Building bonds: the transition from teamwork to friendship in engineering education and its influence on the well-being of female students

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Abstract

This paper explores the lived experiences of female students implementing collaborative project/problem-based learning (PBL) within undergraduate engineering programmes at TU Dublin, in Ireland. The paper emphasises the significance of teamwork in promoting meaningful connections among students that can result in gender inclusivity.

Drawing on a longitudinal dataset of 32 interviews with 13 female engineering students, the research adopts a phenomenological approach to investigate how team dynamics evolved over time. The findings reveal that early challenges often led to feelings of exclusion. However, as peer trust developed, many students transitioned from feeling isolated to forming meaningful friendships, especially with other women. These friendships provided emotional support, mutual recognition, and academic motivation.

The findings reveal that developing such friendships helped students feel valued and understood, navigate gendered barriers, and promote persistence in the engineering discipline. Through this lens, we gain insights into the dynamics of teamwork and its interplay in shaping students' emotional well-being.

This study underscores the need for greater institutional efforts to support peer connection and inclusive team environments. Ultimately, this research advocates for a culture of care within engineering education that prioritises inclusivity and emotional well-being as essential components of student success.

Keywords: Engineering Education, Collaborative Learning, Belonging, Gender Inclusivity, Persistence

1 Introduction

1.1 Background and rationale

Engineering education has increasingly adopted problem and project-based learning (PBL) as a pedagogical strategy to mirror real-world professional practices and foster technical and non-technical competencies. Although the benefits of collaborative learning are well recognized, unequal dynamics within teams—particularly dynamics tied to gender—can limit its potential (Aeby et al., 2019; Henderson, 2023). In this context, this paper reports findings regarding how female students navigate teamwork environments within PBL settings and what role peer relationships and friendships play in shaping students' academic and emotional experiences.

This study aims to contribute to the body of knowledge by examining the lived experiences of female engineering students using an existing longitudinal qualitative dataset, focusing on how their teamwork experiences evolve into friendships and how these friendships, in turn, affect their academic engagement and emotional well-being. Our analyses suggest that friendships may serve to protect female students against exclusion and foster a sense of belonging in engineering.

1.2 Research aim and questions

This research paper explores the following research questions:

a) What are the most common challenges that female engineering students face in PBL settings?
b) How do teamwork experiences in PBL settings evolve into friendships?
c) What impact do these friendships have on female engineering students' well-being?
d) How do friendships influence a sense of belonging and academic engagement?

1.3 Structure of the paper

Following the presentation of the rationale and objectives of the research paper, a brief literature review discusses the state-of-the-art regarding collaborative learning in engineering education, gender and

inclusivity in engineering, and the relationship between well-being and academic success in engineering education. Next, the methodology for this study is outlined, and then findings are reported and discussed to address the research questions. The paper concludes with key takeaways for educators and implications for future research.

2 Literature review

2.1 Collaborative learning in engineering education

Over the past five decades, problem- and project-based learning (PBL) and other collaborative learning approaches have become increasingly integrated into engineering curricula (Kolmos & de Graaff, 2014). These pedagogies are designed not only to support the development of technical knowledge and reasoning but also to enhance personal, interpersonal, and professional skills (Chen, Kolmos, & Du, 2021; Van Helden et al., 2023). Furthermore, collaborative learning as an active pedagogy is praised for emulating engineering practices, thus preparing students for professional collaboration in engineering contexts in professional settings (Mercier et al 2023). In this context, collaborative learning has been associated with academic achievement, improved learning outcomes, and increased student retention and persistence in engineering education (Du et al., 2020, p. 202; Stump et al., 2011).

However, while the benefits of collaborative learning are well documented, research has also drawn attention to its challenges and potential downsides. Some studies highlight the risk of marginalization within teams, where some students may feel excluded or undervalued (Mercier et al. 2023). Additionally, there is a need for a deeper understanding of how students experience collaboration in project teams and how team dynamics influence participation and engagement (Du et al., 2020; Henderson, 2023). These findings suggest that while collaborative learning fosters critical competencies, its implementation must be examined to ensure it promotes inclusive and equitable learning environments for all students.

2.2 Gender inclusivity in engineering

Masculinity in engineering extends beyond the numerical dominance of men, encompassing a deeply rooted culture (Aeby et al., 2019). Such cultural characteristics are often associated with competitiveness and technical dominance (Kamanda et al., 2022), which can influence how students experience teamwork. Gender stereotypes continue to shape role distribution and task allocation (Henderson, 2023; Svihla, Davis, & Kellam, 2023). For instance, Aeby et al. (2019) found that male students are more likely to take on tasks related to coding and maths, while female students more often handle report writing.

These dynamics are particularly challenging for female and underrepresented students, who may face barriers to participation, recognition, or leadership roles in teamwork settings (Isaac, Kotluk, & Tormey ,2023; Keough, Hirshfield, & Fowler, 2021). Being part of a numerical or cultural minority within a team has been linked to unpleasant or marginalizing experiences, which can affect students' academic motivation and confidence (Picard et al., 2022). In this context, there is a need to explore more inclusive and supportive approaches to teamwork in engineering education.

2.3 Well-being and academic success in engineering undergraduate programs

Well-being in collaborative settings often relies on peer relationships. Du and Kolmos (2009) found that students who engaged in collaborative learning formats reported feeling more motivated and perceived technical tasks as more manageable through peer-to-peer support than through individual study. Similarly, Stump et al. (2011) observed that women tend to be more inclined to collaborate than men, noting gendered differences in learning preferences.

Social capital—defined as the resources gained from interpersonal networks—has also been shown to play a key role in supporting students' persistence (Smith et al., 2021). For underrepresented students, such as

women and Black students, peer networks can be especially crucial in fostering confidence and retention, particularly by offering emotional support and access to academic resources (Henderson et al., 2023).

3 Methodology

3.1 Research design

This research is part of a larger project initiated in 2014, aimed at investigating the experiences of female students in Project/Problem-Based Learning (PBL) projects in engineering programs. A total of 72 individual and group interviews were collected at three universities across three European countries: the Technological University Dublin (formerly Dublin Institute of Technology) in Ireland, the Polytechnic Institute of Setúbal (IPS) in Portugal, and the Warsaw University of Technology (WUT) in Poland. The data collection was carried out by Professor Chance and her research team (Chance & Bowe, 2015; Chance & Williams, 2016; Chance, Williams, & Direito, 2021). In the years since, the research team conducted follow-up interviews with some of the participants. In the first year of interviews, the team sought to include all willing female engineering students at DIT and as representaative as possible a sample at IPS and WUT. However, follow-up were scheduled based on availability and opportunity (i.e., convenience sampling).

For this paper, the interviews used as data exclusively involve 32 interviews conducted with 13 students enrolled in engineering degree programs in 2014 in Dublin, Ireland, as this was the extent of our data showing change over time. These 13 students provided at least two interviews each, which facilitated identifying how participants' perceptions of teamwork and friendship had evolved.

The research adopted a phenomenological approach to understanding student experiences, and it encompassed two levels of analysis: (1) the exploration of individual women students' lived experiences in collaborative learning environments within engineering courses and (2) the role of peer support and friendship in promoting students' engagement in their courses and their sense of belonging in engineering.

The methodological approach we selected for this research places emphasis on women students' interpretation of experiences within collaborative learning environments. Ultimately, this examination is essential for understanding the extent to which these experiences are meaningful in fostering feelings of inclusion and belonging among participants in the field of engineering.

3.2 Participants and data collection

The study reports on the lived experiences of undergraduate engineering students at Technological University Dublin (TU Dublin) in Ireland. The longitudinal dataset comprised 32 interviews with 13 female engineering students from six countries. Group codes containing IR indicate Irish origin, ME indicates Middle Eastern origin, and FO indicates others (non-Irish, non-Middle Eastern).

Table 1. Overview of the 13 female participants interviewed

No	ID Group code	Country of birth	Years in Ireland*	Field of interest in engineering
1	IR02	Ireland	Since birth	Structural or manufacturing
2	IR07	Ireland	Since birth	Environmental engineering
3	ME01	Oman	2	Manufacturing and design engineering
4	ME02	Oman	3	Architectural engineering/civil engineering
5	ME03	Oman	1	Computer and communication engineering
6	ME04	Oman	3	Civil engineering
7	ME05	Kuwait	2	Mechanical engineering
8	ME06	Kuwait	5	Mechanical engineering
9	ME07	Oman	3	Civil engineering

No	ID Group code	Country of birth	Years in Ireland*	Field of interest in engineering
10	FO09	USA	3	Computer engineering
11	FO10	India	6	Mechanical engineering
12	FO11	Philippines	12	Mechanical engineering
13	FO12	Philippines	6	Mechanical engineering

* at the time of the first interview.

Interviews were conducted using a phenomenological approach. Each interview was 60 to 110 minutes long and occurred in a single sitting. They took the form of unstructured, open conversations regarding students' experiences in studying engineering, the pleasant situations and the more challenging ones, their experiences of working in teams, and their feelings regarding the predominance of males in the classes.

3.3 Data analysis

Based on the conceptual framework developed from a social phenomenological approach (Deep, 2020; Schutz, 1967a; Schutz, 1967b), we determined three general topics for description. Those topics were: (1) students' backgrounds, (2) students' experiences in engineering at college, and (3) students' plans. Within each of these topics, inductive coding was performed. Narratives with features in common were grouped as categories to help us identify patterns across participants (Saldaña, 2013). Within the second theme, seven subthemes were identified inductively. For this paper, only the subthemes about dynamics in formal study groups, informal collaborative support, and networking were considered; this allowed us to explore the team members' interactions and their development of friendships.

4 Findings

4.1 Challenging experiences for women students in PBL settings

In the early stages, the most common challenges for female students in PBL settings were related to group formation and being one of the few women—or even the only woman—on the team. The testimonies below indicate this is particularly problematic when a participant does not understand something but feels too shy to ask their teammates for help, or when they have an idea but feel ignored and must wait to suggest it again.

- "in the energy cube project, I was also in the boys' group. I couldn't say anything, maybe because I felt shy, don't know. And I can't connect with them." (ME02)
- "in semester one, and now also, I work with another group, with eight boys and just me. So… [laughs]. So, I should be, just like, I try to be fine with them and study. But… when I want to say a new idea for them about labs or experiments or anything, sometimes some of them…. When I speak, actually they say, 'No, this is a bad idea' or 'it's not strong idea. We just, we need another idea.' So when they start saying that, I feel like, inside me I, 'I will not say anything. I just, I will be quiet, and I will listen to them. And if there is something wrong, I can say my idea again'." (ME07)
- "in the bridge [project] I had three boys with me, and they were not listening to me as well. So I can't remember anything good about teamwork then as well." (ME03)

Another challenge mentioned by the participants was the distribution of roles and ensuring a fair workload for each team member. In the first-year interviews, we observed a bias among women, where they assumed that their male teammates knew more about the subjects, and as a result, they adopted follower roles. This may be linked to the perception that male students had prior exposure to engineering-related subjects at previous education levels.

In their testimonies, women participants:

1) joked around the secondary roles they could take: "[an Irish guy]'s a good drawer, so he did the drawings so then as well he did, you know, the dimensions on the cardboard. Like I was always joking,

like 'I'll make the tea!' Because they did Engineering for their Leaving Certificates, so they have a bit of knowledge about construction" (IR07)

2) noted they relied on male peers for technical explanations: "obviously, most of them have more knowledge on, I'd say, the technical stuff, or this and that. So, if I'm struggling with something, I ask them, and they'll gladly help me" (FO11); and
3) even relinquished leadership roles without questioning it. "I wanted to go for that [role], but [one of the male students] was very adamant about it. He really wanted to do that. So, I was just like, 'I'm not that enthusiastic about it, as much as he is, and it's a lot of responsibility'. So, I'll just let him have it. He likes to take charge!" (FO09)

Over time, this dynamic changed as women students realized that after some years in the major, most of them had similar levels of knowledge as the male students on their course. However, some participants felt that the bias against women persisted: "They knew that like, we've been in the same education and all that stuff to everyone perceives around the same level [… but] I noticed that some of them thought that I might not have known how to do it. I listen in class. I know how to do it." (FO11)

Over time, their self-confidence increased and that helped them navigate gender-based challenges.

4.2 Evolution from teammates to friends

Regarding the second research question – how do teamwork experiences in PBL settings evolve into friendships? – one apparent factor is the shared challenge of being one of the few women in engineering. Some students reported that their experience was more enjoyable when there was at least one other woman in the group, as it allowed them to support each other and speak up more confidently.

For example, student ME04 said: "In the Energy Cube [project] I had a Philippine girl. We were two girls and two boys. So whenever we have something, [we were] like 'let's tell them this or that'. It was much better. We were saying, 'Let's do this. Let's do that.' And we could understand each other better that way. I think that was a good group […] It was really good. Because we were all together, working together.

A student from the Middle East expressed the sense of empathy she felt when there was another woman in her team: "Sometimes you're saying: 'Why I'm doing the work with boys, and we don't have another girl in my group?' […] Maybe for girls, they can understand each other, you know – even if she's not Arab, not an Arabic girl, – but because she's a girl." […] Maybe she can understand your situation, being a girl in a group of three boys, so she can say, 'Oh, yeah, I can understand her feelings,' and so, we can offer and then help each other." (ME05).

Similarly, for Irish students, having another woman in the group also improved their performance: "I'm quite an anxious person. I don't particularly like standing up and talking in front of a large group. But I feel if I had to do that by myself, I wouldn't be nearly as confident. But working with [a Middle Eastern female teammate], bouncing ideas off each other, working off what each person said in the presentation, added a lot to it." (IR02)

Another factor that fosters friendships is vulnerability and reciprocity – expressed through asking for help to understand concepts or subjects and offering support in return. Participant F011 mentioned that in her first year, she hesitated to ask for help because she felt it would bother her teammates and she would be seen as less intelligent. Over time, she realized that everyone faced similar challenges and was willing to help each other: "In First Year, I had asked some people, but I didn't want to keep asking them because, for me, I felt I was just bothering them. One other thought I always had was, 'I don't want them to look down on me because I'm a girl. I don't want to sometimes ask them stuff because I don't want them to see me as below them or something like that'. Then, in the second year, I guess I carried on even though I did ask people occasionally, and if they explained to me and I didn't understand, I'd be like, 'Oh, okay.' Even though I didn't understand it because I felt bad having told them to explain it again. But then after that time where I was really frustrated […]. I started to ask more people like, 'Can you sit down and explain this to me because I

have no idea what's going on?' Then they're like, ''Yes, no problem.' They'd explain it. And I guess it's different when you're asking a lecturer and then you're asking your peers to explain it."

Similarly, participant ME05 explained how friendship developed through supportive teammates: "I was absent because I was sick. Then, when I came back to college and saw [my teammate]. I asked, 'What's missing, and what can I do?' And he said, 'If you want, we can go to the library, and then I can show you some works that you can do.' And then, we spent almost two and a half hours together, working on it because he wanted to help me catch up."

A crucial aspect of friendship is that, eventually, students develop trust in one another and attempt to solve their questions together by discussing them rather than always turning to the lecturer. In this way, having a circle of friends becomes a source of learning: "When I have a problem, I try to sort it out with my friends, sitting together and talking about how can I deal with this." (ME05)

Over the years, the reduction of the class size also fosters cohesion and friendships, not only because there are fewer students but also because of the working reputation of those who remain. The following student testimonies illustrate this:

- "I'm second year and the group's slowly been dropping. I think we're around 80 now because some people repeated, some people dropped out, [my female friend] as well. That's why now, one of the reasons I think that I got closer to other people is because it's a smaller class now compared to first year." (FO11)
- "[After] four years of working with the same people, you know who not to have in your group, as well [laughs]! A lot of those people that you don't want in your group didn't make it into Fourth Year anyway, so everybody is so driven this year. The issues of group work – of people not carrying their weight – you don't see it happening." (IR07)

4.3 Impact on self-confidence and emotional well-being

The third research question focuses on the impact of these friendships on the well-being of women students. Participants highlighted various aspects related to their self-confidence and emotional well-being. One key factor was receiving peer recognition for their technical competencies. When teammates valued their contributions and reassured them of their worth, they felt accepted – an experience that had a meaningful impact on their well-being.

For example, participant F011 described her emotional experience in completing a challenging group task: "It was in RoboSumo project. I was in charge of the programming and coding, and I was one of the first people to get the robot to move. So, when I got that done, everyone was like, 'How did you do that? Can you show us? Can you explain to us?' So, obviously, I felt kind of accepted.[…] Because I'm not trying to be sexist or anything, but guys are, most of the time, kind of prideful and they don't ask for help […] So, when I got the robot to move, and then everyone was asking for help, 'Will you show me how to do it?' And stuff like that, I felt like I belonged."

Another important aspect for participants is knowing that they have friends who genuinely want to be around them and offer support beyond the teamwork. Participant ME01 described it simply: "they take care of me, you know? If I'm stuck, they won't leave me like this".

The increase in friendships within the groups also leads to a shift from competitiveness to camaraderie, which may reduce emotional burden and stress. Participant IR07 explained: "In First Year I would have had a circle of friends, but now they're my circle of friends for three years and they're good friends, now. The competitiveness that I would have felt, probably directed to these people as well, is now very much like, 'well done. I'm proud of you for doing it too' […] So if, if I get 89% and my friend gets 90%, or whatever, I'm still really happy because I have got the first and I'm proud of her, or him, or whatever, for doing the same, you know what I mean? Because they are good friends now, like probably life-long friends.

Despite gaining self-confidence and a stronger voice in teams as they progress through the program, women students still struggle with self-doubt, which can prevent them from fully contributing to the team. Participant FO10 reflected on this and acknowledged that she sometimes perceives her teammates' feedback as a critique of her entire opinion, when it is perhaps just a disagreement with a specific aspect of her proposal. In her words: "I've more seen in other people's interactions that sometimes females tend to doubt themselves, even before someone says anything against their opinion. Say, for example, me or one of my female friends would be like, 'I think this is a good idea because of X, Y, Z.' Someone else says, 'I don't agree with Y.' My friend would doubt her entire idea rather than try and see if only Y was wrong. Correct Y, and then the whole thing will be correct. I tend to do that sometimes. If someone says anything against my opinion, I'm like, 'Yes, I'm wrong.' I need to tell myself, 'No, I might not be completely wrong. It may be half of it is wrong. I just correct it, and then, we're fine.' That is a big thing that I find myself doing, and I find other females doing. It's not really something I face from other people."

Conversely, losing friends who drop out of the program has significant implications for those who continue, particularly in finding a new group of friends. Participant F012, described her experience as follows: "Last year, we were together, so whenever we had an exam, she'd be like, 'Let's do this.' Or if she was feeling down, I would be like, 'Let's do this!'. But this year, she went back home because she said that she didn't like electrical engineering that much. So this year, it was kind of [sighs], but my classmates are really good. My Irish friends and my friends from Malaysia and China, we do work together and whenever we have questions we ask each other. They're very supportive."

4.4 Sense of belonging and academic engagement

The last research question centres on the influence of friendships on belonging to the field of engineering and academic engagement. In several instances, students described feeling encouraged when their contributions in group settings or peer interactions were heard, valued, and incorporated into the project, even when accompanied by constructive feedback. Furthermore, the testimony of participant FO11 offers insight into this sense of inclusion by highlighting the supportive nature of team interactions—not only when her peers offered help but also when she found that they respected her wish to try tasks independently first (instead of taking them over), so she could engage more actively in the learning process. She said: "I think when we're doing group work, and you can see that people are really taking into account your opinions, giving constructive criticism, and really applying it, it kind of makes you feel prideful, and then you feel like you belong. Obviously, it's a profession that's so dominated by men. And even it's seen in my labs, I'm the only girl there, everyone else is guys. I guess when we're doing stuff, and they ask for help, and then I ask for help, and then everyone kind of helps each other. In lab, I've never felt like I was pushed to the side, or by myself because the guys are very accommodating, and if they see that I'm struggling with something, they'll offer to help. They don't just take the stuff and do it for me. They are like, 'Do you want me to help you?' And then, at first, I'll be like, 'No, no, I'll try it first, and if I'm still struggling, then, I'll ask for your help.' And then they respect that. They know I'm like, 'No, let me do it first, let me do it first.' I kind of think that's where I feel I belong."

Finally, another key aspect is the role of emotional support from friends in academic persistence – and even in preventing dropouts. Participant FO09 described how the encouragement she received from friends and other students helped her reconsider dropping out of the program in her final year. The emotional support she received played a crucial role in her decision to persist. She expressed: "Well, I spoke with a lot of people – my friends here and other students. Obviously, I knew this in the back of my head, but to leave your final year is crazy. You commit to all these years, all the time spent studying, the money, whatever, the money that you could have made just working in whatever job, so it makes sense to stay. Somebody actually said to me 'You can't make decisions when you're emotional. Think about it, sit with it, drink over it, eat over it, think about it. Think about it for a few days, then make a decision'. That's stuck with me. It made sense. So, however, I feel, I'm still going to continue it. Do it. Do it to the best of my ability as well."

5 Conclusions and recommendations

5.1 Summary of key findings

Although many of the participants initially felt isolated or hesitant to speak up in male-dominated teams, based on the idea that their male peers were more knowledgeable on the subjects, their confidence grew over time, and they began to challenge the gender bias. However, subtle forms of exclusion still persisted and were acknowledged by them in the later stage of the engineering program.

Regarding the development of friendships, female students reported forming bonds with other women who shared similar challenges, offering mutual support and empathy. Additionally, asking for and offering academic help – through vulnerability and a commitment to reciprocity – helped build trust. Finally, sustained collaboration and smaller class sizes strengthened the group cohesion.

The impact of friendships on the self-confidence and emotional well-being of female students was strengthened by peer recognition, validation, and a sense of care. For the sampled women, friendships also contributed to reduced competitiveness and lower stress levels, easing the pressure to constantly prove themselves. Nonetheless, self-doubt and the experience of losing friends due to dropouts remained challenges in the later stages of the program.

Finally, the sense of belonging and academic engagement for these students was promoted by the validation and implementation of their contributions in team projects. Additionally, having the space to try out solutions independently reinforced the inclusive dynamic of the teamwork. Lastly, the emotional support from friends and peers proved effective in encouraging persistence.

5.2 Implications for educators and future research

Given the findings, we believe that educators should consider implementing strategies that foster meaningful peer interactions and collaborative support networks. Additionally, educators can play a key role in cultivating more inclusive and caring environments for learning that contribute to building a more equitable culture within engineering education. An example of this type of initiative is offered by Isaac et al. (2023).

Further research is needed to explore how friendships among female students can contribute to redefining the culture of engineering, particularly by creating environments where women's contributions to teamwork are recognized and valued rather than undermined. Additionally, future studies should investigate the role of social emotions in teamwork, including how feelings such as pride, frustration, empathy, and the like influence students' sense of belonging within engineering teams. Lönngren et al. (2023) provide valuable guidelines for researching emotions in engineering education. Finally, examining the long-term impact of friendships formed during engineering studies, particularly how they extend into professional collaborations and career development, could offer insight into the significance of peer networks promoted in PBL settings.

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