

Applying Project-Based Learning and Backward Design to Antenna Education: A Digital Television Antenna Design Project

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Abstract—Traditional lecture-based methods in antenna education often fail to link theoretical knowledge with practical applications, limiting student engagement. This study integrates project-based learning (PjBL) with backward design to address these challenges in an undergraduate antenna course. Students designed and fabricated a digital television (DTV) antenna covering Taiwan's 533–593 MHz band, progressing through structured checkpoints. A key milestone, Checkpoint 2, involved designing and fabricating an impedance matching circuit to adapt a Wi-Fi antenna for DTV reception, emphasizing hands-on skills and practical application of theory. Action research revealed an improvement in final exam scores and a 27% rise in participation rates, while questionnaire responses highlighted strong preferences for inquiry-based learning, with ratings exceeding 4.0 on a 5-point scale. These results demonstrate the effectiveness of PjBL and backward design in enhancing learning outcomes and practical skills.

I. INTRODUCTION

Traditional antenna courses in engineering education are predominantly lecture-based, focusing on delivering theoretical knowledge such as Maxwell equations, impedance matching, and radiation principles. While these lectures provide a solid foundation, they often lack opportunities for students to apply their knowledge in practical scenarios. This gap results in limited comprehension of how antenna concepts translate to real-world applications. Furthermore, the passive nature of lecture-based learning can lead to reduced student engagement and motivation, ultimately affecting learning outcomes.

Project-based learning (PjBL) has gained recognition as a pedagogical approach that addresses these issues. By involving students in real-world, problem-solving tasks, PjBL enhances active learning and promotes deeper understanding. In the context of antenna education, PjBL allows students to design, fabricate, and evaluate antennas, bridging the gap between theoretical knowledge and hands-on application. However, the effectiveness of PjBL depends significantly on how the projects are structured and aligned with the intended learning outcomes.

Backward design provides a framework to maximize the effectiveness of PjBL. It begins by identifying desired learning outcomes and then designing assessments and instructional activities that align with these objectives. This approach ensures that every aspect of the course contributes directly to achieving the predefined goals. In antenna courses, backward design can facilitate the systematic integration of theory and practice, ensuring that students not only understand the concepts but also apply them effectively.

This paper presents the implementation of a PjBL approach, underpinned by backward design, in a graduate antenna course. The study focuses on designing and fabricating a digital television (DTV) antenna capable of covering frequency band of 533–593 MHz, the specification in Taiwan. Through three formative checkpoints and a summative assessment, students engage in a hands-on, collaborative learning process that emphasizes both theoretical understanding and practical skills. The effectiveness of this approach is evaluated through action research and questionnaire analysis, providing insights into its impact on student engagement and learning outcomes.

II. LITERATURE REVIEW

The integration of project-based learning in engineering education has been extensively studied in recent years. PjBL has been shown to improve student engagement and deepen understanding of technical concepts. For example, in electrical engineering, PjBL methods have demonstrated enhancements in problem-solving skills and conceptual clarity [1]. In antenna engineering, integrating hands-on projects has proven effective in bridging the gap between theoretical knowledge and practical applications [2]. Studies have highlighted that backward design achieves alignment between instructional activities and learning objectives, creating a coherent pathway for student success [3].

Moreover, the use of peer evaluations in project-based settings has been shown to develop critical thinking and collaborative skills. Research demonstrates that peer reviews contribute to an inclusive learning environment where students reflect on their own work and that of others, thus reinforcing learning outcomes [4].

III. COURSE DESIGN

Backward design, a model emphasizing the alignment of learning objectives, assessment, and instruction, serves as the foundation for structuring this PjBL course. The course begins by identifying the desired outcomes—students should be able to independently design, fabricate, and validate antennas suitable for specific applications. Instructional activities and assessments are then developed to support these objectives.

The final project requires students to design a DTV antenna that satisfies stringent criteria, such as covering the 533–593 MHz band. The project emphasizes not only the number of channels received but also the antenna performance metrics, including radiation pattern, gain, and efficiency. To achieve these goals, the course integrates fundamental antenna theory



Fig. 1. Photographs of students' antenna prototypes.

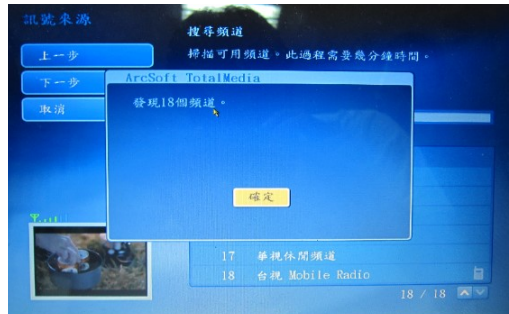


Fig. 2. Interface of the DTV device displaying the number of channels found using the designed antennas.

with hands-on activities, ensuring a balance between conceptual understanding and practical application.

The PjBL is organized around three formative checkpoints, culminating in a summative assessment. Checkpoint 1 focuses on project planning and literature review, enabling students to understand DTV antenna requirements and explore impedance matching networks with reconfigurable or broadband characteristics.

Checkpoint 2 involves designing and fabricating an impedance matching circuit to adapt a commercially available Wi-Fi antenna for DTV signal reception. This hands-on task bridges theoretical knowledge and practical application, reinforcing students' understanding of impedance behavior in antenna systems. Students validate their designs by demonstrating the ability to enable DTV signal reception.

Checkpoint 3 requires students to propose an antenna geometry, supported by simulations of radiation parameters such as pattern, gain, and efficiency. This phase emphasizes the integration of design and analytical skills, preparing students for the final fabrication and demonstration.

The summative assessment represented the culmination of the project, serving as an overall examination of each student's ability to integrate theory and practice. Students fabricated their antennas and presented their results, which were evaluated using a rubric. The rubric included four criteria: the number of channels successfully covered by the antenna, validation of performance through both simulations and measurements, innovative features such as reconfigurability or broadband behavior that enhanced signal quality, and the clarity and professionalism of the presentation. In particular, Fig. 1 displays photographs of the students' fabricated antennas, highlighting their design and craftsmanship. Fig. 2 shows the interface of the DTV device, demonstrating the number of channels successfully received using each antenna.

IV. RESULTS AND DISCUSSIONS

The effectiveness of the project-based learning approach, guided by backward design, was evaluated using both action research and questionnaire analysis. In the action research, the performance and participation of students in the PjBL cohort were compared with those in a traditional lecture-based cohort. The average final exam score for the PjBL cohort was 82%, compared to 74% for the traditional cohort, demonstrating an improvement in conceptual understanding and application. Participation rates in class activities and formative assessments were also significantly higher in the PjBL group, with 95% of students actively engaging, compared to 68% in the lecture-based cohort.

The questionnaire provided further insights into student perceptions of the course structure and its impact on their learning. Responses were rated on a 5-point Likert scale, where higher scores indicated stronger agreement with positive statements. The statement "Inquiry-based learning has helped bridge the gap between academic concepts and real-world industry challenges" received an average score of 4.0, highlighting the relevance of the course content to practical applications. The guidance provided at each checkpoint received an average score of 4.2, demonstrating the value of structured milestones and iterative feedback in supporting student progress. The statement "I would prefer inquiry-based learning for course evaluation over traditional exams" achieved the highest score of 4.6, emphasizing the preference for experiential learning models.

The overall results from both the action research and the questionnaire indicate that the PjBL framework significantly enhances student engagement and learning outcomes. The checkpoint system, supported by peer evaluations, enabled students to refine their designs through iterative feedback and collaborative problem-solving. Furthermore, the practical focus of the projects effectively bridged the gap between theoretical knowledge and real-world engineering applications.

V. CONCLUSION

This study demonstrates that PjBL, guided by backward design, can significantly enhance students' understanding of antenna engineering. The peer evaluation mechanism, combined with a comprehensive rubric, achieves objective assessment and a collaborative learning environment. By aligning educational strategies with industry-relevant skills, this approach prepares students for real-world challenges in engineering design and innovation.

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