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# Technical Student-Run Organisations as Enablers of Engineering Students' Learning in Cross-Disciplinary Teams

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## ABSTRACT

Student organisations and associations on university campuses provide opportunities for students to collaborate with peers from different study programmes and work towards common goals. Engineering students need to develop skills in teamwork, communication, and experience working with professionals from various disciplines. Engineering students often gravitate towards technical student-run organisations (TSROs), where they design and build projects such as space satellites or race cars, often to compete with other student teams. This article employs a case study approach to analyse four TSROs from the Norwegian University of Science and Technology (NTNU), drawing on interviews with student leaders and members. As part of the interviews, students also created organisational maps to illustrate how their organisations function across different study backgrounds and roles. The findings indicate that TSROs facilitate student learning and development in cross-disciplinary teams. However, the structure and division of responsibilities within each TSRO vary, influencing individual collaboration aspects. This article contributes to the understanding of how extracurricular activities, such as TSROs, serve as learning platforms for engineering students, particularly in developing skills essential for teamwork and collaboration within inter-, multi-, trans-, and cross-disciplinary teams.

## KEYWORDS

Extracurricular Activities, Technical Student-Run Organisations, Engineering Education, Cross-Disciplinary Teamwork, Student Learning and Development

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## Introduction

Future engineers will be required to address open-ended, complex, and wicked problems (Kolmos et al. 2024; Lönngren and Van Poeck 2021), making interdisciplinary teamwork skills essential (Rhee et al. 2020). Industry and public stakeholders increasingly expect engineering graduates to collaborate with professionals from the humanities and social sciences (Sortland 2015). A recent review emphasises that technical universities must better organise interdisciplinary and multidisciplinary collaboration, as well as integrated learning opportunities for engineering students (Fremtidens teknologistudier (FTS) 2022). Core elements of cross-disciplinary teamwork include teamwork skills such as team effectiveness, action coordination, and interpersonal competence (Cima et al. 2024). Teamwork may be defined as a process in which a team transforms inputs (e.g., resources and skills) into outputs (e.g., deliverables) (Varela and Mead 2018).

When engineering students collaborate in cross-disciplinary groups, the learning outcomes related to teamwork are greater than when working in discipline-specific groups (Cima et al. 2024). In particular, improvements in interpersonal skills—such as the ability to manage conflict, motivate peers, and regulate emotions—as well as transition skills linked to project execution, are more likely to occur in cross-disciplinary settings (Cima et al. 2024).

Student organisations and associations on university campuses offer opportunities for students to collaborate across study programmes and pursue shared objectives. These organisations vary widely and may include student unions, hackerspaces, engineering competition teams, sports clubs, and more (Pittaway et al. 2011). Engineering students often gravitate towards technical student-run organisations (TSROs), where they engage in discipline-relevant activities. A TSRO may be defined as a student-led initiative in which members—typically engineering students— design and manufacture technical systems such as race cars, drones, or satellites, often in preparation for local or global competitions. TSROs may be purely extracurricular activities (ECA), conducted outside the academic curriculum, or they may be co-curricular, with certain assignments or projects eligible for academic credit.

Research on TSROs remains limited. Existing studies primarily focus on technical achievements (Acosta 2012; Martinez 2012; Martellucci and Giannini 2022), although some have explored the development of innovation competencies (Sivertsen, Haneberg and Solvoll 2023), loneliness (Sivertsen, 2025), leadership skills (Vie, Vie and Fosen 2023), and, importantly, the educational value of participation (Davines 2013). However, no research to date has specifically examined how engineering students learn within multidisciplinary teams or how they collaborate across academic programmes in the context of TSROs—beyond the general recognition that multiple learning processes take place (Bullen and Karri 2002; Davies 2013). Several technical universities—including Delft, Twente, Dublin, Edinburgh, ETH Zurich, Assen, and Karlsruhe—host TSROs in which students undertake extensive projects, often culminating in competitive entries such as drones, satellites, or vehicles for international contests. These projects are sometimes in the literature referred to as ‘student teams’ and involve interdisciplinary teamwork and may therefore serve as a valuable context for engineering students to develop cross-disciplinary skills.

The study addresses the following research questions: Who participates in the TSROs, and how are these TSROs structured? How do students collaborate across roles and study programmes within the TSROs? The study also starts to tap into what skillsets do students develop through cross-disciplinary collaboration in the TSROs?

This article is based on four case studies of TSROs from NTNU. Data was collected through semi-structured interviews with both leaders and members of the TSROs. During the interviews, informants also drew organisational maps that included team structures and members' academic backgrounds. The data were analysed using thematic analysis.

This article is structured as follows: the next section presents a conceptual background, reviewing prior research on ECA and TSROs, key terminology in cross-disciplinary education, and learning outcomes for engineering students working in a variety of cross-disciplinary teams. This is followed by the method section, detailing the case study approach, data collection procedures, data analysis methods, and the organisational map technique. Each case is described following a results section that presents the organisational maps and key findings. The results section includes both individual case analyses and a summary of cross-case similarities. The article concludes with a discussion and final reflections. Sincere thanks to the students who volunteered to participate in this study.

## Conceptual background

### *Learning Outside the Classroom – ECA*

There are many forms of ECA, and Pittaway et al. (2011, p. 38) summarizes the following: "summer schools (Collins and Robertson 2003); games (Schwartz and Teach 2002); competitions (Ridder and Van Der Sijde 2003); exchanges; mentoring (Perren 2003); internships; clubs and societies; workshop programmes; financial support; pre-incubators (Tötterman and Sten 2005); and business support programmes (Lockett et al. 2008; Jones et al. 2008)". The organisations Pittaway et al. (2020) refer to encourage students to invest their time and effort, and although the students have scarce previous knowledge, they are in a position where they can learn with fellow peers and without a formal assessment. The learning environment of the organisations is collaborative, and they have an opportunity to test out their skills without encountering major risks. ECA is a potential arena for learning. Processes, form or structures in a ECA initiative can render possible learning e.g. when students apply for pre-seed funding for their student ventures (Fauchald et al. 2023). From the initiative described by Fauchald et al. (2023) students had a low threshold to apply and when students did this process several times they gained a positive learning outcome from the feedback they received during the process. TSROs are volunteer based organisations that often do not provide study points (or ECTs) to students which makes them extracurricular. As mentioned earlier a TSRO can be co-curricular.

### *Technical Student-Run Organisations' — An Arena for Learning?*

TSROs were briefly described in the introduction as a student-run organisation who work on the design and manufacturing of technical solutions. The TSROs often compete in e.g. the Formula Student, Shell Eco-Marathon, the European Hyperloop Week and these competitions are on an international and often global level with many student teams competing with their race cars, drone, satellite, etc. Not all the TSROs compete in yearly challenges, and some organisations have projects spanning over 2-5 years.

Several students have written master, project or research articles of the phenomenon TSROs. In some examples it is written about the development of technical installations and innovations e.g. Mihailidis et al. 2009; Acosta 2012; Martinez 2012; Martellucci and Giannini 2022. Another example is Elisenberg's (2024) master thesis about a TSRO that competed in Formula Student. Her research topic was the student's reflection and learning process in a TSRO and how this form of ECA differs from a traditional teacher centred course.

Formula Student has both mechanical and mechatronics engineering curriculum, and the exercise of participating provides a challenging, authentic and multi-disciplinary project that is an effective tool to extend formal lectures while also providing a resource for research (Bullen and Karri, 2002). Davies (2013) studied the educational value of the Formula Student and he describes the competition as 'a multi-university student design competition'. The educational value he found from doing interviews with stakeholders connected to the Formula Student were that the competition was an ideal platform to support students learning in mechanical engineering theories and techniques, the experience of implementing and evaluating design solutions, project management skills such as planning, budgeting, organising, directing. Davies (2013) also found that the communication skills improved in terms of experience of resolving conflicts, maintain and enhance a working relationship and professional development through relevant activities. He observed several activities that he found fitting to include or merge with the student's curriculum.

Prior to this, Buchal (2004) studied the same interdisciplinary projects and found it to be a very effective way in achieving desired learning objectives in terms of design process, teamwork and leadership skills and design communication. Buchal's (2004) findings are similar to Davies (2013). The team are self-managed and use informal mentorship and apprenticeship to develop technical and leadership skills (Buchal, 2004). It is important that these projects are student-directed, and that faculty only have an advisory role and there are opportunities to include this in the curriculum by utilizing innovative assessment methods (Buchal, 2004).

### *Terminology of Cross-Disciplinary Learning*

There are several terms related to collaborating across disciplines in education. Scott and Hofmeyer (2007) have produced a more detailed review of cross-disciplinary terminology, because the terms were in danger of becoming conceptually indistinctive and 'thus had limited usefulness for researchers, practitioners and teams. Cross-disciplinary could be used as an umbrella term, and the following multidisciplinary, interdisciplinary and transdisciplinary have been used to describe levels of knowledge synthesis and patterns of practice (Scott and Hofmeyer 2007). There is a blurring between these terms, and it is easy to trip in the terminology, and Tomkinson et al. (2008) have made some simpler definitions of interdisciplinary, multidisciplinary and transdisciplinary to use for educational purposes. Multidisciplinary is when students or professionals from different disciplines work in the same space, but each person is from their own discipline and standpoint. Interdisciplinarity are used when students or professionals from different disciplines learn and work together, sharing views and discussing issues across discipline boundaries. The term transdisciplinary is used when students or professionals work or learn together on issues that defy boundaries or when the people learn with, and from, teachers from another discipline. These definitions of multidisciplinary and interdisciplinary is similar to what Borrego and Newswander (2007) describe.

This terminology is visible in Van den Beemt et al. (2020) review of interdisciplinarity in engineering education, were interdisciplinarity is often interpreted as different engineering domains collaborating and only a few examples that broaden into e.g. social sciences. Van den Beemt et al. (2020) conclude that explorations of new and fruitful ways to integrate interdisciplinarity into engineering education are often hindered by the discipline-oriented nature of academia. Overcoming this could open new opportunities and activities where students acquire interdisciplinary skills for their future professional development.

Kolmos et al. (2024) build their understanding of the terminologies on the work of Borrego and

Newswander (2010), Keestra and Menken (2016), and Klein (2010). Their interpretation of inter-, multi, and transdisciplinarity does not differ significantly from Tomkinson et al. (2008), but Kolmos et al. (2024) provide a perspective that emphasizes practical implications. They describe multidisciplinarity as an approach where different disciplines view the problem from their respective fields, with "no real integration in the solutions which are eventually proposed" (Kolmos et al., 2024, p. 259). In contrast, the interdisciplinary approach is characterized as integrated, leading to a shared solution. The transdisciplinary approach is defined somewhat differently across the literature, but generally adds another dimension closely related to interdisciplinarity, involving both the shaping of new knowledge fields and the crossing of boundaries between academia and practice (Kolmos et al., 2024).

### *Skillsets in Cross-Disciplinary Teams*

Challenges that are complex and often open ended and ill-defined (Gómez Puente et al. 2013) go beyond impressions of what are an engineer's tasks and responsibilities (Vojak, Price and Griffin 2010) and this calls for engineers who can work well with their own discipline and outside the boundaries of it (Barut, Yildirim and Kilic 2006). Engineers need to possess the ability to success, understand, evaluate, synthesize, and apply perspectives and knowledge from other fields than their own (Czerniak 2007). Lattuca (2001) recommended the implementation of interdisciplinary engineering education to train engineering students in bringing together theories, concepts and methods from different disciplines.

Multidisciplinary courses have a good potential to train engineers in having a sustainable perspective in their practice, and there are good reasons for not only teaching in a strictly disciplinary context (Sharma et al. 2017). Although, teaching multidisciplinary courses have some barriers, these include students having limited experience with project management, not sufficient communication skills and limited engagement among students (Sharma et al, 2017). Engineers must have a solid understanding of project management concepts, and emphasizing project management in engineering curricula is crucial (Panuwatwanich, Stewart and Nepal 2011). Project management have been established to be the delivering of engineering projects to fulfil predetermined objectives that has been well established (Smith 2008). Participating in student teams can also add to students fundamental engineering knowledge, personal and professional skills, interpersonal skills, insights into the innovation process and leadership (Bravo et al. 2024).

### *Measuring learning from activities in cross-disciplinary teams*

Richter and Paretti, (2009) note in their review how most researchers consistently use 'learning by doing' as a teaching approach and without attention to teaching inventions and metacognition it is believed students to develop transferable collaboration skills, particularly in complex environments. Fruchter and Lewis (2001) presented a method with cross-disciplinary problem-, product-, project-, process-, people-based learning (referred to as P5BL) teams. In this work Fruchter and Lewis (2001) developed a cross-disciplinary learning framework to describe and assess process-oriented learning that were not captured by traditional assessment tools.

The framework consists of four categories. ") Islands of knowledge: The student masters his/her discipline but does not have experience in other disciplines. 2) Awareness: The student is aware of the other disciplines goals and constraints. 3) Appreciation: The students begin to build a conceptual framework of other disciple, is interested to understand and support the other disciplines goals and concepts, and knows what questions to ask. 4) Understanding: The student develops a conceptual

understanding of the other disciplines, can negotiate, is proactive in discussions with participants from the other disciplines, provides input before input is requested, and begins to use the language of the other disciplines." This framework could be used to assess students through observations and the framework indicate how well the course works to achieve its cross-disciplinary teamwork learning goals (Fruchter and Lewis, 2001, pp. 6.715.3-6.715-4).

## Methods

### *Case study*

This study employed a case study approach (Walsham 1995), incorporating interviews to explore structure, representation in roles, activities, collaboration, and learning within four TSROs at the NTNU in Trondheim. The researcher has prior familiarity with the selected TSROs.

Two informants were interviewed from each case: one in a leadership role and one in a sub-team role. All informants had also previously held non-leadership roles. These participants were selected due to their extensive involvement in the organisations and their minimum of one year's experience, either within the same TSRO or another.

In line with the research questions, the study sought to understand:

1. Organisational structures, member roles, backgrounds, and internal collaboration.
2. The nature of TSRO projects, the alignment of student backgrounds with project demands, and collaborative practices.
3. Informants' reflections on interdisciplinary work and internal workflows.

### *Context*

Student organisations in Norway are typically led and managed by students, and TSROs are no exception (Vie, Vie and Fosen 2023). At the NTNU, some TSROs involve students from up to 24 different academic programmes (Sivertsen 2023). These organisations may be categorised as co-curricular or extra-curricular activities. In some cases, students may earn academic credits (ECTS) for their participation, including through competitions or related academic assignments.

The four cases in this study are TSROs based at Gløshaugen in Trondheim, where students from diverse programmes participate voluntarily. The NTNU is the largest engineering institution in Norway, with approximately 43,800 students. It hosts around 130 student-run organisations, of which eight are classified as TSROs.During the academic year 2023/2024, around 200 students were active across the four case TSROs. As of spring 2024, there are twelve TSROs at the NTNU, with an estimated 400–500 student members.

### *Participant selection*

Eight participants, all engineering students, took part in the interviews. They were enrolled in either three-year bachelor's or five-year integrated master's programmes in Mechatronics and Product Design, Mechanical Engineering, Cybernetics and Robotics, and Logistics Engineering. Participants were in their second or third year of study and were selected due to their roles within a TSRO. All

informants were male and aged between 21 and 24 years. This is broadly representative of TSROs, as the majority of participants are male and typically fall within the 19–25 age range.

Each TSRO contributed two participants: one in a leadership role and one in a technical or support role. All four TSROs welcomed participation in the study and have agreed to be acknowledged at the end of this article. All participants volunteered to take part in the study. The rationale for selecting these individuals is that they dedicate significant time to the organisation and demonstrate strong ownership of its development. They possess extensive knowledge of its operations, and several have previously contributed as members responsible for building the technical solution before assuming leadership roles. This background provides them with experience from other TSROs they have participated in, as well as insights from their own organisation, which enriches their perspective when discussing collaboration and TSRO dynamics.

All participants provided informed consent in accordance with the study guidelines and retained the right to withdraw at any time, with full deletion of their data. Ethical approval for the study was granted by SIKT, as required for all research involving students in Norway. Both participants and their affiliated organisations agreed to take part in the research and acknowledged that their organisations may be identified by name. They also understood that the organisational maps included in the study may make identification possible.

The motivation for selecting these four organisations was that they represent a diverse range of domains in terms of the technologies they develop and the "end products" they deliver, as well as variations in organisational size and maturity. This approach aimed to provide TSROs with broad representation and enhance the potential for the findings to be recognised and applied in other university contexts.

### *Data collection*

Data were gathered through semi-structured interviews, each lasting 1.5 to 2 hours, conducted between January and August 2024. As these interviews spanned different recruitment periods, there were natural variations in membership and project status—typical of TSROs.

The interview guide is presented in Table 1. Follow-up questions were asked based on participant responses but are not listed in the table.

Participants were also asked to draw an organisational map of their TSRO, including names, roles, and study programmes. They were then instructed to draw green lines to indicate who had helped them, followed by a few related questions. Participants named other students within the organisation and described the tasks they had worked on together. Next, they were asked to draw red lines to illustrate whom they had helped. Again, they described the individuals, their positions within the organisation, and the nature of their collaboration.

These maps helped to visualise internal collaboration. Participants were allowed to use their phones or laptops to supplement their memory by checking Slack, Facebook, or other apps, websites, or social media platforms when recalling specific details. The structure of each map varied, as only minimal instructions were provided during the interview. The illustrations of each organisation presented later in this paper are the author's own interpretations. Several participants have reviewed these illustrations and agreed that they are accurate representations of the overall organisational structure.

Table 1: Interview guide.

| Questions from the semi-structured interview guide |
|---|
| Who are you and what is your background? |
| What do [name of TSRO] do, or what is the goal? |
| What role and responsibility do you have in the [name of TSRO]? |
| How do the collaboration work internally in the organisation? |
| How do one become a member? |
| How have you and your team developed the organisation? |
| How do you experience the culture in the organisation? |
| (Giving the assignment of drawing the organisational map) |
| How do these people help you? (referring to those the informant has drawn red lines to) |
| How do you help these people? (referring to those the informant has drawn green lines to) |
| Is there something else you would like to say about the collaboration in the organisation? |

### *Data analysis*

The organisational maps were first converted into standardised figures by the author, based on participant drawings. This standardisation enabled easier comparison between cases, while ensuring anonymity by removing personal names. Collaboration links (originally shown via coloured lines) were translated into descriptive text.

Interview data were analysed using thematic analysis techniques (Braun and Clarke, 2006; 2019; 2023), following the Big Q qualitative approach. All interviews were recorded and transcribed, and the transcripts were initially read multiple times to gain familiarity with the data. During these early readings, recurring topics were noted without distinguishing between main and sub-themes; they were simply emerging ideas from the transcripts and organisational maps.

Coding was then applied to the transcripts, and these codes were gradually grouped into themes. This process was iterative and interpretative: themes were not derived from direct quotations but developed through careful consideration of participant narratives, which were dynamic and conversational rather than structured around predefined topics. The interviews were conducted in a language other than English, and translation added an additional layer of interpretation, requiring the researcher to create concise and representative labels for themes that captured the essence of participants' words.

As the analysis progressed, themes were examined collectively to understand their relationships. Overarching themes were identified (organisation, skillsets, and collaboration) and sub-themes were aggregated under these based on recurring patterns and contextual links in the data. In some cases, connections between themes reflected explicit links mentioned by participants; in others, they represented interpretative connections grounded in the context of the interviews.

The final figure (Figure 1) illustrates these main themes and sub-themes, as well as their interconnections. While alternative ways of connecting themes are possible, the figure represents the researcher's interpretation of how these complex topics relate, based on both participant statements and analytical reasoning. The results section presents a thorough empirical view of these themes.

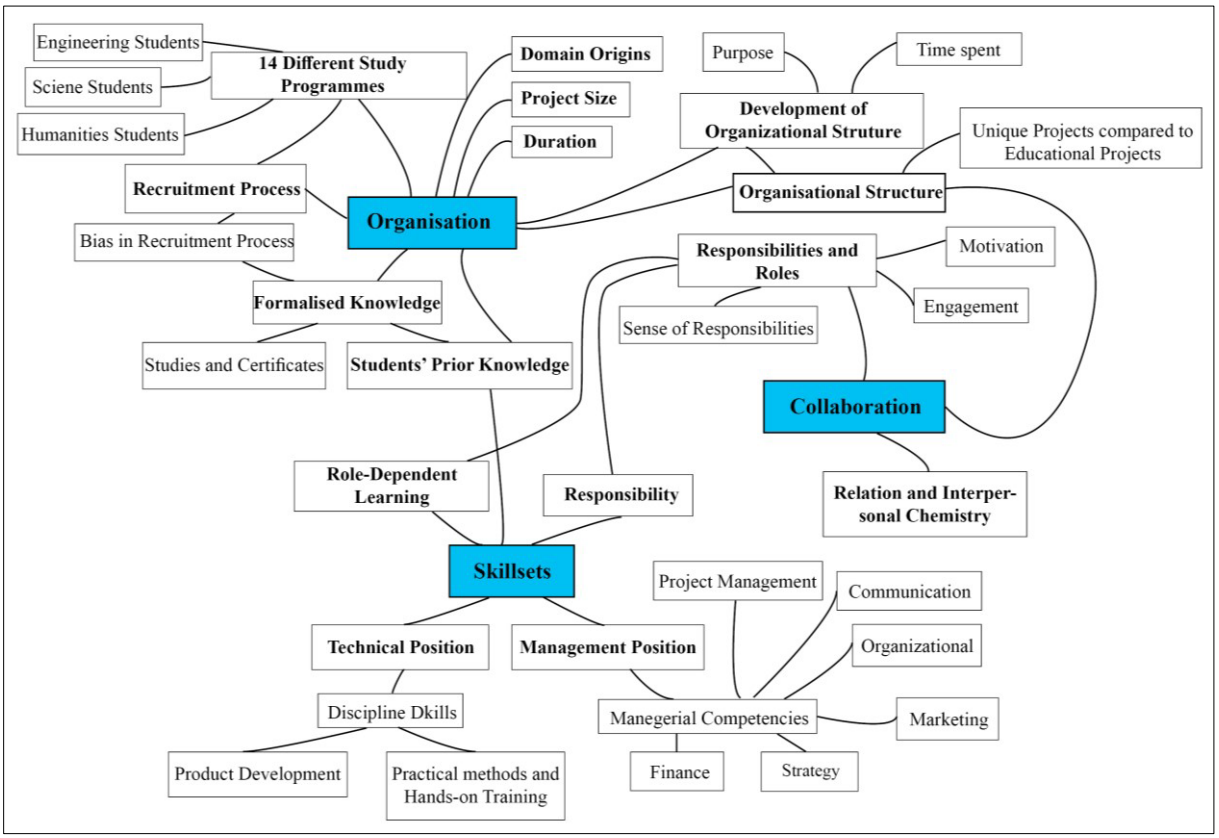


Figure 1: Thematic analysis of the interview data. Final figure.

### *Researcher positioning*

This study is rooted in a pragmatic research philosophy, which acknowledges the existence of multiple perspectives and realities (Saunders, Lewis, and Thornhill 2012). The author has extensive experience researching student organisations, including TSROs, and mentoring students across various disciplines and organisational contexts. This background informs an appreciation for practice-based learning, particularly how students develop engineering skills through collaborative, project-based engagement in student organisations—often involving hands-on experimentation with hardware and software to solve complex problems.

## Case Descriptions

### *Case Presentations*

Students involved in the TSROs are commonly referred to as members, while the leader is usually called the project manager. The organisations are typically composed of several sub-teams with distinct functions and responsibilities. Each of these sub-teams has a leader, often referred to as a team leader. In addition, there is usually a leadership team or board, which may either function as a standalone unit or be composed of representatives from each sub-team—this varies between organisations.

The TSROs are often inspired by one another, and their leaders meet regularly to collaborate and discuss shared interests, creating a sense of community across the organisations. Each TSRO is involved in the design and construction of a product. In some cases, the objectives are defined externally—such as through competitions—while others set internal goals and missions. The following section briefly presents all four case studies. Each includes an organisational chart to illustrate its

structure. While project managers often depicted themselves as part of the management board, they are highlighted separately in these illustrations for clarity and due to their overarching responsibilities.

### *Case 1*

Case 1 (see Figure 2) is one of the smaller TSROs, comprising between 20 and 40 members. At the time of data collection, it had 24 active members. This TSRO designs and builds a race car, participating annually in competitions. It is known for its vibrant social environment and reputation as a place to make friends and have fun. Members are expected to dedicate approximately 5–10 hours per week to the organisation.

Seven different study programmes are represented in this TSRO. The project manager has prior experience in another TSRO. The team leaders have one year of experience in the organisation, with one having two years.

At the time of study, the roles responsible for marketing and finance were vacant, and recruitment efforts were ongoing. These responsibilities had been temporarily redistributed among the project manager and other members of the management board. Most members have academic backgrounds in engineering, closely aligned with their technical roles. For example, members of the electrical team are enrolled in an MSc in Electronics Systems Design and Innovation; those in the autonomous team study MSc Cybernetics and Robotics; and the mechanical team comprises students from MSc Mechanical Engineering programmes.

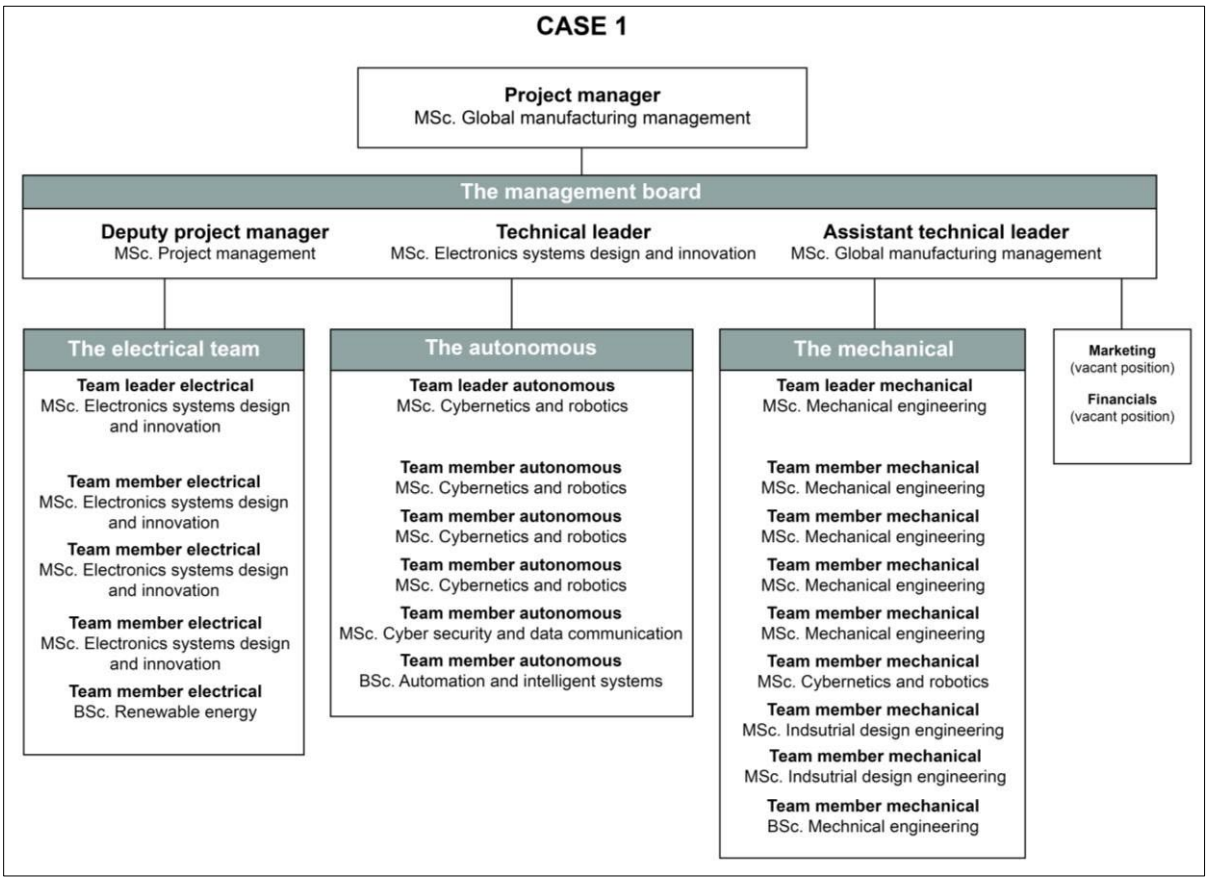


Figure 2: Organisation of TSRO, Case 1

### *Case 2*

Established in 2023, Case 2 is the newest of the four organisations. Like Case 1, it is relatively small, with 32 members at the time of study (ideally 35–40). It also competes in annual racing competitions, although the type of vehicle and competition differ from Case 1.

Case 2 (see Figure 3) has a simple structure comprising a project manager, a management board, an electrical team, a mechanical team, and a strategy member. Members are expected to contribute around 15 hours per week, with leaders typically working more.

The project manager has previously held both technical and managerial positions in two other TSROs. He emphasised that international students often use the organisation as a primary social network, noting the challenges of making friends after moving to Norway. Case 2 is still relatively unknown due to its recent establishment, but its project is considered highly innovative and ambitious.

While the internal structure differs slightly from Case 1, team composition generally reflects the members' academic backgrounds. Two members come from non-engineering study programmes, and there is some diversity even within sub-teams—for instance, the mechanical team includes students from five different engineering disciplines. In total, eight study programmes are represented in this TSRO.

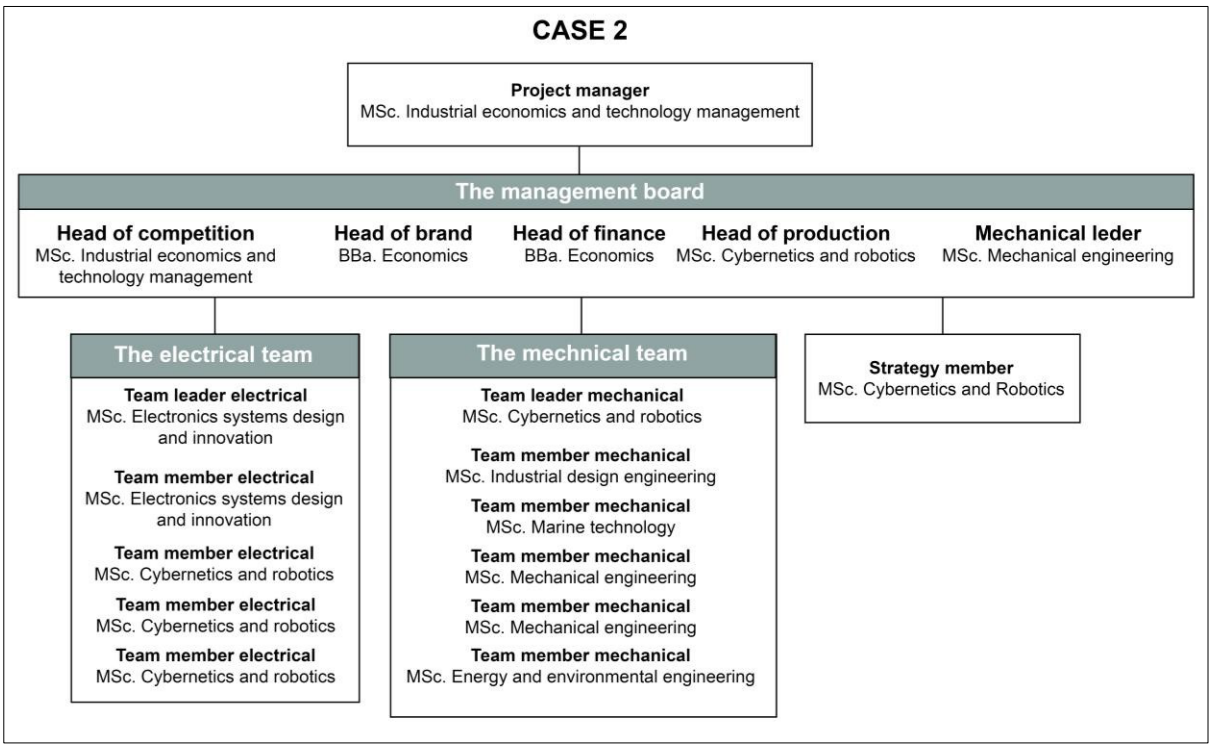


Figure 3: Organisation of TSRO, Case 2

### *Case 3*

This TSRO designs and produces drones, in addition to working on various other technical projects. It has 45 members, although, as with the other TSROs, this number can fluctuate depending on recruitment and retention. Ten different study programmes are represented.

Case 3 (see Figure 4) has a similar structure to Cases 1 and 2, with a project manager, a management board, and several sub-teams organised by function: hardware, autonomy, control, perception, and marketing.

Notably, Case 3 has a larger marketing team with more specialised responsibilities (reflected in their role titles). Like Case 2, it includes a significant number of international students.

All members are enrolled in engineering or science study programmes, and they are expected to dedicate approximately 15 hours per week to the organisation. As in the other cases, leaders typically commit more time. This TSRO also participates in external annual competitions. The current project manager has previously held another role within the organisation.

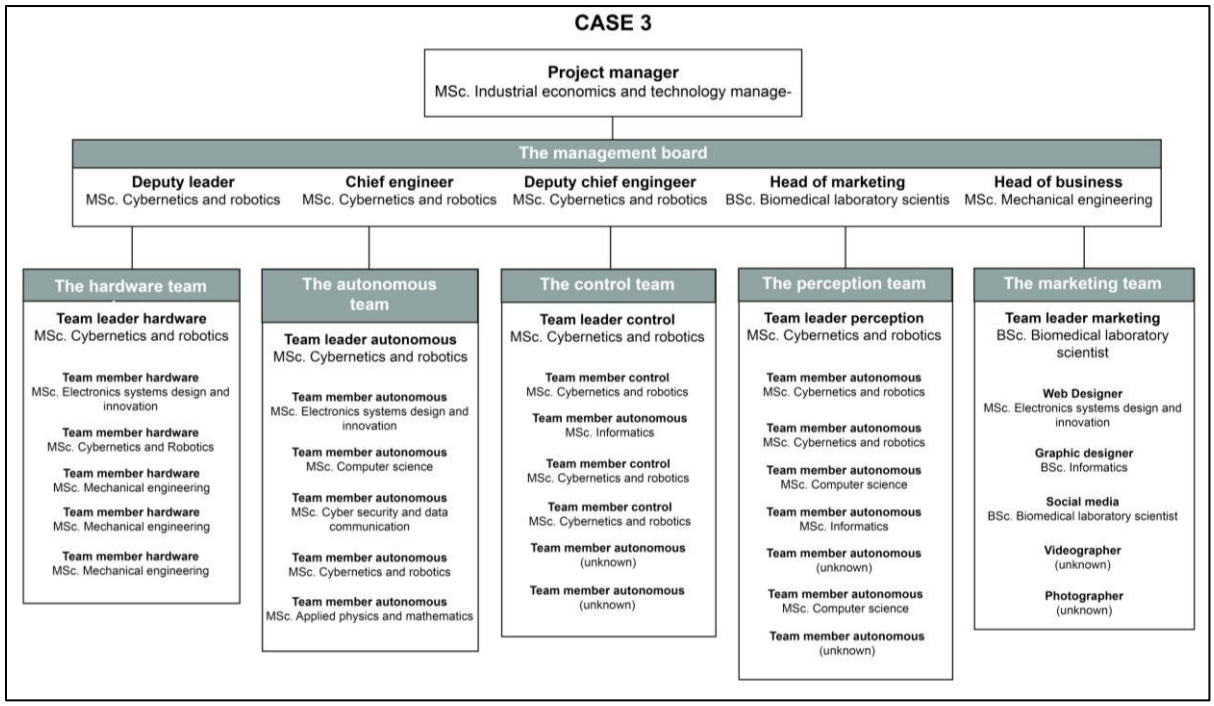


Figure 4: Organisation of TSRO, Case 3

### *Case 4*

Case 4 (see Figure 5) differs from the other cases in both size and organisational structure. It has approximately 105 members and exhibits the greatest diversity in terms of student population. Members come from 14 different study programmes, including social sciences, and some are based at other campuses.

Unlike the other TSROs, Case 4 does not focus on a single annual project. Instead, it oversees several long-term projects, with small sub-teams dynamically allocated to different projects based on current needs.

Case 4 has undergone substantial development in recent years. Initially structured similarly to the other TSROs, it has since evolved into a matrix organisation. Members are expected to contribute 10–15 hours per week, while leaders may work between 30 and 50 hours.

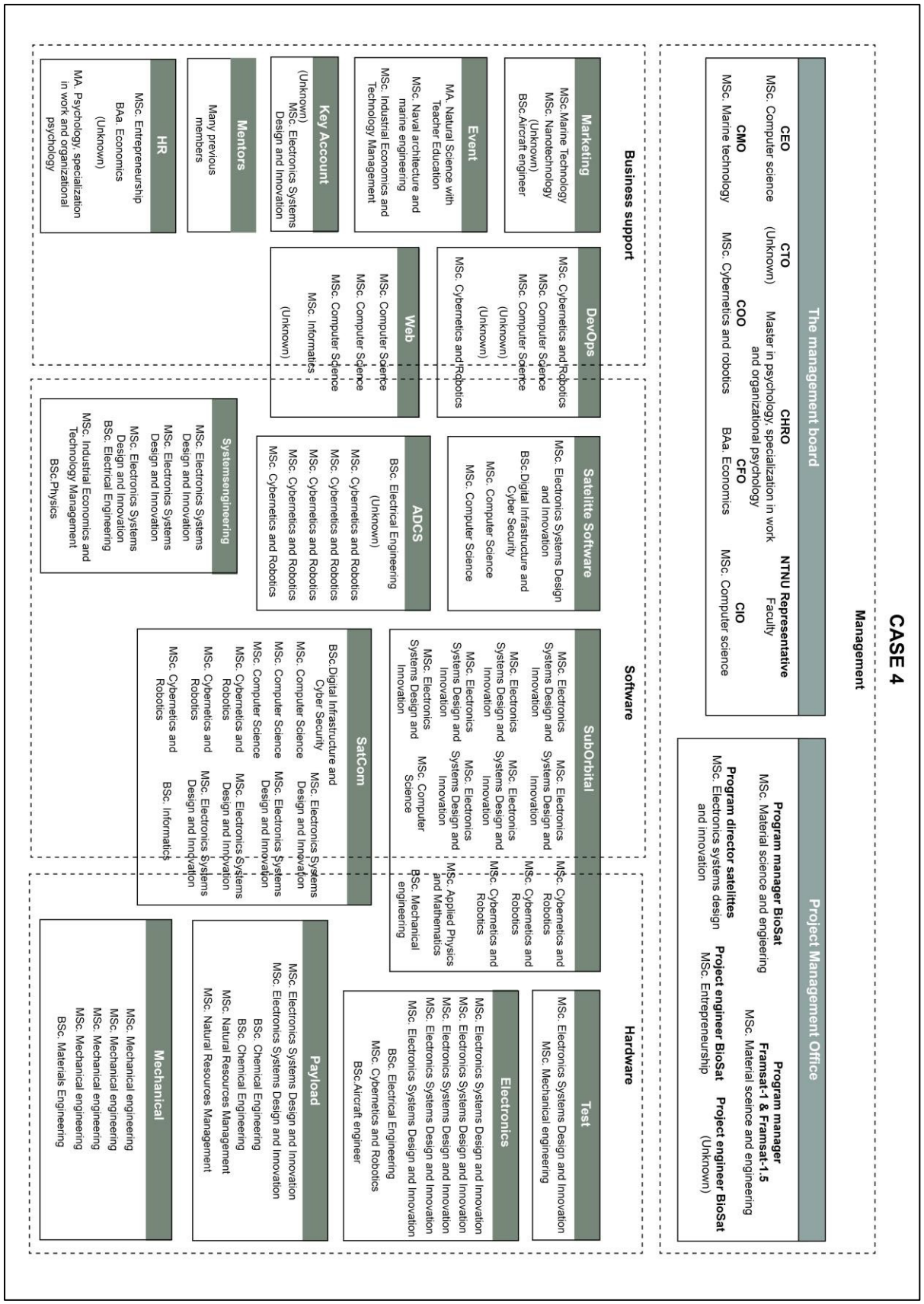


Figure 5: Organisation of TSRO, Case 4

## Results

### *Organisation*

#### *Project Size, Duration, and Domain Origins*

TSROs are significantly larger in scale than typical university assignments, both in terms of personnel, funding, and project duration – this is also addressed by students during the interviews. This scope is something that students find both motivating and challenging. Many TSRO projects span over a year, with some lasting more than three years. While some TSROs operate a single project, others manage several projects simultaneously. Most commonly, a TSRO undertakes one major project where members design, build, and compete with a technical unit.

Each project typically involves between approximately 20 and 100 students (for these three cases at present time there are between 24-105 students participating). This results in more ambitious and time-intensive outputs than those produced in regular coursework (e.g., constructing a satellite versus writing a report). One student noted that while their study programme includes project work, the academic assignments lack sufficient intensity and time demands. This results in unrealistic processes and fails to adequately prepare students for effective teamwork. As one participant put it: "They tried to teach us how to work on projects, but it doesn't work. Extremely few engineering students can say they actually learned how to work in a practical group." The student attributed this to a lack of pressure, conflict, or real-world stakes—factors present in the TSRO environment, especially when interacting with external businesses.

Students are often highly motivated and commit significant time to TSRO projects. One student described the organisational challenge of managing such a large group, in contrast to standard university projects: "We have several projects in our programme, but we often work independently. Maybe we help each other a bit, but usually it's just three of us. It's entirely different when 50 students are working together." In these settings, project leaders are responsible for managing teams and overseeing the entire organisational process.

TSROs have varied origins. Some are initiated by academic staff or institutions, while others are student-founded. One student-led TSRO was created in response to the absence of a dedicated space engineering programme at their university, aiming to provide practical experience and domain-specific knowledge to engineering students. At that time, there were no space engineering courses available at the NTNU, and students saw the formation of the TSRO as a way to fill this gap.

The outputs of TSROs are often shaped by their origins. Academic staff or students typically contribute their domain expertise, which then informs the structure and skill requirements of the organisation over time.

There are considerable differences in the expectations placed on TSRO members regarding working hours. This variation influences the internal culture, public image, retention rates beyond one year, and recruitment capabilities. Weekly commitment ranges from five to sixty hours, depending on the TSRO and the members' role. Team leaders and project managers generally work more hours than team members, although this also varies between organisations.

Among the four TSROs examined in this study, each organisation has between 24 and 105 active student members. These students are enrolled in over 24 different study programmes, primarily within engineering, but also including science and humanities disciplines.

Most TSROs, like Case 1, Case 2, and Case 3, are dominated by engineering students. Case 4 stands out due to its broader representation across various fields and greater diversity. Furthermore, Cases 1–3 typically experience high student turnover, with few members remaining involved for more than a year. Case 4, in contrast, often retains members for longer durations, contributing to more sustained organisational development. One example is that some members in Case 4 hold roles where they deliver seminar-based courses, allowing other members to develop their competencies in different topics. These seminars are led by members who have been in the organisation for more than three years. Another example is the adaptable reorganisation of teams based on project needs and the number of projects being run at any given time.

Table 2: Study programs represented in the TSROs

| Study program | | Represented in case 1 | Represented in case 2 | Represented in case 3 | Represented in case 4 |
|---|---|---|---|---|---|
| 1 | MSc. Global manufacturing management | X | | | |
| 2 | MSc. Project management | X | | | |
| 3 | MSc. Electronics systems design and innovation | X | X | X | X |
| 4 | BSc. Renewable energy | X | | | |
| 5 | MSc. Cybernetics and robotics | X | X | X | X |
| 6 | BSc. Automation and intelligent systems | X | | | |
| 7 | MSc. Mechanical engineering | X | X | X | |
| 8 | MSc. Industrial design engineering | X | X | | |
| 9 | MSc. Industrial economics and technology management | | X | X | X |
| 10 | BA. Economics | | X | | X |
| 11 | MSc. Marine technology | | X | | X |
| 12 | MSc. Energy and environmental engineering | | | | |
| 13 | BSc. Biomedical laboratory scientist | | | X | |
| 14 | MSc. Applied physics and mathematics | | | X | |
| 15 | MSc. Cyber security and data communication | | | X | |
| 16 | MSc. Computer science | | | X | X |
| 17 | MSc. Informatics | | | X | X |
| 18 | MSc. Psychology, specialization in work and organisational psychology | | | | X |
| 19 | MSc. Material Science and Engineering | | | | X |
| 20 | MSc. Entrepreneurship | | | | X |
| 21 | MSc. Nanotechnology | | | | X |
| 22 | BSc. Aerospace engineer | | | | X |
| 23 | MSc. Naval architecture and marine engineering | | | | X |
| 24 | MA. Natural Science with Teacher Education | | | | X |
| | Total: | 8 | 7 | 9 | 14 |

## Organisational Structure

TSROs are structured into various teams with distinct functions, requiring a wide range of skills across the organisation. They include team leaders or project managers and sub-teams responsible for either different projects or specific components of a single project.

For example, in Case 1, there is a mechanical team led by a student enrolled in the MSc in Mechanical Engineering programme. Most team members are from the same programme. In Case 4, the DevOps team primarily consists of MSc Computer Science students. However, Case 4 exhibits greater team diversity—for instance, the events team includes students from three different study programmes (two engineering disciplines and one from teaching). This diversity is more prominent in Case 4 than in Cases 1–3.

A common feature across all four cases is the structure of the management board and team leadership. The management board oversees the organisation's overall direction, including progress, finance, marketing, collaborations, and often sponsorships. Team leaders are responsible for guiding their teams towards specific goals and tasks.

## Formalised Knowledge

Project managers of the TSROs often come from engineering backgrounds and have previously held technical positions. However, they typically lack formal education in leadership, finance, and other essential areas. To address this, NTNU provides support through various courses, and students can access university services to manage conflicts or other challenges.

TSROs mirror real-world organisations where conflict may arise. Students experience these as more authentic than classroom-based learning. Some TSROs maintain collaborations with industry partners, with sponsorships ranging from several thousand to millions of NOK per year. The level of responsibility is significant, and Case 4, for example, even includes a dedicated HR team.

There are limited formal opportunities for students to validate or certify the knowledge and skills acquired through their TSRO involvement in relation to their university degree or the awarding of ECTS credits. A few TSROs offer unique arrangements where students can integrate the development process of a new method or product into a course assignment, thereby earning ECTS credits. However, this option is not available to all TSROs, meaning that practical technical work often does not translate into formal academic recognition.

Currently, all engineering students at NTNU are required to gain work-life experience as part of their degree, typically through collaboration with external businesses. TSRO participation is not considered part of this requirement at present. Nevertheless, some NTNU courses allow students to draw on their practical experience within TSROs for credit-bearing assignments. One example is the course IØ1003 – Managing Voluntary Organisations, which supports student leaders in TSROs by helping them develop and formalise their managerial skills. Several participants in this study referenced this course as an opportunity to connect their TSRO leadership experience with formal learning outcomes.

### Students' Prior Knowledge and the Recruitment Process

TSROs are naturally perceived as technical organisations due to the nature of their outputs. While the university hosts many non-technical student organisations, TSROs predominantly attract students from

engineering and science programmes. Nonetheless, students from other academic backgrounds also participate.

Retention varies among the organisations. Cases 1–3 recruit a large base of their members annually, while Case 4 sees significantly higher retention. Students from Case 4 suggested that teams focused on 'business support' (see Figure 5) play a key role in both retaining and successfully recruiting members.

TSROs also offer valuable learning opportunities for students with limited prior experience. One student remarked: "Many of the students join in their first year, straight from high school. Some, like me, have vocational qualifications, but that's rare. They've never done anything like this, so their field of study doesn't really matter." This is especially true for those in technical roles.

While some students enter university with practical experience (e.g., through trade certifications), most come directly from school. In their early university years, students often engage in large, lecture-based courses that offer little in the way of practical skills. For example, one student noted they only received four hours of welding training, which they felt was inadequate for those without prior experience. Several students expressed that they have a lot of subjects with calculations with small assignments each week and little hands-on group work. The balance between theoretical and practical training varies between engineering programmes and across academic years. Many students consider their work in TSROs as their first true hands-on experience within their field, which plays an important role in shaping their professional identity and their discipline knowledge. Students often find that skills gained in TSROs enhance their academic performance and vice versa. Those who dedicate significant time to TSROs tend to develop strong identification with their teams, whether focused on mechanical, electrical, or other technical disciplines.

Where applicant numbers are high, management boards and team leaders must make selection decisions. Conversely, some organisations cannot afford to be selective due to low application rates. Selection processes are influenced by unconscious biases within the leadership. See a more detailed analysis of these biases in the 'Responsibilities and Roles'. All engineering students interviewed expressed some dissatisfaction with their formal education, stating they often felt underprepared and had to "learn from scratch" in technical TSRO roles.

Despite this, formal knowledge remains a valued asset, and this is an important recruitment criterion. Some teams also consider diversity and gender balance when selecting candidates. One student shared their team's selection criteria: "First, they need to fit into the culture. Second, they need to have the foundation to perform—education is a factor. We don't have the capacity to train extensively. We expect 10–15 hours of work per week from a typical member. When applicants are few, we can't be too selective."

This pattern is consistent across TSROs. Applicants with documented experience or formal training relevant to their intended roles are more likely to be selected. Students described the recruitment process as professional but acknowledged that selection biases—especially towards particular study programmes—can influence the organisational composition. The broader the TSRO's range of tasks and the higher the number of applicants, the greater the diversity of academic backgrounds represented.

## Collaboration

### *Responsibilities and Roles*

Based on organisational charts drawn by the students, it is evident that roles within TSROs are often associated with the students' academic background. This was also confirmed during the interviews with the students. It became evident that they are not particularly aware of this themselves, and the disposition presented below has been developed from the analysis based on the interview data. The prioritisation of the factors is likewise part of my analysis. The positions they assume are influenced by three key factors:

1. The students' own identity, confidence in their abilities, personal interests, and motivation to learn new skills.
2. The leadership team's selection process, often shaped by perceptions of who is best suited for the role (which can introduce selection bias).
3. The number of applicants for a given position.

Regarding the first point, one student explained his motivation for taking on a leadership role: "Last year I led the autonomy group; this year I'm leading the whole organisation. We work heavily on the autonomous systems of the car, aiming to improve energy efficiency—a complex task involving design, mechanics, electronics, and marketing. I've taken on leadership roles before, though I never actively sought them. I just wanted to work on things I found interesting. But when I see a job being done poorly, I feel compelled to step in and do it better. That's why I applied for the leadership role—not because I wanted to lead, but because I believed I could do a better job." In this case, the student had spent a year observing the previous leader, and when the role became available, he saw an opportunity to improve the team's performance.

Other students apply for technical roles in TSROs primarily to develop practical skills. Many reported feeling that their degree programmes lacked opportunities to gain specialised, hands-on experience. They generally found later years (particularly years three and four) more fulfilling, as the content becomes more specialised and aligned with their interests.

There is considerable interdisciplinary collaboration taking place in the organisations in all cases (1–4), especially across the silos of the different teams. There are examples of teams coming together to develop products, but in different situations this could be considered either interdisciplinary or multidisciplinary (using the Kolmos et al. 2024 understanding of the terms). There is also the question of whether the students have enough domain knowledge to master their own "discipline" and whether this forms the basis for being able to work in cross-disciplinary teams, or whether the TSRO represents a situation in which students are only beginning to learn their own discipline – which may be sufficient for the time being.

In all four cases, there are teams with a thematic assignment, such as working on the electronic system of a technical unit. Case 1 clearly shows that students from one study programme are placed in their "assigned team", and here there is greater interdisciplinary collaboration across teams when the product is nearing completion – at which point the hardware and software need to interact. In Case 4, we see a much more mixed team composition, for example in the Satellite software team, which includes three different but highly relevant study programmes. Here the team collaborates interdisciplinarily to develop the software, bridging different areas of knowledge – although many students are still learning and developing skills together, rather than joining with all the necessary disciplinary expertise in advance.

In Case 4, there is far more collaboration across different teams, and because there are many teams and more complex projects that are not repeated annually, there is less of a fixed working process.

The management boards are closer to multidisciplinary collaboration (using the definition of Kolmos et al. 2024), since they collaborate but retain responsibility for their own teams and areas, fulfilling those tasks. Again, the question arises as to whether students already possess the necessary knowledge or whether this is something that develops over time.

Cases 1 to 3 vary between interdisciplinary and multidisciplinary collaboration within different teams and parts of the organisation, but Case 4 also includes examples of transdisciplinary collaboration. This is because students work outside their own discipline, sometimes alongside external partners and mentors. Case 4 is the TSRO that features the most cross-collaboration between backgrounds and responsibilities, as different resources and teams are assigned to assist with various projects. Case 4 does not focus solely on an annual project but instead manages three major projects to which resources (i.e., teams) are allocated.

### *Relationships and Interpersonal Chemistry*

Project managers typically collaborate closely with the management board and team leaders, maintaining frequent dialogue and shared responsibilities. Team leaders coordinate with their own teams, other team leaders, and selected individuals on the management board, depending on their role and responsibilities.

Collaboration patterns are shaped by the organisational structure and the nature of each role. Since TSROs are volunteer-driven, responsibilities sometimes shift, particularly when members fail to fulfil their duties. In such cases, the overall leader may need to step in. The system relies heavily on trust.

Interpersonal chemistry also plays a significant role in collaboration. Students often work more effectively with peers they feel comfortable with. Leaders frequently mention having certain team members who "have their back"—people they trust, who are both competent and reliable. This dynamic contributes significantly to task completion and morale.

### *Organisational Structure*

Team leaders collaborate extensively with the members of their respective teams, as well as with other team leaders whose coordination is essential for achieving planned outcomes. However, some teams operate at a greater distance from these collaborative processes. For instance, the *Marketing* and *Web* teams, as shown in the organisational maps, depend on other teams to generate content but do not

## Skillsets

### *Role-Dependent Learning and Responsibility*

The development of students' skillsets in TSROs is largely shaped by the roles they hold and the responsibilities they undertake. Students typically gain experience related to their assigned tasks; however, in practice, these roles are often fluid. When a team member does not fulfil their responsibilities, tasks frequently shift to others, most commonly to their immediate leader or another proactive member. This informal redistribution of tasks allows students to be exposed to new

challenges and broaden their learning beyond their initial role. But also makes it hard to assess precise learning outcomes of participating – there is not a clear assessment of what each person contributes with.

Moreover, students' learning and development is also influenced by the amount of time they invest in the organisation and the level of responsibility they choose to take on. Those who dedicate more hours and actively seek responsibilities tend to experience faster growth in both technical and interpersonal competences. Increased engagement correlates with a deeper understanding of team dynamics, leadership, and time management.

Students often begin in entry-level or less demanding roles with minimal responsibility, and over time, progress to leadership or more technically challenging positions. Within the student community, there is a shared understanding of which TSROs are perceived as more relaxed and socially oriented, versus those that are highly demanding and competitive. Some TSROs require as little as five hours of commitment per week, with a strong emphasis on community and social engagement. Others may require a minimum of 15 hours per week, focusing more heavily on project deadlines, competition readiness, and technical or managerial advancement. This variation allows students to choose an experience that aligns with their personal and professional aspirations, creating a diverse and dynamic learning environment within the broader university setting.

### *Technical Positions vs. Management Positions*

Students in leadership roles within Technical Student-Run Organisations (TSROs) acquire a wide range of managerial competences, including project management, communication, organisational planning, marketing, finance, and strategic thinking. These skills are often new and distinct from those typically emphasised in their formal engineering education, offering students an opportunity to develop professional capabilities that extend beyond the technical domain. Many students describe this as their first exposure to real-world leadership and team coordination.

Students occupying technical roles focus on deepening their discipline-specific knowledge. This is particularly evident during the product development phase, where they gain practical, hands-on experience with design tools, prototyping techniques, and iterative testing. Through these roles, students enhance their problem-solving skills and become more confident in applying theoretical knowledge to tangible engineering challenges.

Leaders in TSROs often report investing a significant amount of time, sometimes working between 30 to 60 hours per week, to manage projects, coordinate teams, and liaise with external stakeholders. Interestingly, many participants are in their first or second year of study and possess only limited prior technical experience. Despite this, they are often assigned responsibilities aligned with their degree programmes, providing them with early exposure to real-world applications of their studies.

These organisations function as experiential learning environments, allowing students to test, iterate, and refine ideas in workshops and laboratories. Trial-and-error is encouraged, and failures are viewed as part of the learning process. Additionally, students frequently engage with external sponsors or industry partners to source funding and produce components that exceed the university's technical capabilities. This not only broadens their network but also cultivates professional behaviours such as negotiation, budgeting, and vendor communication.

### *Summary of Results*

The findings reveal that TSROs offer students a unique, largescale, and immersive learning environment that contrasts sharply with traditional university coursework. These organisations vary in size, project scope, and origin, but consistently involve high levels of commitment, responsibility, and interdisciplinary collaboration. Students develop skills based on their roles, with those in leadership gaining managerial experience, while those in technical positions refine practical, discipline-specific competencies. Progression often occurs from lower-responsibility roles to leadership positions as students build confidence and capability. The diversity of academic backgrounds, particularly in some TSROs, enhances teamwork and creativity. Time investment, organisational structure, and interpersonal chemistry all influence learning outcomes.

Students often describe TSROs as their first real exposure to hands-on engineering work, and many believe these experiences better prepare them for industry compared to traditional education. Despite a lack of formal recognition for acquired skills, the TSROs serve as powerful platforms for experiential and professional development.

## Discussion: Implications and Contributions

### *Participation and Organisational Structure*

The first research question explored was: Who participates in TSROs, and how are these TSROs structured?

It is evident that TSROs attract participants from a wide array of academic programmes. During the 2023/2024 academic year, 24 study programmes were represented across the TSROs examined. However, a clear majority of participants were engineering students in the earlier stages of their degree. Entry into TSROs is competitive, with students applying for specific roles through a formal recruitment process managed by the organisation's management board. This process tends to favour candidates with relevant academic backgrounds, particularly when specific roles align closely with disciplinary expertise—for instance, candidates enrolled in Economics programmes are more likely to be appointed as Head of Finance.

The diversity of the TSRO is influenced by three key factors: (1) the range of available roles, (2) the success and competitiveness of the recruitment process, and (3) the selection biases of the management board. Case 4, for example, demonstrates a more inclusive and functionally diverse structure, contributing to a greater diversity of academic backgrounds among its members. Conversely, Cases 1 to 3 reflect more role-specific recruitment practices, leading to narrower academic representation.

TSROs are typically structured in a hierarchical yet collaborative manner, with clearly defined roles and responsibilities. At the top of the organisational structure sits the management board, responsible for overall governance, strategic planning, and recruitment. Project managers operate beneath the board, overseeing specific projects or initiatives, often in close coordination with team leaders. Each team leader supervises a group of members working on defined tasks, such as design, development, finance, or communications. While there is a formal recruitment process—often favouring candidates with relevant academic backgrounds—there is also flexibility, with some students assuming roles outside their field of study. This structure allows for both specialisation and interdisciplinary collaboration. Although TSROs emulate professional work environments, most participants are

students in the early stages of their academic careers, making the structure both a learning platform and an operational framework that supports peer-led development and experiential learning.

### *Collaboration Between Students in TSROs*

The second research question considered: How do students collaborate across roles and study programmes within TSROs?

A number of common patterns emerged regarding collaboration dynamics. Project managers typically maintain close working relationships with both the management board and team leaders, often depending on a small circle of trusted colleagues for operational support and decision-making. This inner network forms the core of the organisation's leadership and strategic management.

Team leaders, meanwhile, serve as crucial intermediaries, linking individual team members to broader organisational goals. They frequently interact not only with their direct teams and the management board but also with fellow team leaders to ensure coordination and avoid operational silos. This form of collaboration is essential in large and complex TSROs.

Notably, many students occupying leadership and coordination roles—such as those on the management board, project managers, and team leaders—are engineering students who typically lack formal training in leadership, budgeting, or organisational planning. This challenges existing frameworks, such as those proposed by Tomkinson et al. (2008), which assume a baseline level of competency in these domains.

Particularly in Case 4, the DevOps team represents a vivid example of interdisciplinarity, where students from varied disciplines contribute to shared goals. However, the traditional distinctions between disciplinary identities are often blurred, as many participants are in the early stages of their academic careers and have not yet developed strong disciplinary affiliations. The management board in Case 4 also exemplifies multidisciplinarity, as members collaborate across disciplinary lines, integrating diverse perspectives into collective decision-making.

While one could argue that Cases 1 to 3 exhibit transdisciplinary elements—especially where students are engaging in unfamiliar roles under the mentorship of more experienced peers—the terminology remains fluid. What is clear, however, is that collaboration within TSROs transcends conventional disciplinary boundaries and presents an authentic learning experience that differs markedly from typical coursework.

Despite a preference among management boards for candidates with formalised knowledge relevant to their roles, all cases include examples of students from unrelated academic backgrounds successfully taking on and thriving in unfamiliar positions. This illustrates a degree of openness in recruitment and reflects the adaptability of student participants.

### *Skillsets Developed Through Cross-Disciplinary Collaboration*

The third research question asked: What skillsets do students develop through cross-disciplinary collaboration in TSROs?

While engineering students at the NTNU are required to complete a mandatory Experts in Teamwork course, which focuses on project-based collaboration across disciplines, many TSRO participants are in the earlier years of their studies and have not yet undertaken this module. TSROs therefore represent an important and often earlier opportunity for students to engage in cross-disciplinary, practice-

oriented work. The findings support Cima's et al. (2024) claim that students develop the ability to manage conflict and motivate peers and regulate emotions.

Most students in the TSRO state that this is their first experience of hands-on training in building systems and applying their field in a practical way, developing skills connected to this. For some, coding, sensors, and prototyping are new, while others are, for example, developing skills to simulate air pressure using different software systems. There is considerable diversity in the skills students develop, as the work is highly task-oriented and driven by whatever needs to be completed. Students also report that the skills acquired in the TSRO benefit their academic performance.

Time is also an important factor in the development of skill sets: the more time students spend and the more tasks they complete, the more their learning and skills progress. This applies whether the skills are technical or more human-centred. Others develop skills by observing peers, learning from those who have undertaken similar tasks before them, and consulting detailed log information.

TSROs offer a fertile environment for the development of a range of transferable skills, including project management, technical writing, stakeholder communication, and collaborative problem-solving. Literature supports this view: Mihailidis et al. (2009), Acosta (2012), and Martellucci and Giannini (2022) have all recognised TSROs as arenas for technological development and academic growth. Bullen and Karri (2002) characterise TSROs as settings for authentic, multi-disciplinary challenges, while Davies (2013) highlights their value in applying engineering theory to real-world contexts. Similarly, Buchal (2004) emphasises the importance of design evaluation and teamwork.

However, it is important to stress that not all students will experience the same learning outcomes. The benefits gained depend heavily on the specific role held, the intensity and duration of participation, and the opportunities available within the TSRO structure. At present, there are limited formal mechanisms for students to document or receive recognition for these outcomes.

Fruchter and Lewis's (2001) framework is particularly useful for understanding this variability. Students often begin at the first level—developing basic disciplinary competence—before progressing to awareness of other disciplines (Level 2). With time and sustained involvement, they may advance to Level 3, integrating disciplinary perspectives into their work. Case 4 again stands out as a strong example of this progression, with members adapting the organisational structure to accommodate a broader skillset through progressive leadership. Level 4, involving full transdisciplinary integration, is typically reached only by long-term participants who have accumulated extensive experience and perspective.

### *Educational Potential in the TSROs*

This study underscores the need to reconsider how HEIs design learning opportunities, particularly within engineering and technical disciplines. Student involvement in TSROs provides not only a richer and more demanding learning experience than traditional coursework but also exposes the limitations of current pedagogical approaches in preparing graduates for professional practice. This includes both practical experience with technical processes and the development of human-centred skills.

TSROs challenge the prevailing assumption that structured, credit-bearing academic coursework alone is sufficient to develop the full spectrum of competencies required by graduates entering the workforce. The findings indicate that students perceive this experiential learning style as more meaningful. Evidence from this study suggests that students prefer practical, hands-on learning through extracurricular, student-led initiatives rather than teacher-centred classroom instruction. This points to the need for HEIs to integrate or formally recognise experiential learning pathways as part of a broader, more holistic educational offering. However, challenges remain in assessing learning outcomes, as

there is currently no standardised method for evaluating these experiences, and tasks and responsibilities within TSROs can be fluid. Questions also arise regarding enrolment - who decides who can join? In addition to whether formalisation might compromise the autonomy of TSROs.

Rather than treating TSROs as peripheral or purely extracurricular, institutions could move towards legitimising these organisations as recognised learning environments. For example, enabling formal accreditation of skills gained through TSRO participation—through elective modules, portfolio-based assessment, or recognition on transcripts—would validate the significant effort and learning involved. Another possibility is to consider TSRO participation as fulfilling the work-life experience requirement within engineering degrees. Such measures could encourage broader participation and promote equity for students who cannot commit extensive unpaid hours without academic recognition. Nevertheless, challenges remain, as not all students are accepted into TSROs, creating potential issues of exclusion.

For educators, the findings highlight the need to shift from a primarily content-delivery role to one of facilitation, mentorship, and partnership with students. Educators could engage with TSROs not as distant observers but as active collaborators, supporting reflective practice, helping to structure learning outcomes, and providing targeted feedback. This approach aligns with constructivist learning theories, which position students as active agents in knowledge construction, particularly in complex, real-world contexts.

Moreover, educators must recognise that authentic learning often requires conditions not easily replicated in the classroom: time pressure, interpersonal conflict, high stakes, and responsibility for tangible outcomes. TSROs naturally provide these elements, enabling students to internalise professional behaviours, resilience, and adaptive expertise. Consequently, traditional project-based learning modules could benefit from closer alignment with TSRO practices, particularly regarding student agency, interdisciplinary collaboration, and sustained engagement over extended periods.

From a broader disciplinary perspective, these findings contribute to the growing body of literature advocating for a redefinition of effective workforce preparation in STEM and other applied fields. The gap between formal education and industry expectations is well documented. This study helps bridge that gap by identifying the conditions under which students develop professional competence, autonomy, and identity.

The TSRO model fosters the development of transferable skills—leadership, communication, project management, and technical proficiency—through experiential learning that is student-led, peer-supported, and socially embedded. This aligns with recent scholarship on high-impact educational practices, which emphasises that prolonged, collaborative, and contextually rich learning experiences yield lasting developmental benefits. TSROs therefore offer a valuable model for future curriculum design and student engagement strategies. Currently, all TSRO members are enrolled students at NTNU (not exclusively in engineering programmes), but this aspect warrants further exploration in relation to inclusion within formal educational structures. Future experimentation with TSROs is not intended to replace existing three- and five-year programmes, which have been methodically developed over time; rather, it seeks to identify opportunities to enhance engineering education by leveraging insights from TSRO practices.

## Contributions to the Literature

This study adds a unique perspective to the existing literature by examining TSROs not only as extracurricular initiatives but as legitimate, complex learning systems. Prior research has often focused on co-curricular learning in more general terms, without a specific emphasis on technical, student-run organisations with long-term project cycles and industry involvement. By focusing on the internal structures, recruitment practices, team dynamics, and individual development trajectories within TSROs, this study contributes a deeper understanding of how student-led organisations function as learning ecosystems. Especially what activities and collaboration that happens cross disciplinary.

Furthermore, the findings highlight a significant tension between formal curricula and informal learning environments. While university programmes offer theoretical foundations, they frequently lack the depth and authenticity of applied experiences. TSROs, in contrast, provide context, continuity, and consequence—elements essential for meaningful learning but often absent from formal assessments.

### *Further research*

Several important areas warrant further investigation. For example, what unique learning experiences do engineering students gain through participation in TSROs? To what extent can TSROs serve as substitutes for, or complements to, curriculum-based modules? Future research could also be strengthened by incorporating the perspectives of alumni who have previously participated in TSROs. Exploring their reflections in hindsight would provide valuable insights into how their involvement influenced their opportunities when seeking their first employment, as well as how these experiences may have shaped their professional competencies and early career performance. In addition, interviewing recruiters who have hired graduates with TSRO experience could offer a richer understanding of how such experience is perceived within recruitment processes and whether it is considered advantageous.

It would be valuable to examine how different disciplinary compositions across cases influence team performance and outcome effectiveness. To pursue this, future studies should consider a more homogeneous sample of TSROs, such as organisations competing in Formula Student or similar global competitions. While this approach could enable clearer comparisons, it may also introduce cultural variability that would need to be addressed in the analysis.

Another promising line of inquiry relates to the development of engineering identity (Rodriguez, Lu and Bartlett 2018) and its relationship to career aspirations (Kirn and Godwin 2020), which remains an underexplored dimension of TSRO involvement. Previous studies, such as Boni, Weingart and Evenson (2009), have shown that cross-functional teams can support identity formation. Investigating how such processes occur within TSROs could offer valuable theoretical and practical insights into how extracurricular engineering activities contribute to students' professional self-concept and long-term trajectories.

### *Limitations of method*

This study is based on a small, purposive sample of eight participants (two per case), which provides valuable depth but limits breadth. The non-random selection and the qualitative design mean that the findings are context-specific and should not be generalised to all TSROs or other institutional settings. While the aim was to capture rich, detailed insights into the dynamics of TSRO participation, the limited sample size constrains transferability. Future research should include larger and more diverse samples across multiple institutions to strengthen the external validity and explore whether the patterns

observed here hold in different contexts. The selection of the four TSROs was intended to provide balance by including organisations that differ significantly in size, age, and domain. This diversity offers a broader perspective on what a TSRO can look like and enhances the potential for the findings to be recognised and applied in other university contexts. Furthermore, more robust methods—such as longitudinal studies or skill assessments at multiple time points—could offer deeper insight into learning outcomes.

## Conclusion

Technical Student-Run Organisations (TSROs) represent a valuable arena for engineering students to engage in cross-disciplinary collaboration beyond the traditional confines of their study programmes. This study has identified three key factors that influence the cross-disciplinary nature of TSROs: the structure and diversity of roles within the organisation, the effectiveness of the recruitment process, and the selection preferences of the management board, who often prioritise applicants with formalised knowledge relevant to the position. In addition, the collaboration internally but also the crossdisciplinarity is dependent on the interpersonal chemistry between the students. When these elements align, they create a rich, diverse environment that facilitates meaningful collaboration across disciplines.

The nature of teamwork within TSROs varies, with clear evidence of interdisciplinary, multidisciplinary, and transdisciplinary practices depending on the organisational setup and participant backgrounds. These blurred boundaries of disciplinary knowledge offer students a unique opportunity to engage with perspectives outside their own, enhancing both their technical and soft skills.

Importantly, the learning outcomes students achieve are closely tied to their role, the intensity of their engagement, and the duration of their participation. Students involved in leadership or project management roles often gain broader competencies in communication, organisation, and strategic thinking—skills not typically acquired through traditional coursework alone. Existing frameworks, such as that of Fruchter and Lewis (2001), provide a useful lens for understanding these developmental trajectories, illustrating how students evolve from disciplinary novices to competent collaborators in complex, real-world projects.

This study contributes to the growing body of literature on experiential learning and student-led initiatives in higher education. TSROs are shown to be effective in bridging theoretical knowledge with practical application, suggesting that such models may complement, and in some cases enhance, formal curricula. As such, TSROs should be recognised as significant educational environments that support both professional identity formation and the development of interdisciplinary competences in engineering education.

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