

Contribution Format (Discussion)

Fostering T-Shaped Competencies through Project-Based Learning: Addressing Challenges and Exploring Solutions

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Abstract: Modern day education must go beyond traditional knowledge transfer to equip students with the competencies required to address complex, real-world challenges. This study examines the role of project-based learning (PBL) in fostering competencies that combine deep technical knowledge with interdisciplinary and interpersonal skills, often referred to as T-shaped competencies. Conducted at the Norwegian University of Science and Technology (NTNU), the research utilized a mixed-method approach, incorporating qualitative data from student interviews and process reports alongside quantitative self-assessment surveys. The findings highlight how structured communication strategies, stakeholder engagement, and iterative feedback processes during project-based learning (PBL) can enhance student learning outcomes.. Real-world projects and feedback from interdisciplinary collaborations provided opportunities to integrate theory with practice, enhancing student's problem-solving abilities, teamwork, and understanding of user-centric design. Additionally, assessment methods such as reflective process reports, technical documentation, and oral presentations were identified as effective in evaluating both technical and transversal skills. However, challenges such as inconsistent stakeholder communication, logistical delays, the stress associated with certain assessment methods and resistance to structured frameworks illustrate the complexities of interdisciplinary collaboration and project-based learning. This work provides actionable strategies for addressing these challenges while maximizing the potential of project-based learning. Recommendations include refining assessment methods, enhancing interdisciplinary collaboration, and introducing mandatory feedback mechanisms to ensure continuous improvement.

Keywords:

Project-based learning, T-shaped competencies, interdisciplinary collaboration, educational course design, assessment strategies

1 Introduction

Project-based learning (PBL) has emerged as a key approach in higher education to develop competencies that go beyond traditional knowledge acquisition. It has been widely recognized as an effective educational strategy to foster both deep technical knowledge and interdisciplinary collaboration (Biggs & Tang, 2011). One of the major challenges in modern education is ensuring that students not only acquire theoretical expertise but also develop interdisciplinary and practical skills. The concept of T-shaped competencies emphasizes the need for deep technical knowledge (vertical skills) alongside broad interdisciplinary and interpersonal skills (horizontal skills), which are crucial in solving real-world problems. The integration of real-world stakeholder engagement in PBL helps students develop problem-solving, teamwork, and adaptability skills essential for tackling complex challenges (Van den Beemt et al., 2020). This study explores how PBL can be structured to enhance the development of T-shaped competencies, particularly within the context of engineering education. The research question guiding this study is – ‘How can project-based learning be structured to develop T-shaped competencies among students?’

By aligning with competence-based education frameworks (Kolb, 2014) and emphasizing constructive alignment in assessment (Biggs & Tang, 2011), this study provides insights into improving PBL for higher education. This research aligns with the MNT 2025 conference theme by addressing competence-based education, interdisciplinary collaboration, and assessment frameworks.

This study builds on my master's thesis, which explored how project-based learning can foster T-shaped competencies through structured communication, stakeholder engagement, and interdisciplinary collaboration. The research expands on these findings by further analyzing assessment frameworks and practical challenges in implementing PBL. By drawing on both qualitative and quantitative insights, this work aims to contribute actionable strategies for optimizing engineering education to meet evolving industry demands (Hasan, 2024).

2 Methodology

2.1 Course Setting and Role of Real-World Stakeholders

The course "TTT4270 - Electronic System Design, Project" at NTNU follows a Project-Based Learning (PBL) approach. It is part of the Electronic Systems Design and Innovation master's program. Students engage in interdisciplinary team projects, often collaborating with external partners such as St. Olavs Hospital. These partnerships expose students to real-world challenges where they apply their technical knowledge in electronics, programming, and mechanics to solve healthcare-related problems.

2.1.1 Key Aspects of the Course:

- Collaborative Learning: Students work in teams of 5-6 members.
- Real-World Problem-Solving: External partners define problems, and students develop solutions.

- Design Thinking Framework: Students are encouraged to follow an iterative approach to problem-solving.

2.1.2 Assessment Components:

- Process Report (20%) – Evaluates teamwork, stakeholder engagement, and communication.
- Technical Report (25%) – Documents technical aspects and implementation.
- Oral Presentation (55%) – Assesses the final product, its feasibility, and student's ability to present their work.

The assessment tools in this course were designed to evaluate both technical expertise and soft skills, essential for developing T-shaped competencies. Process reports were used to help students reflect on their teamwork, communication, and problem-solving skills, while also promoting self-assessment and feedback-based learning. Technical reports provided a structured way to document solutions systematically, aligning with industry standards and assessing student's problem-solving abilities. Finally, oral presentations allowed students to articulate their work and demonstrate interdisciplinary collaboration, providing a comprehensive evaluation of their projects.

2.2 Methodological Approach

This study employs a mixed-methods approach to explore how Project-Based Learning (PBL) fosters T-shaped competencies in engineering education. The research integrates both qualitative and quantitative methods to provide a comprehensive understanding of learning outcomes, aligning with best practices in educational research (Creswell & Plano Clark, 2018).

A mixed-methods design was chosen because:

- Quantitative data helps measure improvements in competencies such as teamwork, communication, and technical skills.
- Qualitative insights capture student's experiences, challenges, and the real-world impact of interdisciplinary collaboration.

The combination of these methods ensures a balanced evaluation, considering both the measurable impact of PBL and the subjective experiences of students (Tashakkori & Teddlie, 1998). This approach is particularly important in engineering education, where the goal is to develop both technical expertise and soft skills necessary for real-world problem-solving.

2.3 Data Collection

The qualitative data was collected through student process reports and semi-structured interviews. These sources provided insights into team collaboration, problem-solving strategies, and the effectiveness of structured communication within project-based learning environments, while also capturing student's experiences, challenges, and approaches to navigating interdisciplinary collaboration.

For the quantitative data, self-assessment surveys were administered to students at the beginning and end of the semester. These surveys were designed to measure improvements in various skills, including teamwork, problem identification, design thinking, interdisciplinary knowledge, and communication. Students rated their skills on a scale from 1 (fundamental) to 10 (advanced), allowing for a structured assessment of growth over the course of the project.

To maintain research integrity and participant anonymity, the study adhered to GDPR compliance guidelines, with all data collection conducted via the secure platform Nettskjema.no. Participation was voluntary, and respondents were assured that their responses would remain confidential.

2.4 Data Analysis

The data analysis process was structured to extract meaningful patterns from both qualitative and quantitative sources. A thematic analysis approach was employed to examine student reflections in process reports and interviews to identify recurring patterns and challenges in student learning experiences (Braun & Clarke, 2006). Thematic categories were identified through iterative coding, allowing for a deep exploration of interdisciplinary collaboration, stakeholder engagement, and assessment methods.

For the quantitative data, Python-based statistical tools were used to process survey results. Using libraries such as Pandas and Matplotlib, the data was analyzed to compare pre- and post-assessment scores, enabling the identification of competency development trends. The integration of both qualitative and quantitative insights ensured that findings were validated through triangulation, strengthening the reliability of the study.

3 Results Overview

3.1 Positive Outcomes

The implementation of Project-Based Learning (PBL) at NTNU proved to be highly beneficial in fostering teamwork, communication, and interdisciplinary collaboration among students. A key factor in this success was the use of structured frameworks, such as cooperation contracts and regular progress meetings, which helped students stay aligned with project objectives. These strategies ensured that responsibilities were evenly distributed, reducing confusion and enhancing engagement. When roles and expectations were clearly defined, students reported feeling more motivated and confident in their contributions. Empirical data from self-assessment surveys further validated these observations.

Another significant advantage of the PBL approach was the opportunity for real-world collaboration with external stakeholders, particularly professionals from St. Olavs Hospital. Engaging with industry experts allowed students to receive practical feedback on their designs, enabling them to refine their projects based on real-world requirements. This process helped bridge the gap between theoretical learning and practical application, equipping students with problem-solving skills and a deeper understanding of user needs. The iterative nature of the projects encouraged students to

continuously improve their solutions, integrating feedback to make their designs more relevant and effective.

Furthermore, the development of user-centric solutions emerged as a key outcome of interdisciplinary collaboration. By working closely with stakeholders, students learned to approach problems from different perspectives, considering not just technical feasibility but also usability and accessibility. Survey data indicated improvement in student's ability to recognize and define problems effectively, reinforcing the impact of project-based learning on problem-solving skills.

3.2 Challenges

Despite these positive outcomes, several challenges were identified that affected the overall effectiveness of the PBL approach. One major issue was inconsistent communication with stakeholders. While external professionals provided valuable insights, the lack of timely responses and vague feedback often led to project delays. Some student groups struggled with aligning their work with stakeholder expectations due to unclear or late feedback, making it difficult to make informed design decisions. These communication gaps highlighted the need for a more structured and scheduled feedback process to ensure that students receive timely and actionable guidance.

Assessment methods also posed significant challenges. The heavy emphasis on oral presentations (55% of the final grade) created stress among students, as they felt that their overall performance was disproportionately dependent on a single presentation. Some students reported that the presentation format, while useful for demonstrating technical and collaborative skills, was distracting due to external factors such as time constraints and the pressure of public speaking. Additionally, process reports, which were intended to document learning progress and teamwork, were sometimes perceived as redundant and burdensome.

Another challenge was logistical barriers, particularly in acquiring necessary resources and maintaining smooth project workflows. Delays in accessing equipment and materials affected prototyping and testing phases, limiting student's ability to iterate on their designs effectively. Additionally, misaligned schedules with external stakeholders further complicated project execution, making it difficult to coordinate meetings and implement feedback in a timely manner.

4 Discussion

4.1 Addressing Identified Challenges

To optimize the effectiveness of Project-Based Learning (PBL), structured communication strategies and stakeholder engagement must be refined. The findings from this study suggest that well-defined communication protocols, such as cooperation contracts and regular progress updates, enhanced team coordination and engagement, aligning with Addimando's findings on the importance of structured communication in collaborative learning (Addimando, 2024). Ensuring flexibility within these structures can help accommodate diverse team dynamics while maintaining clear project objectives.

Additionally, stakeholder engagement played a crucial role in fostering interdisciplinary collaboration and technical proficiency. However, this study found that inconsistent communication with external stakeholders created barriers to effective project execution. Engaging professionals from various fields, such as healthcare, provided valuable real-world insights, reinforcing the arguments of Van den Beemt et al. on the importance of interdisciplinary education in solving complex challenges (Van den Beemt et al., 2020). However, as Boud & Soler highlight, maintaining stakeholder engagement requires structured feedback sessions and well-defined expectations to maximize learning benefits (Boud & Soler, 2016). Findings from this study further suggest that addressing logistical and communication barriers can significantly improve student's ability to integrate stakeholder insights into their projects more effectively.

This study also provides insights into the effectiveness of various assessment tools in evaluating the impact of PBL and stakeholder engagement on the development of T-shaped skills. The combination of oral presentations, technical reports, and process reports was found to provide a comprehensive skill assessment but also posed challenges. Presentations were particularly effective in assessing communication and interdisciplinary interaction skills, as supported by Mansilla & Duraising's framework on interdisciplinary work evaluation (Mansilla & Duraising, 2007). However, findings from this research suggest that a more structured and focused presentation format could help reduce student's stress and distractions, enhancing their ability to demonstrate knowledge and project outcomes effectively. Adjusting the weight of presentations and integrating process reports with technical documentation, as proposed by Gibbings & Brodie, could improve the assessment framework without compromising reflection and learning outcomes (Gibbings & Brodie, 2008).

Overall, structured communication strategies, improved stakeholder engagement, and refined assessment methods are key areas for improvement in PBL. These refinements will strengthen both the depth of technical knowledge and the breadth of interdisciplinary collaboration, ensuring that students are better prepared to tackle complex, real-world challenges (Cruz et al., 2020).

4.2 Recommendations

Based on student feedback and course evaluation, several improvements are suggested to enhance the development of T-shaped competencies and address identified challenges in Project-Based Learning (PBL).

4.2.1 Enhancing Design Thinking Support:

Structured engagement with design-thinking mentors can help students develop creative problem-solving skills while addressing complex, real-world challenges. More structured and mandatory stakeholder feedback sessions should be introduced to ensure continuous guidance throughout the project.

4.2.2 Improving Stakeholder Communication:

Mandatory and scheduled stakeholder feedback mechanisms should be integrated to ensure timely and constructive input. Encouraging advisors to engage more proactively in student projects will also improve alignment between project goals and real-world expectations.

4.2.3 Refining Assessment Methods:

Balancing process reports and technical reports can reduce redundancy while still encouraging reflection and documentation. Adjusting oral presentation weightage can help alleviate stress while maintaining the effectiveness of communication assessments. Future studies should explore the long-term impact of refined assessment methods on student skill development.

4.2.4 Optimizing Course Structure and Support Mechanisms:

Expanding the role of teaching assistants to provide additional support throughout the project cycle can help ensure timely feedback and structured learning. Introducing more interactive assessment formats, such as oral exams, may improve the overall evaluation process by allowing students to demonstrate their competencies in a more flexible manner.

5. Conclusion

This study demonstrates that Project-Based Learning (PBL) fosters T-shaped competencies by integrating interdisciplinary collaboration, structured assessment, and stakeholder engagement. While real-world collaboration and iterative feedback enhanced student learning, challenges such as inconsistent stakeholder communication and assessment stress highlight areas for improvement.

To optimize PBL, refining assessment methods, enhancing stakeholder engagement, and strengthening course design are key recommendations. Future research could explore ways to balance assessment rigor with student workload and adapt structured teamwork methods across disciplines. By addressing these challenges, PBL can further evolve as a powerful tool for real-world competency development.

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