Factors Shaping Student Experience in First-Year Engineering Design Course: A Comprehensive Analysis

Wendy Lee; Yuchao Jiang.
UNSW Sydney, Australia
Corresponding Author Email: wendy.lee@unsw.edu.au

ABSTRACT

CONTEXT

First-year engineering design courses often group students from various disciplines to collaborate on projects like building robots or prototypes, introducing challenges such as unfamiliarity and communication differences. Students must balance mastering technical concepts and teamwork dynamics, while the tangible nature of projects demands resilience. Understanding students' perspectives in this context offers valuable insights for enhancing engagement and success in these courses.

PURPOSE OR GOAL

This study aims to uncover the factors that significantly influence students' experiences in first-year engineering design courses, particularly when they collaborate with unfamiliar peers on semi-large-scale projects. We aim to identify how individual attributes, group dynamics, and project characteristics shape student engagement and success. Our research seeks to provide insights that can inform the development of effective pedagogical strategies and interventions, ultimately enhancing student engagement and learning outcomes in these foundational courses.

APPROACH OR METHODOLOGY/METHODS

This study uses mixed methods, including personal experiences, student feedback, and demonstrator input, to examine factors impacting the student experience. Surveys and interviews analyse student perspectives, while qualitative insights from comments reinforce findings. By triangulating data, this research highlights the need for pedagogical changes to optimise student engagement and learning outcomes in engineering design education.

ACTUAL OR ANTICIPATED OUTCOMES

Key outcomes of the study necessitated changes in teaching practice for first-year engineering design courses, including incorporating well-defined mentor sessions, introducing comprehensive team evaluations, and modifying course content to suit delivery timing.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The study addressed research questions by identifying collaboration challenges and emphasising the importance of mentor sessions. It found that individual attributes significantly influence student engagement, highlighting the need for tailored support. Recommendations like team evaluations and course content adjustments positively impacted the student experience.

KEYWORDS

Project-based learning, engineering design, student experience

Introduction

In recent years, first-year project-based learning (PBL) courses have become a cornerstone of engineering education. They offer students invaluable hands-on experiences and practical skills essential for their future careers. These courses immerse students in real-world problem-solving scenarios, encouraging collaboration and innovation from the start of their academic journey. The increasing complexity of engineering challenges necessitates a shift from traditional lecture-based teaching to more interactive and student-centred learning methods, which are crucial for preparing students for the dynamic demands of modern engineering professions (Prince & Felder, 2006).

One such course, DESN1000: Engineering Design and Innovation introduces students to core engineering design principles, focusing on problem-solving through creative solutions that balance constraints such as budget, time, and environmental factors. This course prepares students for the dynamic and multidisciplinary nature of modern engineering by aligning with industry expectations for well-rounded graduates (Dym et al., 2005).

Students in DESN1000 develop essential skills like critical thinking, communication, and teamwork. These skills are foundational for success in both academic and professional engineering environments, equipping students to thrive in a collaborative, modern engineering landscape.

Understanding the student experience in first-year PBL courses is crucial for several reasons. Firstly, these courses are the foundation for students' engineering education, shaping their perceptions and attitudes towards the discipline. Secondly, insights into student experiences can inform pedagogical practices, facilitating the design of more effective and engaging learning environments (Mills et al., 2003). Lastly, by addressing challenges and enhancing student satisfaction, educators can improve retention rates and foster a sense of belonging among students, ultimately contributing to their academic success.

Despite the recognised benefits of PBL, more in-depth research is needed on the specific factors influencing student experiences in these courses. Previous studies have highlighted general benefits, but there is a need to address the nuances and specific challenges students face sufficiently. This research aims to analyse these factors, identifying key challenges and opportunities students encounter during participation. By exploring the nuances of student experiences, we aim to gain insights that can inform pedagogical strategies and enhance the overall effectiveness of PBL in engineering education (Hmelo-Silver, 2004).

This study focuses on first-year engineering students in project-based courses across diverse engineering disciplines. The research will encompass both qualitative and quantitative analyses of student experiences, drawing from various data sources, including surveys, interviews, and personal reflections. The study will consider factors such as team dynamics, resource availability, project variation, and student backgrounds to provide a comprehensive understanding of the factors shaping student experience in these courses. We hypothesise that tailored support and structured mentor sessions will significantly enhance student engagement and learning outcomes. Note that while a positive student experience is important, it doesn't always align with the learning objectives of a design course. Students should be challenged, even if it takes them out of their comfort zone, as this promotes deeper learning. However, the course should still aim to provide a supportive learning environment that facilitates student growth.

More specifically, we aim to answer the research questions below:

> RQ1: What roles do individual attributes play in shaping students' engagement and success in engineering design projects?
>
> RQ2: How do group dynamics, including communication patterns and leadership roles, influence student experiences and project outcomes?

RQ3: What pedagogical strategies and interventions can be implemented to address challenges and enhance student engagement and learning outcomes in first-year engineering design courses?

Background

In engineering education, it is crucial to engage first-year students in hands-on design projects and courses focusing on engineering ethics and technical communication. To this end, courses such as Introduction to Design Innovation are introduced to the common engineering cohort during their first year. In this course, students participate in a comprehensive 10-week design project using a wide range of electrical circuits, programming skills, materials, and advanced tools such as laser cutting and 3D printing (Freuler et al., 2003). These technologies significantly enhance students' creativity and problem-solving skills, which are reflected in the innovative designs they produce.

Extensive research has explored the nuances of student experiences in project-based learning (PBL) courses (Blumenfeld et al., 1991; Frank et al., 2017; Hassan et al., 2014; Patrikeos et al. 2023). Studies delve into various aspects, ranging from pedagogical approaches to the challenges encountered by students in collaborative settings. Additionally, researchers have examined the role of PBL in fostering critical thinking, problem-solving skills, and professional competencies among students (Sasson et al., 2018).

Several factors influence student experiences in PBL courses. Research has investigated the composition of student teams, the availability of resources and support structures, and the impact of project variation and complexity on student engagement (Jiang, 2021; Shpeizer, 2019). Teamwork is a central theme, with studies highlighting the importance of effective collaboration and communication skills in achieving project success (Mujika et al., 2013). Furthermore, students' diverse backgrounds, including demographic factors and prior experiences, shape their interactions and experiences within project teams (Jones et al., 2014; Kokotsaki et al., 2016; Meyers et al., 2010).

Resource availability, both material and human, is crucial for facilitating student learning and project execution (Shpeizer, 2019). Additionally, project characteristics, such as scope, complexity, and relevance, significantly influence student engagement and the overall learning experience in PBL courses (Guo et al., 2020). Understanding these key concepts helps educators design and implement effective PBL courses that enhance student learning and development.

Course Structure

The study was conducted within the DESN1000: Introduction to Engineering Design and Innovation course. This first-year undergraduate course is designed to introduce students to engineering design principles through project-based learning.

Project selection

In this course, students select a design project and work in teams of 6 members throughout the term (10 weeks). Figure 1 shows a list of the projects offered in the term, to which the students fill out a questionnaire to select their preferences. These projects span all engineering disciplines, such as Electrical, Chemical, Mechanical, Computer Science, and Photovoltaics.

Schedule

The course schedule is shown in Table 1. In the earlier weeks, students were taught engineering design principles based on (Dym, 2013), how to generate concepts, and how to work effectively in a group. Project lectures, however, delve deeper into the intricacies of the project's specifics. For example, the design constraints, how to build the subsystems and debugging.

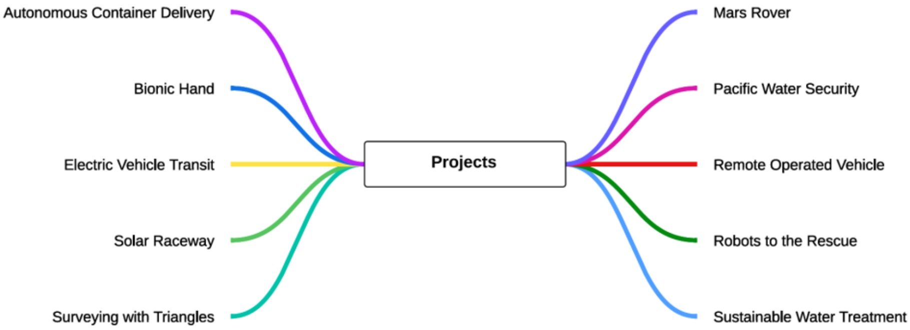

Figure 1: List of available projects

Table 1: Course Schedule

Topics / Week	1	2	3	4	5	6	7	8	9	10
Common Lectures										
Project Lectures										
Technical Stream										
Mentor Meeting										
Graded Testing										

In week 1, students are also asked to split themselves into their respective technical streams, where they will learn the required knowledge to complete the project. These technical streams include Electrical, Computing, Mechanical, and Chemical engineering disciplines, to name a few. For example, for projects autonomous container delivery (ACD) and robots to the rescue (R2R), the students, in groups of 6, split into pairs where each pair attends one technical stream, as shown in Figure 2.

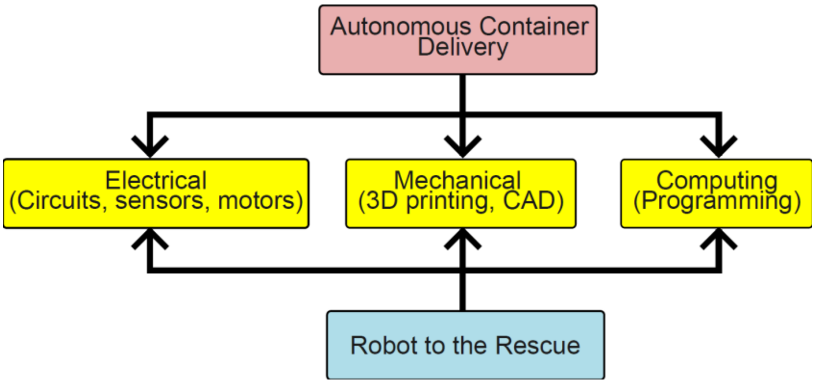

Figure 2: Project technical streams and the basic components covered in each stream

Learning Outcomes

The course instils a systematic approach to engineering design, emphasizing design validation through analytical and practical methods. It focuses on applying technical theory to real-world projects, fostering teamwork, project management, and professional communication. Through hands-on experience, students develop critical skills in problem-solving, decision-making, and collaboration within constraints. This foundation prepares them for real-world engineering challenges, equipping them with the technical and professional skills needed for successful careers.

Assessments

The assessments in this course are divided into three sections:

1. Engineering Design Process (20%)
2. Project assessments (60%)
3. Technical stream assessments (20%)

The engineering design process assessment for the course is a team video presentation where students discuss the design problem and propose potential solutions. This format allows students to demonstrate their understanding of the project and ability to effectively communicate their ideas. Project assessments are tailored to project-specific constraints, such as meeting the design brief's required specifications. For example, in the Robots to the Rescue project, the robot must navigate a maze to rescue a target. Additionally, students assigned to technical streams must complete laboratory tasks to complement the knowledge needed for the design project. These tasks ensure that students develop the necessary technical skills to support their project work.

Methodology

Our methodology employed multifaceted approaches to collect and analyse data, aiming to understand the dynamics of first-year engineering design courses and identify areas for improvement. The following steps outline our comprehensive approach:

Data Collection: We utilised multiple data sources to gather a rich and diverse information set. Data was collected over a semester through lecturer observations, mentor feedback, student comments from MyExperience surveys, and detailed project reports. This approach ensured a comprehensive understanding of the student experience and the course's effectiveness.

Lecturers' Personal Experience: We drew on firsthand experiences shared by project lecturers, who observed and interacted with students throughout the course. Lecturers documented their observations in structured logs, focusing on specific aspects such as student participation, teamwork, and problem-solving skills. This structured approach ensured that all relevant aspects of the student experience were captured systematically.

Mentor Feedback: Input was sought from mentors who offered guidance and support to student groups during project development. Mentors provided detailed accounts of group dynamics, student progress, and the effectiveness of mentoring strategies. Structured interviews and regular feedback sessions were conducted with mentors bi-weekly to capture their observations and recommendations for course improvements.

Report Feedback: We meticulously analysed feedback from student comments in MyExperience surveys and project reports. For the two projects, Robots to the Rescue (R2R) and Autonomous Container Delivery (ACD), we received a reasonably strong response rate. Specifically, 91 out of 139 students provided MyExperience responses for R2R, and 60 out of 135 students responded for ACD. While these responses offer valuable insight into student sentiment, we acknowledge that more data would enhance the analysis.

Utilising both qualitative and quantitative techniques, we identified common patterns and issues. Through thematic analysis of MyExperience survey comments, we gained insights into students' perceptions of the course, challenges faced, and suggestions for improvement. The survey, distributed to all students taking the course, captured a comprehensive understanding from a diverse student body. Project reports, both progress and final, were analysed to assess the application of course concepts and project outcomes.

Data Analysis Techniques: Our methodology embraced triangulation, leveraging multiple data sources to validate findings and ensure a comprehensive understanding of student perspectives and needs. We employed thematic analysis to identify recurring themes and issues from qualitative data using software such as NVivo. For quantitative data, statistical methods such as descriptive statistics and regression analysis were used to interpret survey results, ensuring a robust analysis. This combination of methods enabled us to cross-verify information and draw robust conclusions about the factors influencing student learning experiences.

Analysis of findings

Understanding the myriad factors that shape student experience in PBL courses is crucial for educators and institutions alike (Palmer & Hall, 2011; Sedaghat, 2018). A thorough analysis is devised using surveys and feedback forms from the student cohort of two projects and casual academics. Our analysis highlights several key elements that significantly influence students' journey through such courses, encompassing their backgrounds, teamwork dynamics, resource availability, and project characteristics.

Student background

Students' backgrounds are pivotal in shaping their experiences in project-based courses. Demographic and cultural factors, including the presence of international students, can influence team dynamics and communication patterns. Moreover, personal attributes such as introversion or extroversion may impact students' levels of participation and engagement within their project teams. Additionally, the amount of presumed knowledge and prior experience students bring to the course—particularly if it is their first time in university—can significantly affect their confidence and approach to project work. One student remarked, "*With the pace of the course, I felt overwhelmed at times, especially since I had no prior engineering knowledge*." Another student echoed this statement: "*If I had taken three courses rather than two this term, I think the workload would have been unmanageable*." One student mentioned, "*The coding stream seemed to assume everyone had prior experience. More foundational resources would have been helpful for beginners*." These insights highlight the varying experiences of students and the challenges they face based on their backgrounds.

Teamwork dynamics

The dynamics within project teams are critical determinants of student experiences. Team formation and role allocation processes can impact collaboration and cohesion within teams. Key issues such as effective communication, leadership distribution, and conflict resolution strategies are central to fostering a productive team environment and ensuring equitable contributions from all members.

A recurring theme in student feedback was accountability: "It's frustrating when some team members do not pull their weight. It often feels like the hardworking ones end up doing everything." Additionally, students suggested solutions to enhance fairness in teamwork: "*Allowing students to select their teammates could make the project feel more equitable*." and "*The way teams are assigned could allow for more input from students. The initial team-pairing survey could be more extensive*."

These comments underscore the importance of effective teamwork dynamics and the challenges that arise from unequal participation (Mills, Treagust, et al., 2003). Moreover, random allocation of team members may lead to an imbalance in skills and knowledge, potentially hindering overall team performance.

Resource availability

The availability of resources and support structures influences student experiences in project-based courses. Access to lab assistance, mentors, and help sessions can provide invaluable guidance throughout the project lifecycle. One student said there was a severe lack of demonstrators in technical streams, leading to unnecessary delays.

Furthermore, the organisation of the course materials was a common concern: “Finding information on the Learning Management System was a challenge; there were too many separate documents, making it hard to stay organised.”

These reflections indicate that improved resource availability and organisation can significantly enhance student engagement and learning. Open labs facilitate hands-on experimentation and exploration, allowing students to learn beyond the confines of traditional classroom settings. Such resources are essential for supporting students as they navigate the challenges of project work.

Project characteristics

The characteristics of projects themselves significantly contribute to student experiences. The nature of projects, whether autonomous or remote-controlled, can impact the level of challenge and complexity students encounter. One student commented, “*The ACD project felt overwhelmingly complex compared to other projects, and without proactive support, many teams struggled*.” Another student added, “*It would have been beneficial to start building earlier, as we spent too much time in the conceptual phase without enough hands-on work*.” These insights emphasise the need for carefully designed projects and adequate mentor support to facilitate successful learning experiences.

Furthermore, technical stream and preference considerations may influence project selection and team composition. Variations in testing procedures and resource availability can also affect the feasibility and success of project implementations, thereby shaping students’ perceptions and learning outcomes.

Our analysis observed intricate interactions among these factors and their collective influence on student experiences. Student feedback reveals a consensus on the need for improved support and clearer expectations throughout the course. One student succinctly stated, “*I often felt lost, lacking sufficient guidance and resources to navigate the challenges of the course effectively*.”

By situating our findings within the broader landscape of existing literature, we aim to contribute novel insights while building upon established knowledge in the field. Understanding these elements is crucial for educators in designing more effective and inclusive project-based learning environments.

Implications for practice

Our analysis reveals that several factors significantly influence student experiences in first-year engineering design courses. Demographic and cultural backgrounds and prior knowledge impact team dynamics and participation, with less experienced students often feeling overwhelmed. Effective team formation and role allocation are crucial, as issues like uneven contributions and poor communication highlight the need for better team pairing and accountability. Access to lab assistance, mentors, and organised course materials is essential, with many students facing delays due to a lack of support and resource navigation difficulties. Project complexity also affects engagement and success, with students preferring to start hands-on work earlier and receive more proactive support.

Several key strategies can improve first-year engineering design courses based on these findings. Introducing ice-breaking activities can enhance team cohesion and communication. Robust evaluation mechanisms ensure equitable contributions and accountability. Streamlining resource allocation improves access to essential tools. Training in communication and conflict resolution, alongside mentoring and peer support programs, can address team dynamics and workload distribution. Regularly incorporating feedback from students and stakeholders ensures continuous course improvement. These strategies create a supportive, equitable, and effective learning environment. They enhance student satisfaction and better prepare them for the interdisciplinary nature of modern engineering practice.

Furthermore, one major implication is combining the current projects into one comprehensive project. This combined project approach can address multiple key areas of improvement:

Enhancing Cross-Disciplinary Support Structures: It is critical to provide students with the resources and guidance they need to succeed in project-based courses. Establishing cross-disciplinary support networks can facilitate knowledge exchange and collaboration among students from diverse backgrounds, enriching their learning experiences and fostering innovation.

Streamlining Resource Allocation: Optimizing resource utilisation and ensuring equitable access to essential tools and facilities are vital. By identifying and addressing resource gaps and inefficiencies, educators can enhance the effectiveness and efficiency of project implementations, improving student outcomes and satisfaction.

Conclusion and outlook

Our study provides valuable insights into the factors influencing student experiences in first-year project-based courses. We identified several key factors, including student backgrounds, teamwork dynamics, resource availability, and project characteristics, significantly shaping students' perceptions and interactions within these courses. Addressing these factors is crucial for enhancing student engagement, collaboration, and overall learning outcomes in project-based environments.

Our study contributes to the existing body of knowledge by offering a nuanced understanding of student experiences in first-year project-based courses. By exploring the interplay between numerous factors and their impacts on student learning and development, we provide educators and institutions with actionable insights for designing more effective and inclusive learning environments. Our findings underscore the importance of considering students' diverse backgrounds, fostering teamwork and collaboration, and providing adequate support structures to optimise student experiences in project-based education.

Future research should further explore the dynamics of student experiences in project-based courses across different disciplines and institutional contexts. Longitudinal studies tracking students' progress and development throughout their academic journey could provide deeper insights into the long-term impacts of project-based learning on student outcomes and career trajectories. Additionally, investigating the efficacy of specific interventions and pedagogical approaches in addressing challenges identified in our study could inform evidence-based practices for enhancing student engagement and success in project-based education. Continued research is essential for advancing our understanding of effective teaching and learning strategies in engineering education and beyond.

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