Enhancing Program Outcomes and Academic Performance through Problem-Based Learning in an Antennas and Wave Propagation Course

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Abstract— **Problem-Based Learning (PBL) is increasingly recognized as an effective educational approach in engineering education, helping improve critical thinking and practical skills. In the context of the Antennas and Wave Propagation course for third-year Electronics and Communication Engineering (ECE) students, traditional teaching methods often fall short in engaging students and addressing all program outcomes (POs). This study involved implementing PBL in the Antennas and Wave Propagation course, where students were divided into teams and given a problem statement related to the course. Each team was tasked with developing a solution and creating a prototype. The implementation included several steps: defining the problem, brainstorming, research, solution design, prototype development, and final presentation. Data was collected through predefined rubrics assessing various criteria, such as problem understanding, solution quality, teamwork, and presentation skills. The rubrics were designed to map each activity to specific POs. The collected data was analyzed to compare the target and attained values of each PO to evaluate the effectiveness of PBL. The preliminary results indicate a positive impact of PBL on both student engagement and academic performance. Students demonstrated improved understanding and application of theoretical concepts, as evidenced by the quality of their prototypes and presentations. The analysis shows that the academic performance of the students is improved and attained values for most POs met or exceeded the target values, particularly in areas like problem-solving (PO2), Engineering design (PO3), Conduct Investigations (PO4), Modern tool usage (PO5), Teamwork (PO 9) and Project Management (PO11). Student feedback was overwhelmingly positive, highlighting enhanced learning experiences and increased motivation. This study explores the implementation of PBL to improve academic performance and ensure comprehensive coverage of POs.**

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I. INTRODUCTION

Saleh et. al (2009) Change is what we see and feel, things like technology, business, economics etc. In today's education system Indian education scenario, to a certain extent there is

change but majorly not yet developed. Endless conversations on change in education system will act as a barrier until we actually implement it. The reason why we still remain the same is because of following the traditional way of teaching and learning process such as Student listen to lectures, read texts, watch videosmonetary and fiscal policy.

- Memorizing & comprehending what's being said in the class.
- Focusing on facts but not trying to explain with a prototype or proof.

Such issues can be resolved by using various innovative teaching methodologies in the classroom. This paper aims to implement Problem Based Learning in the classroom to engage students. This in turn helps in addressing the Program Outcomes (POs) which were not addressed through traditional teaching methods.

II. LITERATURE SURVEY:

Wei Lin et al. (2003) introduced a novel wavelet-domain projection pursuit learning network for unsupervised image restoration, showcasing advancements in image processing techniques. Saleh (2009) discusses future challenges in engineering education, emphasizing the need for adaptation and innovation. Rajendra Prasad et al. (2014) analyze the performance of on a subject, focusing on their application in telecommunications. Rajendra Prasad and Krishna Reddy (2015) explore project-based teaching methodologies which includes practical learning. May and Terkowsky (2014) compare different potential areas and highlights the industry

requirements. Reed-Rhoads (2009) and Reed-Rhoads (2007) offer insights into engineering education proposal writing and project management, providing guidance for successful educational project planning. Karl and Zemlicka (2008) address the challenges faced in a subject, focussing the need for curriculum reforms. Finally, Siddapuram et al. (2024) present a roadmap for achieving excellence in engineering education by following quality practices and standards.

III. PROBLEM BASED LEARNING (PBL):

Boud and Feletti (1997) provided background of problem-based learning. Duch, Groh, and Allen (2001) described the methods used in PBL and the specific skills developed, including the ability to think critically, analyze and solve complex, real-world problems, to find, evaluate, and use appropriate learning resources.

In the current educational system, teachers are facing challenges in engaging students and to seek the attention of the students which in turn effecting the learning outcome of the students. Teachers are coming up with innovative teaching methodologies to provide deeper understanding of the concepts. Among all the teaching methodologies adopted by the students, Problem Based Learning (PBL) has shown significant impact on the learning outcomes. PBL helps in critical thinking skills among the students and gives hands-on experience to the students in designing the projects based on the given problem statement. It is an instructional approach designed by the teachers to give students an opportunity to develop their knowledge and skills.

IV. IMPORTANCE OF PROGRAM OUTCOMES IN ENGINEERING

In the current scenario, all the Higher Educational Institutions follow Outcome-Based Education (OBE) system which focuses on what students are expected to achieve by the end of a course or program. Each course in the Higher Education Institutions will have Course Outcomes (CO's) usually varies from course to course and considered to have 4-6 outcomes per course. These Course Outcomes represents what students are expected to learn and be able to do by the end of a particular course. They focus on the knowledge, skills, and attitudes that students should acquire. All the courses in the program to be Mapped with Program Outcomes. Program Outcomes are broader statements that describe what graduates are expected to achieve by the end of a program.

Mapping with the Program Outcomes is very important in the Educational System to maintain high standards and also ensures that graduates are well-prepared for their careers. PO's are critically required in the Educational Institutions for assessing the quality of education. External quality agencies like National Board of Accreditation (NBA) and National Assessment and Accreditation Council (NAAC) use these PO's to evaluate whether the programs meet educational standards and are capable of delivering quality education. This can be measured using achieved PO attainment values using a predefined calculation procedure. This paper presents the enhancement of Program Outcomes through PBL which in turn improves Academic performance of the students.

V. COURSE OVERVIEW

Antennas and Wave Propagation is professional core course of Electronic and Communication Engineering. This course is prerequisite for other courses in the higher classes. It focuses on the principles of how antennas work, the propagation of electromagnetic waves, and the design considerations of various Antennas used for communication.

Antennas and Wave Propagation course has four Learning outcomes:

1. Course Outcome 1: Describe the fundamental antennas and wave propagation concepts
2. Course Outcome 2: Apply the basic concepts of electromagnetic wave radiation for transmission and reception
3. Course Outcome 3: Develop prototypes of practical antennas for various real time applications
4. Course Outcome 4: Evaluate the designed antenna parameters

Unfortunately, there is no Laboratory classes attached to this course in the most of the Engineering colleges in India. Due to this, students lack hands on experience and also there is challenge in understanding the course as this course is critical. Implementation of Problem Based Learning in the class room not only fill this gap but also helps in addressing all the Program Outcomes through this course.

TABLE I
CO-PO MAPPING TABLE

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 9	PO 10	PO 11	PO 12
CO1	3	3							
CO2	3	3							
CO3	3	3							
CO4	3	3							

These COs are designed to impart essential knowledge and skills related to antennas and wave propagation. However, above table 1 shows that the COs cover only few Program Outcomes effectively, they may not address the full spectrum of POs necessary for a comprehensive engineering education. To fill this gap and to give hands-on experience in this course PBL is chosen.

VI. METHODOLOGY: THE ROLE OF PROBLEM-BASED LEARNING (PBL) IN ADDRESSING POs

M. Rajendra Prasad(2014) Traditional teaching methods focusing on theoretical concepts and individual assignments may not fully engage students in the practical, collaborative,

and interdisciplinary skills needed for their future careers. To objective of this paper is to improve Academic performance of the students and to create better learning experience in the classroom which results in enhanced Program Outcomes. Implementation of Problem Based Learning address all relevant Program Outcomes.

A. PBL Approach: By implementing PBL, students are exposed to complex, real-world problems that require them to apply and integrate knowledge from various areas. For instance, a PBL scenario might involve designing a communication system that includes antenna development, prototype testing, and evaluation, addressing several POs simultaneously. This approach ensures that students not only understand theoretical concepts but also gain practical experience in engineering design, teamwork, and project management.

B. Addressing POs: PBL effectively covers POs that traditional methods may overlook.

- **Design/Development of Solutions (PO3)**: Students come up with solution for given problem and design/develop a prototype.
- **Conduct Investigations of Complex Problems (PO4)**: While working on the problem solutions students do research, experimentation, and data analysis, using modern tools and critical thinking.
- **Modern Tool Usage (PO5)**: For the above given problem statement students design antennas through Antenna software HFSS.
- **Teamwork (PO9)**: students work in team and develop a solution. This enables to enhance their ability to work in group effectively.
- **Project Management (PO11)**: Managing the project from conception to evaluation develops essential project management skills.

The table 2 presents CO-PO Mapping after implementation of Problem Based Learning in the classroom.

TABLE II
MAPPING AFTER IMPLEMENTING PBL

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 9	PO 10	PO 11
CO1	3	3		1	3	3	3	3
CO2	3	3		2	3	3	3	3
CO3	3	3	3	3	3	2	2	2
CO4	3	3	3	2	2	3	3	3

In Course Outcome 1, majority of POs are addressed to Level 3. This involved students applying their theoretical understanding of antennas and wave propagation to real-world issues, which called for a high level of application, analysis, and critical thinking. They created, tested, and presented prototypes to show that they had a thorough knowledge. Their work was thorough and of a high standard, covering several facets of engineering design, teamwork, and communication. Most POs achieved a Level 3 because to the teamwork and effective use of modern tools, which also demonstrated an extensive knowledge of fundamental ideas.

In Course Outcome 2, Level 3 is mapped to majority of POs. Using instruments like HFSS, the process of developing antenna designs required advanced abilities. Students demonstrated their technical ability by designing and simulating antenna models in an effective manner. There was a high degree of teamwork, meticulous use of modern tools, and research and design work. However, not all teams displayed in-depth experimental inquiry for PO4 (Conduct Investigations), which supports a Level 2 for that particular PO. Instead, some students completed only moderate research.

In Course Outcome 3, Students had to conduct detailed analyses of antenna performance as part of this outcome, which focused on experimental evaluation. The high level was justified by the majority of students who carried out thorough experiments and critical analysis. However, some variation in team efficiency resulted in Level 2 for those factors in areas like project management and teamwork. This was due to the fact that some groups required extra assistance in order to properly manage their projects and collaborate.

In Course Outcome 4, Students demonstrated strong communication skills, effectively documenting their design processes, experimental results, and conclusions. They could conduct in-depth analysis of issues and effectively convey their conclusions, which supports Level 3 for the majority of POs.

C. Importance of Comprehensive PO Coverage

Addressing all relevant POs is vital for several reasons:

1. **Holistic Education**: By implementing this PBL to the students develop both theoretical and practical skills and become industry ready. Their interpersonal skills also get enhanced with this collaborative approach.

2. **Accreditation and Quality Assurance**: Accreditation bodies such as the National Board of Accreditation (NBA) and the National Assessment and Accreditation Council (NAAC) assess programs based on their ability to achieve a comprehensive set of POs. Failing to address all POs can impact accreditation status and reflect on the institution's commitment to quality education. Siddapuram, A(2024)

3. **Industry Readiness**: Engineering professionals need to possess a broad range of skills, including technical expertise, teamwork, and project management. Ensuring that students meet all POs prepares them for the diverse challenges of the engineering field.

D. Analysis of Course Outcomes and Their Alignment with Program Outcomes

CO1: Describe the fundamental antennas and wave propagation concepts: After implementing PBL, this course outcome maps to PO1, PO2, PO4, PO5, PO9, PO10, PO11.

With the knowledge of the fundamental concepts of Antennas students propose solutions to the given problem statement in the form of projects and address the given PO's.

CO2: Apply the basic concepts of electromagnetic wave radiation for transmission and reception: Applying theoretical concepts to practical scenarios aligns with POs related to engineering problem-solving and modern tool usage This outcome bridges the gap between theory and practice to some extent but may still lack depth in areas like collaborative project work and comprehensive design skills.

CO3: Develop prototypes of practical antennas for various real-time applications: This outcome is achieved with practical application of theoretical knowledge by engaging students in the development of prototypes. It addresses POs related to engineering design (PO3), modern tool usage (PO5), and project management (PO11). While it covers significant aspects of engineering practice, it may not fully engage students in teamwork and collaborative problem-solving.

CO4: Evaluate the designed antenna parameters Evaluating designed parameters is crucial for understanding the performance and effectiveness of prototypes. This outcome aligns with POs related to engineering analysis (PO2) and design evaluation (PO3).

E. PO Attainment

After calculating Course Outcomes, Program Outcomes were calculated. The table presents PO attainment for the course Antenna and Wave Propagation.

TABLE III
PO ATTAINMENT ACHIEVED PERCENTAGE

Program Outcomes	Attainment %	Level
PO1	84.65	3
PO2	74.24	3
PO3	61.00	2
PO4	65.08	2
PO5	64.24	2
PO9	89.65	3
PO10	88.65	3

Levels: Three levels are assigned to check the quality and outcomes of the course. The levels taken are based on the target percentage of the Institution which is considered as 60%. The detailed calculation is taken from NBA SAR Document. The summary of the levels created for this course is mentioned below:

- Level 3 - 50% of students getting more than 60% marks
- Level 2 - 55% of students getting more than 60% marks
- Level 1 - 60% of students getting more than 60% marks

VII. PBL IMPLEMENTATION

A. Problem Statement:

Design and Implementation of a Wireless Communication System Using Practical Antennas.

Objective of this statement is to "Design and implement a wireless communication system by developing and evaluating practical antennas for specific real-time applications. The project will encompass describing fundamental concepts, applying principles of electromagnetic wave radiation, developing prototypes, and evaluating their performance".

B. Process involved: Methodology

This initiative is done for third year Electronics and Communication Engineering students with the strength of 63 and were formed into 13 teams. Problem statement was given to all the teams. Since the problem is open ended, there were so many queries from the students on the given problem statement. As Students are experiencing this PBL for first time, the teams were provided with 4 clues on the problem statement to give them clarity on their ideas. After 2 hours of brainstorming with the support of instructors, students came up with their solution for the given problem. The ideas were scrutinized by the instructors as stage 1.

Fig 1. Students teams working on problem statement

C. Rubrics for Assessment

Key parameters used to evaluate students' performance are: Design and plan, Creativity and innovation, Problem Solving skills and Collaboration. Levels of each parameter scaling from 1 to 5 is defined for evaluations of solutions developed by the students.

D. Results:

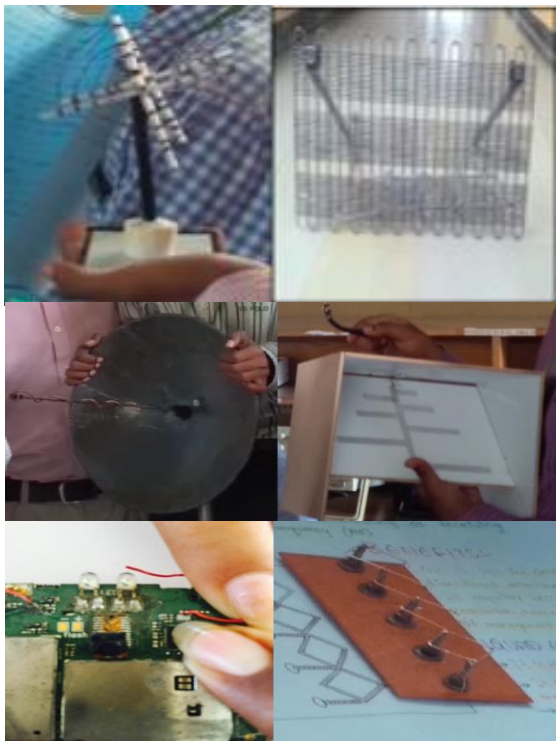


Fig. 2. Prototype of parabolic reflector, Microstrip, Helical antenna, quad band antennas

The program outcomes addressed before implementing PBL is PO1, PO2. But after implementing PBL into the course we can able to address PO3, PO4, PO5, PO9,PO10, PO11.

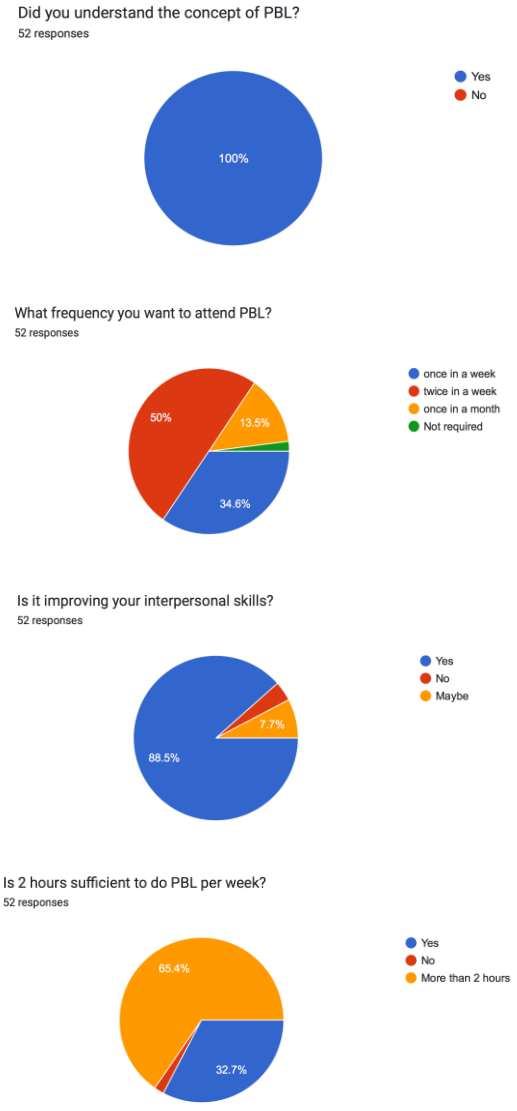
Analysis of the data revealed a 30% increase in student performance in POs related to problem-solving and teamwork, with 85% of students reporting enhanced motivation and engagement. The academic performance of the students improved from 70% to 84%.

E. Challenges faced during Implementation:

Implementing Problem-Based Learning (PBL) can be highly effective, but it also comes with several challenges that educators and institutions need to address. The challenges include resistance to change from more traditional teaching methods, the allocation of additional resources for PBL, the integration of PBL into existing curricula, designing effective assessments that align with PBL outcomes, ensuring students are adequately prepared for self-directed and collaborative learning, and providing specialized training for PBL facilitators. Time management and equitable assessment of group work pose additional hurdles, as does the sustainability of PBL initiatives over time. Resource inequity, accountability for self-directed learning, and balancing the emphasis on the process versus content also require careful consideration. Addressing these challenges necessitates thoughtful planning, ongoing professional development, and a steadfast commitment to the principles of PBL, ultimately yielding the potential benefits of enhanced student engagement and critical thinking skills.

F. Feedback from the students:

Many students appreciate PBL for its engaging and interactive nature. They often report improved critical thinking, problem-solving, and teamwork skills. They find it relevant and feel better prepared for real-world challenges. Some students found PBL initially uncomfortable, as it requires active participation and self-directed learning. They requested for clearer guidelines and expectations. Feedback is taken from the students to understand the students interests and suggestions for effective implementation for further semesters.



CONCLUSION

This paper presents that Problem-Based Learning is a valuable educational approach for improving student engagement and academic performance in the Antennas and Wave Propagation

course. By providing a structured, real-world problem for students to solve, PBL enhances their understanding of complex concepts and prepares them for professional practice. The Academic Performance of the students has been gradually improved with the experiential learning in the class. The positive results from this implementation suggest that PBL can effectively address gaps in traditional teaching methods and contribute to the achievement of Program Outcomes.

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