

Evaluating how Problem-Based Learning influences students' development of IMechE-defined Skills and Competencies

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Research Overview

This study evaluates how Problem-Based Learning (PBL) influences engineering students' development of professional competencies aligned with IMechE standards. Using a model-driven approach, it identifies key pedagogical factors shaping competency outcomes. Findings highlight student autonomy as the strongest predictor, alongside instructional support and professional identity development within PBL environments.

Purpose of Study

Engineering education has increasingly shifted towards active, student-centred pedagogies in response to the growing complexity of global and professional challenges. Among these, Problem-Based Learning (PBL) has gained prominence for its potential to integrate technical knowledge with practical problem-solving, collaboration, and professional skill development. However, despite widespread adoption, there remains limited empirical evidence linking PBL implementation to recognised professional competency frameworks.

This study addresses this gap by evaluating the effectiveness of PBL within the context of Cardiff University's School of Engineering, where a first-year PBL intervention has recently been introduced. Specifically, the research examines the extent to which PBL contributes to the development of competencies defined by the UK Standard for Professional Engineering Competence (UK-SPEC), as interpreted by the Institution of Mechanical Engineers (IMechE). These competencies include knowledge and understanding, design and problem-solving, communication, leadership, and personal commitment.

Existing literature demonstrates that PBL supports a wide range of learning outcomes, including teamwork, communication, creativity, and problem-solving. However, findings are often fragmented, focusing on isolated aspects such as project design or student motivation, rather than examining how multiple pedagogical factors interact to influence competency development. In addition, most studies evaluate short-term outcomes

within individual modules, with limited attention to long-term or programme-level impacts. This study therefore adopts a model-driven approach, integrating multiple dimensions of PBL implementation into a unified framework. By linking these factors to IMechE competency outcomes, the research aims to provide a more structured and evidence-based understanding of how PBL contributes to professional engineering development.

Research Methods

The study employs a quantitative research design informed by a structured literature review, conceptual model development, and survey-based data collection. A systematic literature review initially identified five key dimensions influencing PBL effectiveness: skills development, project design and structure, support and resources, student agency and motivation, and interdisciplinary and systems thinking.

These dimensions were incorporated into a conceptual framework linking PBL implementation factors with IMechE-defined competencies. Based on this framework, a survey instrument was developed comprising 24 factor-based questions and five overall competency measures. Responses were collected using Likert scales to capture students' perceptions of their learning experiences. The survey was administered to undergraduate engineering students across multiple year groups and disciplines, yielding 162 responses, of which 83 valid responses were retained following data cleaning and attention checks. Data analysis was conducted in two stages. First, Exploratory Factor Analysis (EFA) was used to identify underlying dimensions within the dataset. Second, multiple regression analysis (using Weighted Least Squares) was used to examine the relationship between these factors and overall competency development. Additional non-parametric tests were conducted to assess differences across demographic groups.

Results and Discussion

The findings show that the effectiveness of PBL is inherently multi-dimensional, with different aspects contributing unequally to competency development. Among the identified factors, student autonomy and confidence emerged as the strongest predictor of IMechE-aligned competency outcomes. This suggests that students' ability to take ownership of their learning and engage actively with problem-solving processes is central to the success of PBL.

In addition, professional identity development and instructional support were found to have significant positive relationships with competency development. These findings highlight the importance of aligning PBL activities with real-world engineering practice,

while also ensuring appropriate scaffolding and facilitation. Rather than being entirely student-driven, effective PBL environments require a balance between autonomy and structured support to enable meaningful engagement.

In contrast, interdisciplinary collaboration and systems thinking showed a negligible direct impact on competency outcomes. While these elements are strongly emphasised in the literature, the findings suggest that they may not translate immediately into measurable competencies. Instead, they may develop more gradually over time or remain less visible within students' self-assessments. This highlights a potential gap between intended curriculum outcomes and students' perceived learning.

Another key finding is the absence of significant differences in competency development across year groups. This suggests that a single, one-off PBL intervention may not lead to cumulative growth in professional competencies throughout the degree programme. While PBL exposure appears beneficial, its impact may diminish without continued reinforcement in later stages of study.

Overall, the results indicate that PBL contributes meaningfully to engineering competency development, but its effectiveness depends on how it is designed and integrated within the curriculum.

Conclusion

This study provides empirical evidence that Problem-Based Learning supports the development of IMechE-defined engineering competencies, particularly through enhancing student autonomy, confidence, and professional identity. The findings suggest that isolated or short-term PBL interventions may be insufficient to achieve sustained competency development. Instead, a more systemic and integrated approach is required.

Keywords

Problem-Based Learning, Engineering Education, Competency Development, IMechE, Student Agency

Please note: Due to the word limitations, no references have been added. If requested, we are happy to provide a version with the references.