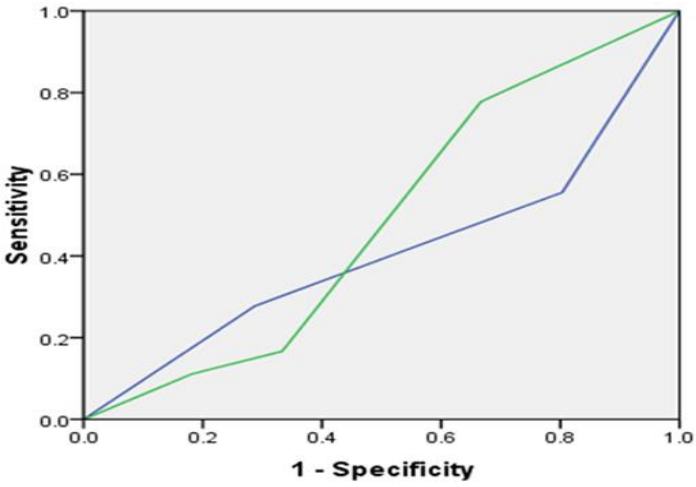

Figure 4. Statistical graph

In figure 4 the residuals appear generally meet in points. It satisfies the normal assumption therefore so that the PBL activity is more suitable for Biology for Engineers course and proved statistically.

IX. OUTCOMES

The outcome of problem-based learning activity is that Third year students applied Biology knowledge on real life problems and uploaded the work on Moodle server. All the case studies uploaded are available on Moodle link. Students now have confidence to apply their knowledge in the biology instrument development.

X. CURRENT CHALLENGES

Students as well as faculty not possessing the knowledge and skills in Biology area. Solution: Six faculty members from institute joined together and form a group to develop the skills in the biology domain and upgrade themselves with involvement of Alumni and Biology experts.

XI. CONCLUSION

The utilization of Problem-Based Learning (PBL) in the Biology for Engineers course has proven to be an effective and dynamic teaching-learning activity. PBL, also known as Problem-Based Learning, has demonstrated its ability to substantially enhance students' understanding of course concepts, with over 90% knowledge retention. This approach has fostered out-of-the-box thinking, promoting creativity and the development of essential skills among students. The student-centered nature of PBL makes it a powerful tool for experiential learning, providing a step-by-step, in-depth understanding of biology course contents and real-life applications, which is particularly beneficial for third-year undergraduate students. PBL activities within the Biology for Engineers curriculum, have witnessed the remarkable growth of creative, applied, and design thinking approaches. This methodology empowers students to take ownership of their learning journey, allowing them to fully engage with the course material and develop a deep appreciation for the subject matter. PBL serves as a catalyst for not only gaining knowledge but also for nurturing creativity and practical skills that are essential for a career in engineering and biology. The case study presented in this paper highlights the positive impact of PBL in achieving the course objectives. This approach enriches the overall learning experience by encouraging students to think critically, solve problems, and apply their knowledge in real-world contexts. The integration of PBL activities in the Biology for Engineers course not only enhances students' comprehension but also instills a sense of ownership and enthusiasm, making it a valuable strategy for educators aiming to provide holistic and effective education in the field of biology for engineering students.

XII. PROPOSED PLAN (FOR 2023/24)

The competition will be organized on students' case studies. E.g., Poster presentation, Mini symposium. Continue to implement the PBL to Electronic Devices and Marketing for Engineers courses.

XII. REFLECTIVE REPORT

The journey of implementing PBL in the Biology for Engineers course has been transformative. The challenges were identified and addressed systematically, resulting in improved student engagement and understanding. PBL not only enhanced knowledge retention but also nurtured creativity and practical skills. The positive feedback from students and statistical analysis affirms the success of this approach. The proposed plan for the future ensures sustained improvement and innovation in the learning process.

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