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Developing perceptions of teamwork in First and Second Year Engineering Students

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ABSTRACT

CONTEXT

Effective teamwork and inclusive collaboration are essential skills for engineers to work in project teams and collaborate with communities to develop appropriate and innovative solutions to complex global challenges, such as those identified in the United Nations Sustainable Development Goals. Understanding how engineering students' perceptions and experiences of teamwork evolve during their degree is crucial for educators to tailor their instructional strategies and support students' development of these important skills. This study examines the academic experience of two cohorts of students in their first and second years of engineering programs at the University of South Australia and their development of teamwork skills.

PURPOSE OR GOAL

Engineering programs at the University of South Australia have been updated to include a Professional Practice Core (PPC) to support development of professional practice skills. The aim of this study is to evaluate the impact of the PPC on first and second-year students' teamwork preferences and competencies, and to understand any concerns students face when working in teams. The findings will inform future course development to better support and enhance team performance and individual development.

APPROACH OR METHODOLOGY/METHODS

First and second-year civil, mechanical and electrical engineering students at the University of South Australia were surveyed midway through a multidisciplinary team project in 2021 and 2022 to assess their perceived teamwork competency, preferences and any things they were unsure about in regards to teamwork. The paper-based survey was distributed during class, and the quantitative data was analysed using an unpaired t-test, while qualitative thematic analysis was performed on the open text responses.

ACTUAL OR ANTICIPATED OUTCOMES

A statistical analysis showed significant improvements in students' attitudes towards teamwork from their first to second year, including increased willingness and competence. Thematic analysis highlighted shifts in teamwork concerns, with communication and personal performance becoming more prominent.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The study shows significant positive changes in students' teamwork attitudes and abilities, highlighting improved acceptance, willingness, and confidence, alongside evolving concerns in communication, conflict resolution, and leadership, which can inform future course development.

KEYWORDS

Teamwork, student experience, professional practice courses

Introduction

Effective teamwork and inclusive collaboration are essential skills for engineers working in project teams and collaborating with communities to develop appropriate and innovative solutions to complex global challenges, such as those identified in the United Nations Sustainable Development Goals (United Nations, 2015). The ability to work across cultural boundaries is particularly crucial in engineering due to the profession's global reach. As the field of engineering becomes increasingly interconnected, the need for graduates who can effectively participate in diverse team environments has never been more critical.

Teamwork training in engineering curricula prepares students for their future careers as professional engineers by equipping them with the necessary skills to collaboratively work on projects. Teamwork initiatives, such as team-based projects, peer feedback opportunities, and team skills training, are perceived as important by students for their skill development and overall teamwork experiences (Grocutt et al., 2020).

Students' teamwork engagement can vary with each project and are also influenced by the curricular design. A scaffolded approach to skill development can enhance these experiences, helping students gain a more comprehensive understanding of teamwork. Sheppard et al. (2008) recommends the inclusion of a professional practice spine where 'each year of their program, students should have experience with and reflect on the demands of professional practice, linking theory and practice'. The inclusion of a professional practice spine helps to embed a consistent approach to developing engineering design and professional practice skills (Frank et al., 2011).

Understanding how engineering students' perceptions and experiences of teamwork evolve over a program is crucial for educators to tailor their instructional strategies and support students' development of these important skills. This study examines the academic experiences of students in their first and second years of engineering programs at the University of South Australia and their development of teamwork skills.

Background

In 2020, the engineering programs at the University of South Australia were updated to incorporate a common professional practice spine, referred to as the Professional Practice Core (PPC). The PPC features a sequence of courses designed to progressively support the development of essential professional practice skills throughout the four years of the program.

In the first year, students take an introduction to professional practice course and an introduction to design course. In the second year, they complete an introduction to project management course, followed by an introduction to systems engineering course in the third year. In the fourth year, students complete a capstone design course. Throughout these courses, students develop essential professional skills and attributes while collaborating on cross-disciplinary engineering projects.

Throughout these courses, students accrue hours towards their 450-hour engagement with professional practice, a requirement for accreditation by Engineers Australia (Engineers Australia, 2019). Other hours are accrued through engagement with extracurricular activities and a minimum of six weeks (225 hours) of in-industry experience (Smith et al., 2024).

To support students teamwork experience, a consistent approach is used for all team projects in the PPC courses. All projects address serious engineering challenges that are designed to enhance and solidify students' learning throughout their degree, with project teams in the first, second, and third years being multidisciplinary, consisting of a mix of civil, mechanical, and electrical engineering students. In the final year, students work in discipline-specific teams,

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collaborating across different engineering specialisations. For example, in civil engineering, students work in teams specialising in geotechnical, structural, and water engineering. Each course includes teamwork foundation activities to help develop and apply inclusive collaboration skills, understand the impact of rank on team collaboration (Collett, 2015) and apply different leadership styles and conflict resolution strategies. Team projects require a team agreement, which allows students to decide how the team operates, including the structure, leadership style, and methods for conflict resolution. Additionally, to help students improve their teamwork skills and develop self-awareness of how to work in teams, the online peer assessment tool SPARKPlus (Freeman & McKenzie, 2002; Willey & Gardner, 2010) is used to facilitate peer assessment and self-assessment of their contribution to team projects. Other scaffolded teamwork activities for each year level are provided below.

In the first year first semester course 'Sustainable Engineering Practice' students work in allocated diverse and multidisciplinary teams of six students to complete the Engineers Without Borders (EWB) Challenge project. In this project students work together to find culturally sensitive and sustainable solutions for remote communities around the world. Activities based on the Blue Wren Cultural Portal (Hanchant-Nichols et al., 2022) are embedded in the course and help prepare students to develop necessary skills to work on the EWB Challenge such as respectful and inclusive communication and importance of empathy. Students also learn to understand their rank within a team and the impact this has on team function and communication.

In the first-year second-semester course 'Engineering Design and Innovation', students work in self-selected teams of five to design and build an innovative project solution to meet set requirements. This project helps students practice their innovation, design, building, testing, and analysis skills. In this course, students reflect on their prior teamwork experiences and share these with their peers. Students also review various leadership styles and their impacts on team function.

The second-year course 'Project Management for Engineers' focuses on developing students' project management skills and understanding the ethical, social, and environmental responsibilities of engineers. Students work in self-selected teams of six to project manage the installation of an Energy Hub in a remote Aboriginal Community (Duff et al., 2019). They develop a stakeholder engagement plan, project timeline, work breakdown structure, and allocate roles and responsibilities for the planning and monitoring stages of the project.

The third-year course 'Design Management for Engineers' focuses on further developing students' conceptual design, systems engineering, teamwork, communication, and business management skills. Students work in self-selected teams of six to develop a design solution for a project based on Mars. This large-scale project requires students to further develop and apply their systems engineering skills and focuses on conflict management, including dealing with difficult conversations.

In the final-year course 'Engineering Capstone Experience', students work together as large allocated project teams to research and develop a feasibility or option study for a project. These industry-based projects involve regular contact with an industry representative. In this course, students further develop their teamwork skills, including leadership style development, mentoring abilities, and self-management skills to meet team goals. They also develop their negotiation skills while working with their team and industry clients to determine roles and responsibilities to complete the project task.

Team projects are also included in many of the discipline courses. These courses do not typically include explicit teamwork development activities; however, they do provide students an opportunity to apply and practice the teamwork skills learnt in the PPC courses.

To evaluate how well this approach supports students to work in teams, an evaluation study was undertaken during 2021 and 2022 to assess first and second-year students' perceptions of teamwork. This paper focuses on two research questions from this evaluation:

RQ1: Does the program positively impact first and second-year students' preferences and competence in teamwork?

RQ2: What are the areas of teamwork uncertainty for first-year and second-year engineering students?

Method

First and second-year Mechanical, Electrical, and Civil engineering students at the University of South Australia were surveyed to assess their teamwork competency. The survey targeted first-year, first-semester students in 2021 and second-year, second-semester students in 2022. Surveys were conducted during weeks 7 and 8 of a 13-week course, representing the midway point of the team project.

A mixed methods approach was used, combining both quantitative and qualitative data to provide a comprehensive assessment of students' teamwork competency. This approach was chosen to capture not only measurable aspects of teamwork but also the nuanced perceptions and experiences of the students, enhancing the overall depth and rigor of the findings. By blending these methods, the study benefits from the strengths of both approaches and minimises the weaknesses (Johnson & Onwuegbuzie, 2004).

A paper-based survey was distributed during class to maximise response rates and to ensure broad participation. While self-reported data can introduce biases and limitations, such as reliance of students' perceptions, these were balanced by the inclusion of open-ended questions that allowed for more detailed qualitative insights. To address potential handwriting interpretation issues and transcription errors, surveys were entered and double-checked by a second person. Illegible responses were marked as such after verification.

The survey first gathered participant information, including their degree program, start date, age, gender, and whether English was their second language.

The teamwork competency section asked students Likert scale questions to indicate their preference for working in a team versus alone, their willingness to engage in teamwork, and their current perceived competence in working in a team. A quantitative analysis of the survey data was performed using an unpaired two-sample t-test assuming unequal variances to compare data between students in the first and second-year courses.

A qualitative thematic analysis, following (Braun & Clarke, 2006) six-phase approach, was undertaken on quotes from first (n=84) and second (n=65) year students in response to the open text question, “One area of teamwork I am unsure about.” This approach included the following phases: 1) Familiarisation with data; 2) Identifying codes; 3) Searching for themes; 4) Reviewing themes; 5) Defining and naming themes; and 6) Writing up. Comments were treated holistically as a whole unit of analysis without breaking them down into smaller parts. Each quote was matched with one prominent theme.

A total of 135 students were enrolled in the first-year, first-semester course, with 121 responding to the survey (24% English Second Language (ESL), 92% Male and 67% under 20 years of age). In the second-year, second-semester course, 137 students were enrolled, with 117 responding to the survey (43% ESL, 92% Male and 45% under 20 years of age).

This study received approval from the University of South Australia Human Research Ethics Committee, ensuring all procedures complied with the ethical standards for research involving human participants.

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Results and Discussion

A statistical analysis was performed on the three Likert scale questions and results are presented in Table 1. The results show significant changes in students' perceptions towards teamwork from their first to their second year.

First-year students showed a stronger preference for working alone (mean = 1.87) compared to second-year students (mean = 2.14). This increase is statistically significant (p = 0.002), indicating a growing acceptance of teamwork as students progress in their studies.

Students willingness to engage in teamwork increased from the first year (mean = 4.00) to the second year (mean = 4.23), with the difference being statistically significant (p = 0.025). This suggests a positive shift in students' attitudes towards teamwork as they progress through their degree.

Students' perceived competence in teamwork improved from their first year (mean = 3.97) to their second year (mean = 4.12), with a statistically significant difference (p = 0.042). This reflects an enhanced confidence in their teamwork abilities as they gain more experience.

Table 1: Statistical analysis of changes in students' perceptions of teamwork.

		1st Yr, 1st Sem Wk7 2021	2nd Yr, 2nd Sem Wk8 2022	t-test	p-value	df
Do you prefer to work alone or in a team? *(1 work alone, 2 I don't care, 3 work in team)*	sample size (n)	119	115			
	mean	1.87	2.14	-3.07721	0.002	232
	median	2	2			
	mode	2	2			
	Standard deviation (std)	0.67	0.65			
How willing are you to give teamwork a go? *(1 not alt all, 2 slightly, 3 moderate, 4 very 5 extremely)*	sample size (n)	121	115			
	mean	4	4.23	-2.26	0.025	234
	median	4	4			
	mode	4	4			
	Standard deviation (std)	0.86	0.86			
Rate your current perceived competence working in a team *(1. Not competent, 2 Barely 3 Somewhat 4 competent, 5 Very competent)*	sample size (n)	118	115			
	mean	3.97	4.12	-2.05	0.042	229
	median	4	4			
	mode	4	4			
	Standard deviation (std)	0.61	0.55			

Overall, the presented data supports RQ1 “Does the program positively impact first and second year students' preferences and competence in teamwork?”. The significant improvements in all measured aspects suggest that students become more accepting, willing, and confident in their teamwork capabilities as they advance through the program. This increase in confidence is supported by the carefully developed and scaffolded professional development around teamwork integrated into the courses, enabling students to effectively apply the learning they have undertaken. While factors such as the ability to choose their teams in second year may have contributed to this increased confidence, the course structure and the support provided to students would also have played a key role in shaping their teamwork skills and attitudes.

Although survey questions specifically addressing team selection were not included in this study, this could be explored in future research.

The thematic analysis identified six themes that spanned the first and second years. The percentage of quotes received in the survey matching each theme is provided in Table 2, along with representative quotes for each theme. The themes identified include: Communication, Conflict Resolution, Work Allocation and Fairness, Time Management and Availability, Leadership and Role Assignment, and Personal Performance and Confidence.

This analysis responds to the research question: RQ2 "What are the areas of teamwork uncertainty for first-year and second-year engineering students?" The data presented in Table 2, alongside the representative quotes, highlights how these areas of uncertainty evolve from the first year to the second year. These findings provide valuable insights for the academic staff at the University of South Australia to understand the changing dynamics and concerns within team settings, which can directly inform teaching practices and curriculum development. For instance:

- **Communication** remains a significant concern, with a slight increase in its percentage of quotes from the first to the second year. This suggests ongoing challenges and a growing awareness of the importance of effective communication methods and tools. The representative quotes indicate that team members are focused on finding the best communication platforms and strategies to ensure efficient collaboration. To address this, academic staff could emphasise communication skills within team projects, offering specific training or resources on effective communication platforms and techniques.
- **Conflict Resolution** saw a slight decrease, indicating that while conflicts are still a concern, team members might be developing better strategies to handle disagreements. The quotes reflect common issues like managing under-contributing members and knowing when to hold team members accountable, which are crucial for maintaining a productive team environment. This suggests that integrating further conflict management training into the curriculum could support students in navigating these issues more effectively, building on the skills already being developed.
- **Work Allocation and Fairness** showed a notable decrease in the percentage of quotes in the second year. This could indicate improved practices in task distribution or a shift in focus to other emerging issues. The emphasis on fair task allocation and accountability remains vital, as seen in the quotes, but it appears to be less of a pressing issue over time. Academic staff could build on this by promoting more structured team formation activities or peer assessment processes that reinforce fair work distribution and accountability from the outset.
- **Time Management and Availability** maintained a consistent percentage across both years, underscoring its persistent relevance. Team members continue to grapple with coordinating schedules and ensuring timely completion of tasks, reflecting the ongoing challenge of balancing team commitments with personal responsibilities. Providing students with tools and strategies for effective time management, including workload distribution and scheduling tools, could help address this ongoing issue.
- **Leadership and Role Assignment** increased slightly in the second year, indicating a growing concern about effective leadership and clear role definition within teams. The quotes highlight the need for identifying suitable leaders and the impact of leadership on achieving team goals. In response, introducing leadership development opportunities and clearer guidelines on role assignment within team projects could help students understand leadership dynamics and enhance team performance.
- **Personal Performance and Confidence** saw a significant increase in the second year, suggesting that as team members gain more experience, they become more reflective about their own performance and confidence levels. Issues such as accepting criticism and trusting team members are more prominent, indicating a deeper self-awareness and a desire to improve personal contributions to the team. This insight could guide the incorporation of further reflective practice exercises in the curriculum, where students assess their performance and confidence in team settings, supporting personal growth.

While communication and time management remain consistently important, the increasing focus on personal performance and confidence may suggest a maturation process where team members are more introspective on their own performance. The decrease in concerns about work allocation and fairness might reflect improvements in these areas, possibly due to more experience, initial team setups, and learning activities that have positively impacted their personal performance and confidence.

Overall, the trends suggest that team members are becoming more adept at handling practical aspects of teamwork, like communication and task management, and are shifting their focus towards personal growth and effective leadership. These findings indicate several opportunities for curriculum enhancement, including increased focus on leadership skills, reflective practices, and communication training, which could better prepare students for professional teamwork environments. By tailoring teaching approaches to these evolving needs, academic staff can support both team performance and individual development.

Table 2: Comparison of first and second-year students' responses to the question 'One area of teamwork I am unsure about', showing the percentage of quotes for each theme along with example responses.

Theme	% of Total Quotes (1st Year) (n=84)	% of Total Quotes (2nd Year) (n=65)	Example Quotes (1st year) (n=84)	Example Quotes (2nd year) (n=65)
Communication	20.2	23.1	*"How to balance being passionate and not controlling communication"* *"How to ensure everyone is on track and meeting deadlines"* *"Whether my team will be able to communicate effectively and complete our work."*	*" Communicating frequencies to gain optimam (sic) amount of work done. "* *"Communication with my team if I need assistance."* *"The best form of communication to use,ie messenger, whatsapp also how to share files,ie share point google drive"* *"Listen to everybody."*
Conflict Resolution	13.1	12.3	*" Dealing with a team member who is not understanding the task and not willing to take information on board."* *"How to effectively deal with group members who we under-contributing."*	*" Conflict management Disagreements within the team "* *" Knowing when to hold someone accountable for lack of work and attendance without knowing their personal situation.."*
Work Allocation and Fairness	35.7	20.0	*"Fairly allocating tasks"* *"How much work each member is responsible for and what type of work."*	*"Ensuring everyone does their fair share."* *"Holding people accountable for their tasks and actions."*
Time Management and Availability	16.7	16.9	*"Finding ways to meet up with my team as we all have other Commitments (work,Sport)"* *"How to get everyone together at the same time."*	*"Making myself more available for team meetings."* *"Time management ,forward planning and preparation. I often find that my groups are doing a last minute dash to finish work on time"*

Leadership and Role Assignment	9.5	12.3	*"How do we correctly choose a team leader, how do we tell who is the best option."* *"Is it worth having a leader."* *"The best way to assign roles to team members."*	*"Leadership"* *"Leading the team"* *"Leading our team to meet our goals."*
Personal Performance and Confidence	4.8	15.4	*"How to be more firm."* *"Relinquishing control and trusting others to do their part to a similar if not better standard."*	*"Accepting criticism."* *"Trusting the team to finish their sections."* *"Not sure about other peoples perception on me as a person"*

Conclusions

The results from the statistical analysis reveal significant positive changes in students' attitudes towards teamwork from their first to their second year. There is a growing acceptance of teamwork, increased willingness to participate, and enhanced confidence in their teamwork abilities. These improvements are statistically significant and suggest that the program positively impacts students' preferences and competence in teamwork.

Additionally, the thematic analysis highlights evolving concerns, with increased awareness of communication, better conflict resolution strategies, improved work allocation practices, and a focus on leadership and personal performance. These insights provide valuable direction for future curriculum development aimed at further enhancing team performance and individual growth in engineering programs.

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