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Will I fit? The impact of social and identity determinants on teamwork in engineering education

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In engineering as with many STEM spaces, the environment delivers many cues that affect psychological fit, which affects choices students make. Teamwork experiences can be particularly challenging for equity-deserving students. Using focus groups at a medium-sized multi-cultural Canadian university, we examined how engineering students navigated and experienced teamwork and how that interacted with social determinants (e.g., money and time constraints) and identity, including gender, race, and sexuality. We used the framework of State Authenticity as Fit to Environment to develop themes of teamwork choices, experiences, and outcomes. Social fit (respect from peers) and self-concept fit (whether self-image matches stereotype) affected many choices and experiences including selection of teammates with similar identities or allies. Women and low socio-economic status students sought self-concept fit by avoiding coding within teams. Visibly under-represented students felt pressure to excel to validate self-concept fit. The team environment itself sent messages about social and self-concept fit to many students, though the focus on collaboration and applications with social benefits often aligned with goal fit. These fit-guided choices and threats to fit nudged many students away from engineering careers. Interventions to address factors that cause negative experiences for marginalized students include strategic group composition, supporting mentorship and affinity groups, rotating group roles, structured collaboration, inclusive teamwork training and increasing diversity.

KEYWORDS

gender, race/ethnicity, sexual orientation, socioeconomic status, teamwork, focus groups, fit, engineering study and teaching

1 Introduction

Teamwork is an essential skill for engineers, is increasingly used as a pedagogical tool (Chowdhury and Murzi, 2019; Hernández-de-Menéndez et al., 2019; Cruz et al., 2017) and can be a positive experience for a diverse student population. Projects that speak to effects on people and improving the world have been shown to excite a diversity of students and mitigate gender differences (Diekman et al., 2017). Similarly, the opportunity to work collaboratively on a project is appealing to many women and those from more communal cultures (Areepattamannil and Lee, 2014). Indeed, equity-deserving students' success has been linked

to high-impact practices in pedagogy, including collaborative and project-based learning (Finely and McNair, 2013; Gipson and Mitchell, 2017).

Teamwork outcomes for equity-deserving groups are not always positive. For example, women in engineering have faced well-documented issues of exclusion on teams (e.g., Ingram and Parker, 2002; Wolfe et al., 2016). Even in problem-based learning, women sometimes struggle to participate in teams (Hirshfield and Koretsky, 2017) and to develop an engineering identity (Du, 2006). Students tend to eschew diversity in teams (Rodriguez-Simmonds et al., 2017), women often end up in non-technical roles and experience more disrespect (Meadows and Sekaquaptewa, 2013). Work by Silbey (2016) and Seron et al. (2016) suggests that these negative experiences deter women from pursuing engineering careers after graduation. What drives these choices that perpetuate inequities in engineering?

Biased processes around engineering teamwork as a pedagogical tool have not been as well documented for those with a wider range of identities. There has been insightful work about overall experiences of queer and Black students in engineering (e.g., Cech, 2015; Ong et al., 2020), but there has been less work to determine whether diverse identities experience teams in the same way as women (exceptions include Cech and Waidzunas, 2011; Ong et al., 2020; Yoder and Mattheis, 2016). This is exemplified in the literature cited in the background section, which has much more focus on women in engineering in teams.

Our objective was to provide a comprehensive explanation of teamwork choices, experiences, and outcomes that encompasses the influence of a wide range of social identity factors. We argue that a theoretical framework that addresses students' psychological fit within an engineering environment facilitates this comprehensive explanation and provides us with a mechanism to suggest high-impact interventions to interrupt biased processes in teamwork.

First, we introduce our theoretical framework, then show how it is relevant to choices students make during teamwork, teamwork experiences they have and outcomes, using the existing literature on teamwork and social identity. We describe our qualitative methodology, then center our participants' voices in the results, showing how identity-based fit to environment has affected their teamwork choices, experiences and outcomes. Finally, we discuss how fit and social identity interact with teamwork in engineering and use that as a basis to suggest inclusive interventions that would provide more equitable outcomes for students.

2 Background

We will first introduce the theoretical framework of psychological fit to environment, which we will then use to explicate the literature about choices around teamwork, identity-based experiences within engineering teams and finally, outcomes of inequitable team experiences.

2.1 Theoretical framework: state authenticity as fit to environment

In order to comprehensively address teamwork choices, experiences, and outcomes in the context of social identity, we sought a theoretical model that would allow us to go beyond gender, would explain individual choices and would include the effect of environment that would center systemic issues as a focus for intervention. Schmader's state authenticity as fit to environment (SAFE) model suggests that choices are guided by a desire to fit, which is determined by the environment. Three aspects of psychological fit determine authenticity and thus future choices: social, self-concept, and goal fit (Schmader and Sedikides, 2018). We found the SAFE model appealing because it was developed to explicate how environment interacts with identity to constrain choice (Aday and Schmader, 2019) and has since been applied to gender in STEM (Schmader, 2023), though not specifically to team experiences.

Social fit (like belonging) means that you can express yourself without navigating others' expectations, which can be challenging in a team context. Small social cues can signal acceptance and inclusion or disrespect and exclusion, which affects interpersonal fluency. For example, a student could interpret an eyeroll during a team interaction as a signal that they do not fit socially. Even anticipation that a student might not be liked or respected by some peers can affect behavior and choices in an effort to improve social fit.

Self-concept fit means that features in an environment align with an individual's self-concept. So, a student could have stereotypes about an "ideal" engineer, reinforced by environment that might not match their own self-concept. For example, identities represented in images, role models, instructors, and the peer group will affect self-concept fit and cognitive fluency. If a student's self-image (e.g., as a quiet gay man, inexperienced coder, or skilled communicator) does not match their impression of an engineer (e.g., outgoing heterosexual man, a good coder, or a bad writer), their self-concept fit will be threatened.

Goal fit refers to motivational structures that fit with an individual's goals or values. When actively engaged in a goal-oriented task, goal fit will affect motivational fluency. Technical or career goals (e.g., wanting to be an engineer or learn coding) would be included, but so would the purpose of learning (e.g., a project that links theory to community benefit), the structure (e.g., working communally in a team or quietly alone), and academic orientation (e.g., a preference for mastery, performance or performance avoidance; Ames, 1992). Students will seek team experiences that afford them fit with their particular goals.

Others have attempted to provide a framework for interactions in teams. The idea of belonging (Foor et al., 2007; Rainey et al., 2021; Wilson and VanAntwerp, 2021) is similar to social fit while social identity theory (Tajfel, 1979; Turner and Oakes, 1986), which uses context to explain intergroup relations is similar to self-concept fit. Work by Ridgeway (1991) and Ridgeway and Markus (2022) suggested these self-concepts drove behavior in teams. Eccles expectancy value model (Eccles, 2005) was extended to explain gendered choices in teams (Fowler and Su, 2018), but mostly encompasses goal fit. We argue that the SAFE model's more comprehensive framework of social, self-concept and goal fit better describes the range of choices, experiences, and outcomes of a diversity of students in engineering teams.

Essentially, the SAFE model predicts that environment will nudge choices because people seek experiences that allow them to feel more authentic (Schmader and Sedikides, 2018). Students will thus avoid situations in which they face stereotypes, under-representation and exclusion because these interfere with self-concept fit and social fit. Environmental cues from the engineering context including team

composition, role allocation and resource constraints will affect how students of different identities navigate and experience teamwork, resulting in accumulated feelings of lack of fit and authenticity that will drive some folks away from engineering. We will explore how students with a range of identities experience teamwork in the context of the SAFE model.

2.2 Teamwork choices are driven by fit

When faced with teamwork-based course work, students make a number of choices that are guided by fit, mediated through social identity and environment. They choose with whom to work, what roles to adopt and how much to work.

Selection of teammates is likely driven by a desire for self-concept fit, which can be reinforced if you find other engineering students who share your identity, and by social fit, which is easier if you do not have to navigate cultural or gendered differences. Indeed, when students choose their own groups, they often gravitate to teammates with shared identities (Rodriguez-Simmonds et al., 2017), which is not surprising, given that friendship networks in diverse schools self-segregate by race, ethnicity, immigrant status, or social class (Bonilla-Silva and Embrick, 2007; Titzmann et al., 2012). However, a range of perspectives brings differing background and knowledge to problems, which improves outcomes despite not being as easy or comfortable (Ely and Thomas, 2020; Galinsky et al., 2015; Greitemeyer et al., 2006; McLeod et al., 1996; Schulz-Hardt et al., 2000; Stahl and Maznevski, 2021). Even when students know that less diverse teams suffer in how much they learn about technical content and building interpersonal relationships, they still prefer to avoid the complexity that comes with diversity (Rodriguez-Simmonds et al., 2020; Rodríguez-Simmonds et al., 2023).

When instructors leave role selection within teams up to students, roles are likely to be driven by self-concept fit (Am I a good coder? A good writer?), goal fit (Do I care about grades? Do I value a particular technical skill? Do I care if I appear arrogant? Do I value conflict avoidance?), and social fit (How can I get others to respect and like me?). Students navigate their own need for fit with their teammates, often with inequitable results.

In teams, women are more likely to take on non-technical roles (Strehl and Fowler, 2019; Keogh et al., 2018; Meadows and Sekaquaptewa, 2014), which might be due to goal fit (e.g., performance orientation) or self-concept fit, but is also likely due to navigation of social fit. Although this is sometimes viewed positively as a choice or as leadership (Ayre et al., 2013), women often need to assert their right to fully participate and are explicitly excluded from technical roles. Women often navigate teams by employing masculine or Eurocentric strategies of focusing on technical arguments to maintain their status in a group (Henderson, 2021), asserting self-concept fit.

Engineering students are skilled optimizers: if their academic orientation values performance (goal fit), they will work to maximize grades and minimize effort—particularly since their programs typically require long hours. So, if students are assessed primarily on the outcome of a project, they will find the most efficient way to get the most grades, and if some students have more knowledge or confidence in particular tasks (e.g., coding or writing), they are more likely to take on those roles. Self-concept fit similarly predicts that stereotypes about men as coders and women as communicators will be self-fulfilling in guiding role choice.

Having prior knowledge in many technical engineering areas is related to socioeconomic status, as many lower-income background students have less experience before university with concepts such as coding and computer aided design (Nite et al., 2020; O'Connell and McKinnon, 2021). Women also engage less with coding prior to university (Corneliussen and Prøitz, 2016). Conversely, women have greater confidence in their communication abilities than do men (Eagly and Steffen, 1984; Martinez and Christnacht, 2021).

Self-concept fit is highly vulnerable to stereotypes, where cues from culture and the environment suggest that a successful engineer fits particular stereotypes (Verdin et al., 2018). Stereotype threat leads to pressure to exceed expectations (McGee et al., 2017; Wierzchowski, 2019), likely because when students feel a threat to their self-concept fit because their social identity does not match the dominant culture, they strive to prove their fit in other ways, such as through academic performance. When students perceive that majority group members will have limited interactions with students from their own minoritized identity group and that there are stereotypes against that group, the students reported responding with "model" behavior (McGee et al., 2017; Tang, 1997) to optimize social and self-concept fit. In the literature, this is referred to as social tuning, where people adjust their behavior to presumed expectations, including conforming to stereotypes (Kawakami et al., 2012; Sinclair et al., 2009). Outside team contexts, women of color in engineering spoke of coping strategies to improve social fit, including adapting their behavior to the dominant culture (code switching), letting comments pass, affirming their culture, and giving back (Ong et al., 2020).

2.3 Fit experiences in teams depend on identity and social determinants

Social identity affects feelings of fit during teamwork experiences. Students who are women, racialized (meaning someone affected by racism or race-based discrimination) and/or 2SLGBTQIA+ (2-spirit, lesbian, gay, bisexual, trans*, queer and/or questioning, intersex, asexual or "+": people who identify as part of sexual and gender diverse communities, who use additional terminologies) have reported different teamwork experiences than their majority group colleagues. Teamwork experiences can either cement fit, engineering identity and self-efficacy or can exacerbate a sense of exclusion. For example, Hispanic students developed higher self-efficacy through group problem-based learning experiences (Chen et al., 2015) and transdisciplinary group work led to better learning outcomes for under-represented students in engineering (Greenhalgh-Spencer et al., 2017). Similarly, Beigpourian and Ohland (2019) concluded that women and racially under-represented students will benefit from instructors adapting to new pedagogical styles and better designing collaborative scenarios. For those who share communal values (often women and some cultures) teamwork can contribute to goal fit (Ong et al., 2020; Cech, 2014).

In many engineering spaces, women experience that sense of being the "only" (Fabert et al., 2011), which would threaten self-concept and social fit. This feeling of otherness affects confidence and is exacerbated by the paucity of diverse role models in engineering (Cech, 2014; Cech and Rothwell, 2018; Litzler et al., 2014). Women's contributions are not acknowledged, and their attempts to contribute are ignored (Ingram and Parker, 2002; Paretti and Smith, 2013; Tonso,

2006). Engineering students evaluated feminine speech patterns (e.g., conceding weakness) more harshly (Wolfe and Powell, 2009). Tonso (2006) documented many negative experiences of women in teams and concludes, troublingly, that teamwork is not superior to lecture-based learning for women.

Black, Latinx, and Native American/Native Alaskan students and Asian-American/Pacific Islander students were also less likely to have their ideas used in the design process (Henderson, 2021); that experience of disrespect would affect social fit. African Americans also under-perform in otherwise all White groups (Thompson and Sekaquaptewa, 2002). African American men minimized the effect of race specifically within team interactions, though did identify racism and chilly climate in their overall university experience (Cross and Paretti, 2015).

Gay men in engineering often struggle to reconcile their social identity with an engineering identity (Hughes, 2017), suggesting issues with self-concept fit. In a detailed survey of engineering students, Cech and Rothwell (2018) found that 2SLGBTQIA+ students experienced more marginalization (social fit) and negative health outcomes. Pertinently, these students were also more likely to have their engineering work devalued by peers. Women, Black and Hispanic students were more likely to report a domineering teammate and feel they had been excluded from learning opportunities on teams, with intersectionality magnifying effects (Wolfe et al., 2016).

Social fit is a recurring theme in engineering: women and 2SLGBTQIA+ students reported similar measures of personal and professional disrespect, social exclusion and stress and avoided certain teams or group projects (Cech, 2015). Asian and Black students reported feeling nervous and stressed, and to a lesser degree, shared experiences of social exclusion. 2SLGBTQIA+ students more than all other students reported feeling exhausted by keeping personal and professional lives separate in an effort to maintain social fit (Cech and Rothwell, 2018). Jennings et al. (2020) recently reviewed experiences of 2SLGBTQIA+ students in engineering and noted that there remain many gaps in the field, including understanding intersectionality.

Safety and disclosure, essential elements of social fit, are important for effective teamwork. Personal safety in group settings contributes to the effectiveness of the group (Shah-Fairbank et al., 2021). Google famously showed that psychological safety was the key predictor of team effectiveness (Google, 2017 Re:work) but for those outside the majority group, feelings of personal safety and comfort often do not occur in group settings (Ross et al., 2017; Verdín et al., 2018). For example, students are not always comfortable disclosing personal trauma within an engineering team, which can lead to further exclusion (Langus et al., 2019). This was particularly relevant for 2SLGBTQIA+ students in engineering, who were less open about their sexuality with colleagues than in other fields (Yoder and Mattheis, 2016), faced extra academic and emotional labor to fit into heteronormative engineering cultures and experienced added isolation (Cech and Waidzunas, 2011).

An excellent review of experiences of women of color in engineering (Ong et al., 2020) shared several themes that are relevant to teamwork experiences: self-efficacy, social pain, navigation and support, which largely relate to self-concept fit and social fit. Self-efficacy was often an increasing barrier for women of color in engineering and included perceptions of low academic ability (e.g., Marra et al., 2013). Relationships between gender and select other identities have also been explored outside of the teamwork scenario (e.g., Beigpourian and Ohland, 2019; Ro and Loya, 2015; True-Funk et al., 2021), however much remains to be learned about evaluating and improving the teamwork experience and guiding change with effective interventions.

It seems intuitive that social determinants will affect students' teamwork experiences, which might explain the paucity of literature specifically looking at teamwork and time or money constraints. When social determinants affect relationships with teammates, for example, because non-academic time commitments make it difficult to meet, this will affect social fit. One study looked at staff and faculty perspectives on the relationship between student employment and retention and time to graduate. Faculty members perceived that part time jobs interfered with engineering students' abilities to succeed in their academics, primarily because of the high workload. Notably, faculty members voiced that such time commitments showed a lack of commitment to engineering, despite recognizing that students had financial or caregiving constraints (Tyson, 2012). This conflict between expectations from professors and the reality of other time commitments could interfere with students' self-concept fit in engineering. A recent study of out-of-class participation for engineering students found that a job was the most common non-academic activity, but sports, clubs and design teams (among many others) also occupied many students (Simmons et al., 2018). These were often perceived positively by students, but pertinently, the biggest barrier to engagement was lack of time, and for those who participated, they noted that their free time was reduced and their schedule was less flexible, implying that scheduling team meetings and contributing equally to projects could become a barrier.

Socioeconomic status, often linked with race (Battle and Lewis, 2008), can also affect how actively students engage with a group (Mahsud et al., 2021; Schell and Hughes, 2017). Recent reviews of intersectional identities and financial needs of engineering students found the need for more research (Espino and Rodriguez, 2019; Espino et al., 2022). Financial constraints are likely to add time pressure to students who have to work part-time; furthermore, creating physical models is often a costly burden on teams. If other team members do not share these constraints, it could interfere with self-concept fit (Espino et al., 2024), while conflicts arising due to availability could jeopardize social fit.

2.4 Outcomes of inequitable team experiences

Fit is a powerful driver of choices. Therefore, if some students' sense of fit is threatened during teamwork experiences that will nudge future choices as students try to find opportunities that will maximize their sense of fit. The stakes are high for effective teamwork: the consequences of implementing ineffective teamwork practices are inequitable and often detrimental group experiences (Rosser, 2010). These experiences can carry forward beyond a student's education through to careers by impacting confidence in skills, feelings of belonging and choice of roles (Griffith and Dasgupta, 2018; Litzler and Young, 2012; Hanus and Russell, 2007; Silbey, 2016; Seron et al., 2016; Rittmayer and

Beier, 2008). Engineering role identity, a form of self-concept fit, (Godwin, 2016) shapes future-time perspectives and the intent to continue in engineering (Godwin and Kirn, 2020; Pierrakos et al., 2009). Similarly, women's professional role confidence predicts their persistence in engineering (Cech and Rothwell, 2018; Luo et al., 2021). Eccles and Wigfield (2002) emphasizes that previous achievement-related experiences lead to future choices. The feelings of discomfort that accompany the fear of failure and pressure to excel for marginalized groups feed the feelings of not belonging that connect with group dynamics, learning outcomes and ultimately career paths (Henry et al., 2021; Nunes et al., 2022). We argue that the motivation to find fit drives many of these choices.

3 Methods

Here, we describe our qualitative approach, which is grounded in the positionality of the researchers. We describe the setting, participants, and details of how the data were collected and analyzed and finally the limitations of our approach.

3.1 Methodological approach

We chose a qualitative approach because it leaves space for nuance and new discoveries. To interpret our data, we used a deductive method of reflexive thematic analysis, meaning that the coding lens of analysis and theme generation came from existing teamwork literature. Reflexive thematic analysis is a flexible approach; the lack of stringency and encouragement for iterations and continual development is widely documented (Braun and Clarke, 2006, 2012, 2019, 2021). Reflexive thematic analysis is suitable when research addresses an individual's experience (Braun and Clarke, 2019), as is the case with the testimonies of interview and focus group participants collected for this study. Reflexive thematic analysis differs from other methods, such as "codebook," "coder reliability," and "thematic coding" approaches, with the key difference being the use of codes to build and develop themes from data (reflexive methods) compared to codes being categorized and used as evidence for pre-determined themes (codebook approach). All research was approved by the local Research Ethics Board.

3.2 Positionality statements

The trustworthiness and validity of qualitative analysis is heavily impacted by the researchers involved in the generation of questions, thematic analysis, evaluation of data, and dissemination of knowledge (Secules et al., 2021). Consistent with feminist research methodology, our identities are embedded in the collection and interpretation of the data. KSJ is an Associate Professor of Chemical Engineering who has lived experiences of working and researching in male-dominated spaces. She is an able-bodied, cisgender, heterosexual woman, White settler born and currently living in Canada. EB identifies as an able-bodied, cisgender, heterosexual, North African, Arab woman and immigrant to Canada. Her research interests stem from personal experiences as a woman of color living in Canada and abroad whose scholarly work examines systemic injustices toward subaltern groups and women. At the time of the data collection, MM was completing a master's degree in Gender Studies and Feminist Research, and identifies as a cisgender queer woman, White settler born and currently living in Canada. SE is an undergraduate Chemical engineering student who identifies as an able-bodied, cisgender, heterosexual woman, White settler born and currently living in Canada.

3.3 Setting

This research was conducted at a medium-sized, public, research-intensive urban Canadian university, where students were admitted directly into engineering but did not declare discipline choice until second year. Though demographic data are not available, the engineering student body is diverse and (at the time) was approximately 25% women. In Canada, women undergraduate students persist in engineering programs, in fact, taking less time to graduate than men (Wall, 2019), though retention in engineering careers is lower among women (Frank, 2019). This is consistent with American data that shows social identity has little effect on persistence in engineering programs (Lord et al., 2009).

3.4 Participants

We offered four identity-themed focus groups approximately an hour long that included women, those facing non-academic time commitments, racialized students (meaning someone affected by racism or race-based discrimination), and 2SLGBTQIA+ students, believing that these would provide safe spaces for sharing where deeper explorations could happen as a result of the discussions. Students were also offered the choice to participate in a general group not specific to any identity or in private interviews if the timing of the preferred focus group did not work. This gave a total number of focus groups as five and interviews as four. Given the challenges of intersectionality, we encouraged students to self-select which group they preferred. We recruited upper year engineering students to participate in "a study on how identity affects teamwork and collaboration." We used in-person recruiting in a location central to engineering students combined with word of mouth and social media postings and all interested students were included in the research.

All focus group participants were undergraduate engineering students at a medium-sized, public, urban, multi-cultural, research-intensive Canadian post-secondary institution. The interviews and focus groups were conducted in person shortly before pandemic restrictions were imposed. Table 1 shows the intersecting demographics of the participants. We did not ask participants to choose their own pseudonyms and we felt it was important to link identity to quotes. Recognizing the meaningfulness of naming (Allen and Wiles, 2016), we chose not to use potentially stereotypical pseudonyms in reporting results.

TABLE 1 Participant details.

Participant	Women	Racialized*	2SLGBTQIA+	Time commitments
1[e]	X	X		X
2[b]	X	X		
3[b]	X	X		
4[a]	X	X		
5[a]	X	X		
6[a]	X	X		
7[a]	X	X		
8[c]	X		X	
9[c]	X		X	
10[c]	X		X	
11[d]	X			X
12[d]	X			X
13[f]	X			X
14[f]	X			
15[f]	X			
16[a]	X			
17[c]		X	X	X
18[d]		X		X
19[b]		X		
20[e]		X		
21[e]		X		
22[e]			X	

*The majority of the racialized students were South Asian and also included East Asian and Black participants. The organization in the Table by identity is for clarity. The participant's focus group is given by the superscript: a = women; b = racialized; c = 2SLGBTQIA+; d = time constraints; e = interviews; f = general.

3.5 Data collection

All focus groups and interview participants were asked the same open-ended questions. We examined questions of team structure but did not explicitly ask about fit:

1 Tell me about your experiences with teamwork in your first year of engineering. What did you like or not like?
2 Your identity encompasses many aspects. For example: your gender, race, nationality, sexuality and ability are components of your identity, but many aspects of your lived experience, such as whether you have a part-time job, live on campus or are comfortable speaking English might also affect your experiences. Have you observed (for yourself or others) that identity plays a role in teamwork?
a This could include the roles different people take on teams (e.g., calculations, mock-ups, writing/proofreading, organization, idea generation)
b When you or others choose groups, is identity a factor?
c Did your group composition affect how "easy" it was to work together? Were there benefits to diversity?
3 Did you find that your learning was enhanced or limited by working in teams?
a e.g., does everyone do what they are already good at and avoid learning new things?
b Or did you learn from and/or teach peers?
4 How could we ensure that all students have an equal learning experience in project / team-based learning and are assessed appropriately?

3.6 Data analysis

Audio recording of the focus groups used a portable recording device. The recordings were uploaded to an in-house secure system (MacVideo) that provided an initial automatic transcription that was then corrected manually by one of the researchers. We used Text Analysis Mark-up System (TAMS) Analyzer to assign codes to passages of text as per the reflexive analysis methodology. This is an open-source MAC OS software created by Matthew Weinstein and distributed under the General Public License (GPL) license. Coding and identification of themes occurred iteratively while revisiting the literature, using the six-phase framework originally outlined by Braun and Clarke (2006) in conjunction with their subsequent publications from 2006 to 2021 which provide greater detail on analyzing focus group and interview data. Stages of analysis are described below

sequentially; nevertheless, reflexive thematic analysis is an iterative process: instances of cross-over and repetition of steps, as required for in-depth analysis, are noted accordingly.

3.6.1 Phase 1: familiarization with data

An investigator who did not participate in the interview process corrected automated transcriptions captured by an internal and secure platform by listening to the audio recordings. The recordings were then exported into transcript files with names removed in preparation for analysis.

3.6.2 Phase 2: generating initial codes

Once all documents were inputted into the TAMS Analyzer as text files, each document was coded individually with initial codes by one researcher. These codes were created by assigning key words such as expectations, gender and understanding that suggested themselves after familiarization with the data. All documents were coded and revised as new codes and concepts were identified to create a complete set of relevant data to be sorted and analyzed.

3.6.3 Phase 3 and 4: generation of themes and review

The codes found in the previous sections enabled two of the researchers in collaboration to explore patterns, repetitions, and areas of interest. Because the focus group questions primarily addressed structural issues of teamwork (e.g., roles, group selection, and resource constraints), we initially focused there. It was only through reflexive analysis that we first identified the centrality of comfort, later recognizing it as fit. We used a deductive approach to reflexive thematic analysis, meaning that the themes were based on concepts and findings from the literature. As patterns and themes were generated, this was done in an iterative manor by revisiting the transcripts and having new codes assigned. The phases cyclically repeated as more codes were added and connections began to be made. We initially used a concept map to identify connections between prevalent codes and identified themes. These themes were then reviewed, revisited, and redefined to ensure that they pertained to the focus and rationale of this data.

3.6.4 Phase 5: defining and naming themes

We further developed the themes alongside the corresponding literature and the theoretical framework. In this process, additional codes and revisiting of stages 2–4 were implemented where codes were then used as building blocks to develop the message and story of the data. The additional codes were used to create subsets of the larger codes allowing for more specific area of the passages to be explored. This is where the clear, informative naming and defining of themes occurred. We also revisited the data to ensure we were representing the range of engineering student identities. For this data set, three initial themes were psychological fit, learning outcomes and career trajectory.

We then decided the theoretical framework of fit was inextricably integrated in the data, so more useful and intuitive themes were: teamwork choices that were driven by fit; fit experiences in teams affected by identity; and future choices guided by fit experiences in teams.

3.6.5 Phase 6: generating report and writing findings

By combining key quotations and passages from the coded transcript documents, the results were organized into the three sections focusing on the aforementioned themes along with an evaluation of interventions in literature, in practice, and suggested by the student data.

3.7 Limitations of research

Although the focus groups were created to target a variety of marginalized groups and structured to engage with a wide range of experiences, there are key groups that are not fully represented in the interview and focus group population or have limited representation. Some of these key groups are the majority group in engineering, which is straight White men. Other groups underrepresented in this study are students who were Indigenous, trans*, non-binary, openly experienced mental illness or physical disabilities, and who discussed family obligations. We did this work prior to the pandemic when experiences of virtual interactions in teams were minimal. Although most teamwork has returned to in-person, we can only speculate that virtual experiences might affect fit differently, for example by decreasing social interactions thus making social identity less salient, and providing more flexibility for students with non-academic time commitments.

Participants who had experienced challenges with teamwork might have been more motivated to participate in the research than those who enjoyed all aspects of teamwork, or who did not consider their identity salient, which could color results. Moreover, the capacity of understanding concepts related to systemic racism and discrimination toward marginalized groups requires a deep understanding of (among others) critical race, feminist and queer theories. Our findings suggest that most engineering students are less articulate and aware in describing their own experiences of inequities and systemic injustice, perhaps because of their lack of exposure to the discourses and theoretical terminology related to social issues. Finally, although we believe that the work can be extended to other STEM spaces, including at the high school level, we acknowledge that engineering undergraduate experiences might differ in particular ways due to the differences in workload, expectations and population.

4 Results

Through quotations, we will emphasize how social, self-concept and goal fit mediate teamwork experiences that affect more than just women. When we use teamwork as a pedagogical tool, we provide specific structures and supports that affect and are affected by feelings of fit in ways that are influenced by social identity. Our first major theme is how teamwork choices (e.g., group selection, role adoption, and pressure to excel) are affected by fit. Our second major theme concerns how fit experiences in teams are affected by identity. Finally, our third theme focuses on the consequences of inequitable teamwork on future choices including career trajectory. The major themes and codes we identified are described in detail in Table 2.

TABLE 2 Theme/code definitions.

Concepts	Definitions	Fit
	Theme: Teamwork choices are driven by fit	
Group selection	The process of selecting groups by students without constraints.	Social, self-concept
Friendship/Allyship and safety	Interpersonal relationships within the team with those both inside and outside your identity group. Allyship (actions of support by a teammate) can be distinct from friendship. We include physical safety (e.g., team meeting locations and times) and psychological safety, the feeling and belief that interpersonal risk taking within the team (e.g., speaking up, asking questions or giving ideas) is safe.	Social, self-concept
Group roles	The position, tasks, and responsibility a person takes on in the team setting, both technical and non-technical.	Social, self-concept, goal
Pressure of representation	The pressure to excel to represent your identity in the best possible light as a reaction to perceived stereotypes.	Self-concept, social, goal
	Theme: Fit experiences in teams depend on social determinants and identity	
Social determinants	Social aspects that cause time constraints due to extracurricular, familial and part-time work obligations as well as constraints due to finances.	Social, self-concept
Identity fit	The student's sense of identification with the engineering profession. This encompasses the concept of self-efficacy: feelings of being sure of themselves and their abilities to perform technical skills in team settings. It also reflects the increased confidence gained through mastery of tasks.	Self-concept
	Theme: Consequences of inequitable teamwork on future choices	
Future choices	Plans and fears for future career choices. How teamwork experiences have changed perspectives on engineering careers and discipline choices.	Goal, Self-concept, social

4.1 Theme 1: teamwork choices are driven by fit

This section will show how social fit, self-concept fit and goal fit guide students' choices about teamwork. Who do they choose as teammates? Allies provide social and self-concept fit. What roles do they choose within their group, and how are those driven by self-concept, goal and social fit? They also spoke about the pressures they felt to perform at high levels to counter perceived stereotypes, particularly when they felt under-represented (social fit; ensuring respect from peers and self-concept fit, affirming their status as an engineer).

4.1.1 Group selection is driven by the need for fit through similar identities and allies

When students had the opportunity to select their own groups, they reported a range of experiences. Many students sought social fit by selecting friends or others from their identity groups to be in their teams. In contrast, one Black student did explain that he intentionally chose people who were outside his friend/identity group because he felt it gave a richer experience, perhaps satisfying his self-concept as an inclusive engineer, but this was the exception, not the rule. He stated that,

> The gender or race or sexuality in a group, it brings different perspectives. People have different life experiences, that especially if you are doing projects that revolve around human-centered design, it's a big component.

In contrast, a South Asian man sought social fit: "As well as being culturally diverse is good, having someone from where you are from makes you feel more comfortable."

Our results show that many students selected friends or those they had success working with before. As a result, students reported more positive teamwork experiences in upper-year courses and teams because they could use their positive and negative past experiences to select a team that satisfied their need for social fit and that aligned with their goals. Students also agreed that having at least one other person in their own identity group made their team feel safer and helped them to share their ideas. Shared culture and gender seemed particularly salient in supporting self-concept fit. One racialized man said,

> If you have someone that's in your group like from where you are from, you can kind of divert from other people's opinions because you have someone who might understand you better, back you up that could give you more confidence…you have a more sense of closeness with people that have similarities with you.

One woman in our focus group reported the following: "I try and make sure that there's at least one other girl almost always, and I just find it, it gives me more confidence to speak my mind in front of a group of guys." Another woman highlighted self-concept fit, "the people that I generally always work with are all girls. I do not know if that's just because we share similar interests or stuff or if that's just like a natural way."

Where sharing an identity was not possible, students sought possible allies and social fit within other marginalized groups, as with this gay man, fearing homophobia, who said, "I usually gravitate toward females because I feel like … there's some sort of like less judgment."

Students recognized that ensuring their team had an ally was important, because it can mitigate feelings of exclusion (social fit barriers). One woman student said: "I should not have had to go through him to get my group to listen to what I was saying. And so,

like it's great. Like an ally who knows, right." Students also appreciated that allies could remove the burden from them: "It's like the onus should not be on the person being marginalized to fix the system marginalizing them." Students worked hard to create safe communities for themselves, like this Black man, who highlighted how his allies improved his social fit:

> Now I have this really strong group of people who like respect my identity, and we support each other's identities and our support for each other and all the different ways that we can be. And I had to build that up. I had to make a support system and a team of people who make me feel comfortable.

He continued, noting how trust and openness contributed to team dynamics: "The best group experiences I've had, have involved having either like a friend or somebody who I would consider like an ally. In a lot of ways where they are alike, I guess, more not understanding, but more privy to certain experiences."

The impetus toward homogeneity speaks to the push for social and self-concept fit. Although the students reported feeling comfortable in homogeneous groups, they missed out on the opportunities to learn to effectively collaborate with a diversity of students.

4.1.2 Fit determines group roles

Good grades affirm a student's sense fit based on their goals and their self-concept fit within the environment, so often drive learning; in turn, assessment that includes only project outcomes drives choices within teams. Similarly, if a student has a stereotype-driven self-concept (e.g., "I am a coder" or "I am good at writing"), they will make choices which reinforce that self-concept. Finally, students seek social fit, which often means avoiding conflict (which itself could be driven by communal goals and self-concept). The drive to find fit nudges student choices about which technical and non-technical roles they assume within a team. A gay woman confirmed, "Doing what you are good at is the best, especially because you are being graded on it or, you know, someone's expecting your product and they want the best products so, do what you do best." A racialized man reflected on the consequences of ineffective teamwork resulting from lack of fit: "As much as teamwork is collaborative, you do not grow as strong individually as you would have if it's good projects by yourself."

Some students believe they are better pre-qualified to do particular tasks more efficiently (self-concept fit). One student noted that division of duties: "that sense, like students who were previously educated in this stuff would just kind of like take on that role." This effect was insidious, with students often accepting it without questioning the consequences, with a Muslim woman commenting, "Some people had strengths and they would like lead toward those and work on those which I think everyone else encouraged." Schmader's SAFE model (Schmader and Sedikides, 2018) suggests that self-concept fit is driven by seeking familiar situations—and if students do not have coding experience, they might avoid it, because they do not identify as "coders."

This does not just happen to women—a Black man reflected:

> Maybe it is not because I'm like a racialized student. Maybe it's because I'm low income. But they have, they have already learned this coding thing because they did it as a high school extracurricular or they took a class or whatever it is that they did prior to university … And oftentimes my job is relegated to, you just, you are going to do the writeup or you are going to do the documentation or okay. I'll take care of this. You just do this part. I mean, sometimes it's nice to you know, not have to do the heavy lifting. But it's like taking away from my learning experience because then I do not get a chance to do that thing.

Within a group, women often took on administrative roles such as proofreading, notetaking and formatting: "I noticed that a lot of people that wrote the reports are female." This was a common experience where in some cases the women were only given these less technical roles and missed concepts and in others, they did this work on top of other work giving them an unequal share of the project: "It would be an even split in technical roles and the female students would also do the reporting on top." This indicates that men might be missing out on the opportunity to develop their communication skills.

Opportunities to engage with the material can also be affected by this confidence gap: a women student noted "some extreme cases where one person practically did the entire project idea and the other two did not know what was going on." This identity-based difference in self-concept can be magnified as the opportunity to practice unfamiliar skills evaporates.

In another case, a gay man did not fully engage in an attempt to seek social fit:

> I would find myself in an all-male group. And a lot of the times in those situations because I guess I'm … restricting and hiding myself, I guess from being social and things like that kind of leads to not acting as active a part in the group that I would like to, in a way. So for example, I would just basically hear everyone out and I would say, and I would just sit back and just be okay sure like, I do not have a problem with that. You can do that. I do not mind I'll just do whatever you guys want to do just try to like not rock the boat.

4.1.3 Representation and the pressure to excel, driven by a desire for fit

Many students from non-traditional, visibly different identities reported that they felt extra pressure to perform at the highest level for fear others would judge their whole group negatively, a reaction to trying to get respect from peers (social fit) and a recognition that they do not match the stereotype of an engineer (self-concept fit). For example, a Black man discussed the how the desire for social fit caused him to change behavior (social tuning):

> When I step into certain settings, I have to make sure I greet everybody and be very polite and cordial and like, you know, try and make everyone smile, be presentable in the way that you do not have to be if you kind of already feel a right and obligation to the space and you already feel well-represented.

A gay woman said she refrained from asking for help, again seeking social fit, because, "When you are a woman in a group of men,

it can be very difficult to admit you do not know something because of fear of being ridiculed or being looked down upon."

A Black man reflected on majority group experiences: "When you are like one of 700, like guys … You do not care. You do not have to … You do not need to like, make a great example of yourself."

That pressure for social fit, however, sometimes discourages teamwork at all, as the student continued:

> One thing that I've actually found myself doing is when profs offer the opportunity to work in pairs or work alone, I work alone out of fear that if I work in a pair and I'm doing something wrong or I come across as dumb, that looks bad. So, I'd rather just do the work alone … It's so stress inducing and like kind of anxiety inducing to be the delegate for the entire community.

High standards could also be a consequence of identifying as a top performer (self-concept fit) or having goals to achieve good grades (goal fit), which could be gendered or cultural (Areepattamannil and Lee, 2014). A White woman shared the difficulties in workload that come along with having higher standards:

> And they take that on personally because they have those high standards. They do not really mind because they recognize that their group mates do not have those same high standards. And that's the only way to get to those high standards. But the consequence is still that the girls are putting in more time than the boys and they are spending more time proofreading and making it a pretty final document.

On a more positive note, goal fit regarding community and fairness induced a Muslim woman to avoid procrastination in group projects:

> In groups I find I do not want to let my group members down, so I'll be sure to get things done on time … I'll even prioritize that over say an individual thing … It's almost okay for me to let myself down. But I do not want to be the cause of someone else like not doing well.

4.2 Theme 2: fit experiences in teams depend on social determinants and identity

If students' non-academic lives (social determinants) or social identity was not the same as their peers, their experiences on teams often interfered with their sense of fit within engineering. Students spoke about the stereotypical engineer and whether they identified with that image (self-concept fit).

4.2.1 Social determinants interfered with fit

Many students across identities spoke about the difficulty in participating fully in team meetings scheduled outside of class due to outside time commitments like extracurriculars, part time jobs or commuting. Others spoke about financial limitations in buying materials for group projects.

When a student's non-academic time commitments interfere, conflict and threats to social fit could arise, as with this student who said of their team, "They will not account for the fact that on top of the *x* hours of class we are all spending, I also have ten more hours of work that I'll be doing this week." Another shared, "They'll schedule a group meeting at 9:00 PM and think there's nothing of it." These time constraints can be due to work, commuting, familial commitments or feelings of physical safety leaving a meeting at night.

Worrying about expenses was another factor with the same negative outcome. A Black man described a final year design project experience:

> We want to create something cool or whatever. But there's financial limitations on myself, based on my economic background that do not exist for other members of the group. And so, when they are pitching ideas or suggesting buying things or just buy whichever part works on that. Well, I do not want to spend $75. Like I want to keep the cost as low as I can because I've got rent to pay and groceries to buy, things that other students do not necessarily think about when they come from different backgrounds.

These pressures on social fit can interfere with a student feeling like an engineer (self-concept fit) and fully engaging with team projects.

4.2.2 Identity affected fit

Many students spoke about feeling isolated due to their social identity and how they did not feel that they fit into a stereotypical engineering space. Race, religion and sexuality were key factors of identity that interfered with self-concept fit in engineering spaces.

Inclusive teamwork also provides important opportunities to build friendships and networks. This Muslim woman reported increased belonging and motivation, due to social fit and goal fit for communal work:

> I love working in groups to be honest. I find it a lot more fun. I think when I do a project on my own, it can be a little tedious and kind of lonely and it just feels like you are doing just work versus when I'm in a team…it feels like sometimes it's a social event rather than just like a school event.

However, the tension between professional and social dynamics can interfere with safety and social fit, as one woman noted: "I also have had a group mate who hit on me. And then when I did not say anything, got upset about it. And now they want to work together again. And I'm like, oh man, you made me feel really uncomfortable."

A racialized man reflected on the challenges of self-concept fit: "I've passed every test, I've gone into the program, I've gotten through my degree to this point, as well as everyone else in the room. But I do not feel like I'm everybody else in the room because of historical trends of Black engineers."

Issues with social fit can be exacerbated by religion. A Muslim woman shared:

> I do not drink and I do not like to be in an environment where people are drinking. … It's mostly just like how you form

> relationships with other people and how like we'd say, say be sitting with a group of people and people are like, oh yeah, last night we did this, this and this and then you are like oh that's cool but like you cannot really contribute to the conversation.

Sexual orientation is also a minefield in engineering. A gay man addressed how self-concept fit interfered with team engagement:

> The feeling of not wanting to share or always, I guess being afraid of what someone will think of you obviously greatly hinders your ability to interact in a group because I feel like you cannot be at your most productive or your most creative or you cannot have the highest level of participation that you want to if you aren't truly being yourself … So you automatically have your shield up and your guard up before you even begin to start working on a group project.

A key aspect of social fit with teammates is respect. A gay woman explained complicated links between sexual attraction and respect that can lead to invisibility:

> Men oftentimes respect women more when they are attracted to them and give them more of their attention. But it's not necessarily the type of respect that you actually want to get because it's like this sort of a temporary superficial respect. And then as a woman who is gender nonconforming and also gay, I often do not have that privilege of and then it sort of can feel like you are invisible to some men. … So they may perceive you as more intelligent, but at the same time, you are not feminine, so you are not attractive. They do not actually really want to interact with you that much. So it's just like a whole sort of whirlpool of different influences.

A number of students highlighted the stereotypical engineer. The archetypal engineering student was always presented as something "other" than the students represented, suggesting that they faced struggles identifying as an engineer. This speaks to issues with self-concept fit, which could drive students away from the field. A Black man laughingly said:

> We love the term Eng boy for this very typical, masculine— and to be fair, we also say there's also a lot of Eng girls. And Eng girls often have a similar energy as the Eng boys … We also say bro-grammers. … It's just like they have … masculinity that like they exude where they are like, oh, I'm so great, I'm so good. Look at me and all my things and all my I'm such a good engineer.

A gay woman reflected on the social fit dangers of not conforming to the stereotype:

> They look kind of uniform. And so, when they see someone that stands out from that uniform, then you immediately become either the target of them ignoring you and treating you silently, or the target of abuse, whether it's a micro-aggression or blatant disrespect.

4.3 Theme 3: consequences of inequitable teamwork on future choices

Our focus groups showed that students were experiencing varying levels of psychological fit and learning based on social identity. We believe that these experiences are nudging students away from specific career trajectories.

Students in our focus groups did draw direct links between their social fit in teams and anticipated industry experiences. A Black man said:

> I'm in groups and somebody will say something like that just makes me feel so othered and alienated, even though you are my friend … So I am selective … I'm terrified for in industry like graduating, looking into work next year like I do not get to have this control over my settings. And so if I, if I'm entering a workspace, that's, you know, whatever it is, it has a culture that's been determined.

Similarly, a gay woman spoke about self-concept fit in anticipating that industry work environments will reflect the toxicity she has experienced in team settings:

> It's something I've considered when applying to jobs. Like I've looked at the pictures of the team at a company. And if it's majority men and that is like it ranks lower on my list of places that I want to work at. And that's not to say that that will, they will automatically be bad men. The type will do bad things, but it's already alienating being in that environment.

Our work here showed that fit drove teamwork behavior; it stands to reason that students will make future career choices that maximize their authenticity, presumably by seeking technical areas in which they have developed mastery and confidence (goal and self-concept fit) and by seeking psychologically safe spaces (self-concept and social fit). Saliently, a woman connected disrespect in teamwork environments (social fit) to her future career: "It's just like going to be my engineering life. Am I going to go through my engineering work in the civil field is look, being looked down upon because I'm a girl?"

Social exclusion will influence students' future choices, as will the ability to be in comfortable situations in which they can behave in authentic ways. In focus groups, some students discussed self-concept fit: "I do not feel like I'm everybody else in the room." Will these students choose to remain in spaces where they do not feel represented? In contrast, collaborative environments might satisfy goal fit.

After spending an hour discussing teamwork, one woman shared, "Sometimes I do not like saying that I am in like engineering … I do not feel like I necessarily want to do an engineering career." Unfortunately, this woman's quote did not reflect a unique experience, and was vocalized by many others in our interviews and focus groups. The consequences of negative teamwork experiences can have long-lasting outcomes that extend far beyond a student's undergraduate experience, rippling into the trajectory of their careers. We believe that teamwork experiences in undergraduate engineering education have the potential to inspire and motivate students—and to nudge students away from disciplines and careers that are not traditionally associated with their identities, driven away by a desire for authenticity and fit.

5 Discussion

5.1 Fit was central in teamwork experiences

In Schmader's SAFE model, authenticity affected by three types of fit drives behavior (Schmader and Sedikides, 2018). Ideally, teamwork will achieve students' goals (goal fit), they will feel accepted socially (social fit) and they will see their own self-image reflected in their image of an engineer (self-concept fit).

For engineering students in our focus groups, achieving goal fit in teamwork did not seem to present any barriers, with some students appreciating the motivation and purpose associated with team projects, though highly valuing grades did lead to students doing extra work. However, social fit and self-concept fit were both threatened during team experiences. All students sought social fit while selecting groups, often explicitly selecting allies or others with shared identities. The roles students took within teams were driven by conflict avoidance (goal and social fit), desire for high grades (goal fit), and confidence in previously acquired skills (self-concept fit), but rarely because of a desire to grow proficiency in specific skills (goal fit), though some students reported frustration at the lost opportunity to learn. Many students felt that they had to work harder to positively represent their identity.

Social determinants that constrained the time and money students could dedicate to teamwork threatened social fit within groups. Stereotypes and the engineering environment affected self-concept fit, which was central in feeling like an engineer and in experiencing the pressure of representation. When students looked to their future in industry, they were concerned that they would not be able to build supportive structures in spaces that were not diverse (social fit and self-concept fit).

Our work suggests that engineering teamwork satisfied under-represented students' goals regardless of identity, but that students' gender, sexuality and race negatively affected their self-concept and social fit. These threats to authenticity in engineering teamwork led students to question their ultimate career trajectory.

5.2 Influence of identity on fit

For the first time, we have brought together teamwork choices, experiences and outcomes with the framework of fit to environment, looking at implications for a wide range of social identities. In Table 3, we have summarized and reorganized our observations based on identity.

Our findings for women reflect what has been reported in the literature, though with a new lens. Pressures for social fit including a need for female friendship, experiences of sexism, tensions within groups between professional and romantic relationships with teammates and social conflict avoidance or submissiveness often led to homogeneous group selections, the need to change behavior and feeling disrespected. When self-concepts were affected by pre-existing skills gaps in communications or coding and self-concept fit was challenged by under-representation and stereotypes, women were driven toward particular roles, felt a pressure to excel and experienced imposter syndrome. When a woman's goal fit was determined by a desire for collaboration, a drive to do good for others and a performance focus, she was more likely to enjoy team experiences with relevant projects but also had the drive toward certain roles reinforced.

When we examine social fit pressures for racialized students, a desire for shared culture and experiences of under-representation and racism again led to homogeneous group selection and social tuning and model behavior. When self-concept fit was threatened by low representation and anticipated racism, students felt a pressure to excel but tried to avoid teamwork altogether. Goal fit is very culturally dependent and diverse, with some cultures experiencing similar motivations from teamwork as women. Some experiences of racialized folks on teams and some broader cultural pressures have been previously reported in the literature, but the specific effects on teamwork choices we report are a novel contribution.

For 2SLGBTQIA+ students, homophobia and fear of homophobia drove many of the teamwork choices and experiences driven by social and self-concept fit. As has been previously reported outside teamwork contexts, queer students often avoided disclosure and experienced high levels of stress. Where possible, queer students tried to include allies when selecting teams. In this diverse community, our results did not highlight shared goals or values that would affect teamwork.

Social determinants including time commitments and financial challenges limited social fit, making it more difficult for students to build social connections, and through self-concept fit and goal fit, interfered with engineering identity and the ability to build social connections. These are new observations in a teamwork context.

By using this framework of fit to environment to describe the choices, experiences and outcomes for a diversity of students, we gain the tools to understand possible intersectional experiences better. For example, a South Asian woman might have culturally learned submissiveness, have protective parents, have a long commute, avoid drinking, have strong coding experience and have low representation in engineering. Thus, her social fit would be threatened because it would be difficult to find teammates with shared identities, she might experience sexist and racist disrespect from teammates, she would defer to others to avoid conflict and would adapt her behavior to the dominant culture. She would have more difficulty building social bonds because her long commute and protective parents would interfere with scheduling team meetings and her alcohol avoidance would preclude her from many socialization opportunities. She might share some self-concept barriers with other women, but her strong technical background would mean she would be inclined to take on coding roles but might take on more than her fair share because she feels a pressure to excel to represent her race and gender, affirming her identity as an engineer. She might feel that her collaborative and communal goals align with teamwork, but her performance orientation might drive her to efficiency rather than learning.

By using the framework of fit to environment to describe how identity drives teamwork choices, experiences and outcomes, we have provided a novel perspective on teamwork in engineering education that will guide improvements in our pedagogical practice.

5.3 Interventions: implications for educational practice

Many suggestions have been made in the literature about best practices in teamwork. Here, we highlight approaches that, based on our results, we believe will have the greatest impact on

TABLE 3 Identity interactions with teamwork.

Identity	Fit	Factors affecting fit	Choices	Experiences and outcomes	References that identified similar outcomes
Women	Social	Friendship	Pick similar group members	Increased sense of belonging and motivation; less skill with diverse teams	Rodriguez-Simmonds et al. (2017)
		Sexism	Change behavior to dominance	Decreased social fluency	Henderson (2021)
		Professional vs. romantic relationship	Avoid potential teammates	Feeling disrespected	Tonso (1998)
		Conflict avoidance or submissiveness (cultural)	Defer to others in role choices	Feeling ignored or under-valued	Bear et al. (2014); Henderson (2023)
	Self-concept	Good at communicating	Choose writing roles	Choose less technical careers	Meadows and Sekaquaptewa (2013)
		Inexperienced in coding	Choose roles that avoid coding	Avoid some disciplines/areas; learn less	Corneliussen and Prøitz (2016)
		Under-represented; anticipate stereotypes	Feel pressure to excel; avoid teams; afraid to ask questions	Stress, imposter syndrome	Wierzchowski (2019)
	Goal	Collaborative values	Choose to work in teams	Positive experience	Allen et al. (2021)
		Do good for others	Choose or enjoy particular projects	Motivation	Diekman et al. (2017)
		Performance focus	Roles that rely on previous skills	Avoid some disciplines/areas	Fowler and Su (2018)
Racialized	Social	Shared or conflicting cultures	Pick similar group members or allies	Sense of belonging and motivation; less skill with diverse teams; decreased social fluency	McGee and Martin (2011)
		Under-representation	Social tuning, model behavior	Isolation; stress; lack of fluency and authenticity	Kawakami et al. (2012)
	Self-concept	Few role models; low representation in peer group; anticipated racism	Feel pressure to excel; avoid teams; afraid to ask questions	Stress, decreased cognitive fluency	McGee and Martin (2011)
	Goal	Communal values (culture dependent)	Choose to work in teams	Positive experience	Boucher et al. (2017)
		Do good for own community	Choose or enjoy particular projects	Motivation	Boucher et al. (2017)
		Performance focus	Roles that rely on previous skills	Avoid some disciplines/areas	Nite et al. (2020)
2SLGBTQIA+	Social	Homophobia	Avoid disclosure; passive behavior to avoid attention; select groups with allies	Isolation; stress; lack of fluency and authenticity	Cech and Rothwell (2018)
	Self-concept	Low representation and fear of homophobia	Avoid disclosure; passive behavior to avoid attention; select groups with allies	Isolation; stress; lack of fluency and authenticity	Cech and Rothwell (2018)
	Goal	?			
Social determinants	Social	Time commitments: Part-time job; extracurriculars; commuting; family support; parental protectiveness	Work harder to adapt to team-mates' needs or cause conflict	Harder to build social connections	Simmons et al. (2018)
		Budget constraints in projects	Cause conflict in teams	Stress	Espino et al. (2022)
	Self-concept	Time or budget constraints	Feel unable to contribute equally	Less engineering identity	Espino et al. (2024)
	Goal	Fulfill non-academic priorities	Take on "easier" roles	Harder to build social connections	Simmons et al. (2018)

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TABLE 4 Summary and impact of key interventions for equitable teamwork.

Area of focus for intervention	Methods	References
Group selection	Best practice recommendation: Assign groups strategically to minimize lone members of an identity group within a team.	Monteiro et al. (2020); Palmer et al. (2011); Klawe (2013); Sekaquaptewa and Thompson (2003); Sekaquaptewa et al. (2007)
	Alternative: Allow students to choose at least one other group member in their team to ensure an ally is present. Ensure teammates have similar prior experience levels (e.g., in coding).	
Allyship	Best practice recommendation: Support and publicize identity-based mentorship and affinity groups.	Ong et al. (2018)
	Alternative: Implement action-focused training on allyship.	
Group roles	Best practice recommendation: Mandate the rotation of group roles in different projects to give all students opportunities to learn and try various parts of the project.	Fredrick (2008); Monteiro et al. (2020)
	Alternative and Supplementary: Implement individual assessment to actively ensure that students are being exposed to all areas of course content.	
Social determinants	Best practice recommendation: Provide in-class time for group work to be completed in an open, safe, and accessible environment. Limit project budgets.	Montero and Gonzalez (2008); Tyson (2012)
	Alternative: Setting clear expectations within teams; ensuring regularly scheduled virtual team meetings and milestones.	
Inclusive teamwork instruction	Best practice recommendation: Integrate teamwork skill development and inclusion awareness/ training into course curriculum. Actively assess teamwork skill development.	Mina et al. (2014); Turns et al. (2014); Carlson et al. (2005); Cestone et al. (2008); Lewis et al. (2019); Chromik et al. (2020); Thakur et al. (2021)
	Alternative and Supplementary: Share inclusive teamwork best practices and inclusion resources (links etc.) on course webpage or platform. Incorporate qualitative peer feedback or reflection focusing on teamwork skills.	
Identity fit; Pressure of representation	Best practice recommendation: diversify faculty, student body, publicized role models and student leadership.	Hernandez et al. (2021); Palmer et al. (2011); Kizilcec and Saltarelli (2019)
	Alternative: Highlight asset model.	

building inclusive teamwork experiences for equity-deserving students in engineering and potentially in similar STEM environments. Constraining choices that have inequitable outcomes is easiest to implement, so we focus first on these themes highlighted within the focus groups: group selection and group roles. Some of the issues around social determinants can be addressed by creating meeting structures and stated project budgets. We also believe there is an opportunity to address some of the effects of stereotypes and environment, though these are more pernicious and potentially difficult. Instruction in equitable teamwork could help. We have drawn from literature to share best practices based on our results.

Our suggested interventions and recommendations are outlined (Table 4). As a consequence of this research, the institution where the study was conducted has made a conscious effort to implement many of these interventions.

5.3.1 Group selection

Students were motivated by social and self-concept fit when they selected their own groups, but it resulted in decreased diversity, whereas randomized groups interfered with social fit. Controlling group composition can address isolation, the pressure of representation and overall student teamwork experiences (Palmer et al., 2011). When groups are selected by an instructor, a common best practice is to ensure that women are not isolated on teams (not "soloing" women), because that interferes with their self-efficacy (the belief that you can succeed in a task) and performance (Meadows and Sekaquaptewa, 2014; Monteiro et al., 2020 Sekaquaptewa and Thompson, 2003; Sekaquaptewa and Thompson, 2002; Viallon and Martinot, 2009). One study found that undergraduate engineering women do best in majority-woman teams (Dasgupta et al., 2015). Strategically assigned teams should incorporate multiple identity groups while including at least two people of the same identity group to mitigate isolation while maintaining the benefits of diversity. However, instructors often know little about students' identities beyond gender. An alternative is to allow students to select a peer to act as a support or ally. For coding tasks in first year, minimizing disparities in prior experience within teams could increase self-concept fit, as shown by Klawe (2013).

5.3.2 Allyship, friendship, and safety

We saw that students sought social fit by surrounding themselves with allies, but that this typically took time and effort. Helping students rapidly find others with shared identities can help students engage with allies early in their engineering experiences (Ong et al., 2018). Starting with First year orientation week, we suggest helping students engage with identity-matched mentors and peers. Identity-matched mentorship during these transition times has been shown to be potent and long-lasting (Wu et al., 2022) (Wu et al., 2022). Supporting affinity groups is also essential to build community and support, catalyzing opportunities to improve social fit (Abdullah et al., 2016).

5.3.3 Group roles

In our results, social, self-concept and goal fit motivated role selection, resulting in inequitable opportunities to learn. We suggest mandating rotating technical and non-technical roles (Fredrick, 2008; Monteiro et al., 2020). At minimum, simple administrative tasks, such as taking minutes and submitting milestones should be rotated.

Even when given the opportunity to take on unfamiliar roles in a team setting, students with limited prior experience often lack confidence in their skills and might struggle to take leadership roles or take on key project parts for fear of failure (Nelson et al., 2013). Optional skills workshops put on by the university can help students bridge experience gaps (Meadows and Sekaquaptewa, 2014), but need institutional resources and extra work from marginalized students.

In courses with multiple projects, it is practical to assign and rotate group roles. For smaller projects, monitoring team roles and coupling them with individual assessments can improve equitable learning.

5.3.4 Social determinants

Because teamwork often requires time commitments for team meetings outside scheduled class time and potentially unlimited project costs, our results showed that students with time and financial limitations struggled with social fit in teams. Structured collaboration has a substantial effect on the experience of students in a group setting (Montero and Gonzalez, 2008). We recommend adding budget limitations on projects and designating time in class or tutorials for group work. One limitation to this intervention is that instructors might be reluctant or unable to allocate valuable teaching time to allow students time to work in class. At minimum, instructors should ensure teams agree on clear expectations for milestones and regular meetings. Virtual meetings improve flexibility and should be regularly scheduled at the outset of the project.

5.3.5 Inclusive teamwork instruction

Teamwork and inclusion skill development is essential for team-based work in engineering students' careers. Interventions must ensure that students are both effectively taught and assessed (Dobbin and Kalev, 2018; Loya, 2021; Mobley and Payne, 1992; Turns et al., 2014).

Improving awareness of barriers like imposter syndrome and microaggressions (Handley et al., 2021; Khan and Zolfaghari, 2021) that impact marginalized groups improves the functionality of diverse teams (Leicht-Scholten et al., 2009; Turns et al., 2014). In cases where this is not possible, sharing resources in class or through course communication platforms could act as an alternative. However, teaching about diversity and inclusion in teams is not enough; students recognize the value of diversity but are less willing to adopt more inclusive team behavior when under time pressures (Rodriguez-Simmonds et al., 2017). Rodriguez-Simmonds et al. (2020) reported similar findings, with students still valuing efficiency and technical content over diversity. Thus, we argue that inclusion and teamwork need to be taught in tandem and explicitly assessed.

Explicit instruction in equity and team norms has the potential to increase inclusive behavior in teams, improving social fit. Similarly, assessment of teamwork could reinforce the value of effective communal skill development, though relying exclusively on peer assessment raises concerns about bias (Stonewall et al., 2018). Efforts are beginning in teaching equitable behavior and teamwork in engineering education (e.g., Chromik et al., 2020), though there are mixed reports about mandatory equity and inclusion training (Brannon et al., 2018; Thakur et al., 2021). One approach showed a video to students that exemplified then discussed equitable teamwork practices, which equalized the time men and women spoke during a team activity (Lewis et al., 2019).

Group dynamics and teamwork can be assessed using guided reflections and qualitative peer feedback (Mina et al., 2014; Turns et al., 2014). Qualitative peer feedback allows students to receive recognition for their contributions and constructive feedback for personal skill development (Carlson et al., 2005; Cestone et al., 2008) but it must be carefully structured, as it has been shown that unprofessional peer reviews disproportionately affect women's productivity and career advancement (Silbiger and Stubler, 2019). We caution against using peer grading, given the potential for student bias to affect results (Thondhlana and Belluigi, 2016) and are intrigued by new approaches to guiding peer assessments (Stonewall, 2022). Additionally, knowing that individual assessments will be incorporated alongside team tasks can serve as motivation for all members to participate and practice skills.

5.3.6 Identity fit; pressure of representation

In both these cases, we saw that self-concept fit was the major barrier, which is due to a mismatch between the student's concept of themselves and their concept of a stereotypical engineer and to under-representation of the student's identity in the engineering environment. Although we cannot easily change stereotypes in society, we can affect the messages the engineering environment sends (Kizilcec and Saltarelli, 2019). For example, prioritizing building a more diverse faculty and engineering student body provides role models and examples that normalize a range of identities. Similarly, being intentional about highlighting diverse role models and ensuring that the student leadership (e.g., in first year orientation week) is diverse should help.

As a supplement to the hard work of increasing diversity, Mesmin Destin has shown the benefits of using an asset model. This approach employs panels and reflections to help first-generation students link their lived experiences to assets they bring to engineering (Hernandez et al., 2021), which would improve students' self-concept fit by highlighting their strengths.

6 Conclusion

In this work, we demonstrate for the first time how the framework of psychological fit can be applied to explicate teamwork choices, experiences, and outcomes. This novel approach allowed us to show how students with diverse identities integrate with an engineering environment to nudge choices about teamwork and ultimately about future careers.

Choices about teamwork were driven by psychological fit. A desire for social and self-concept fit drove students to select teammates with similar identities. Previous experiences and stereotypes embedded self-concepts that often resulted in women avoiding coding and taking on communication roles. Students with visible under-representation, notably women and racialized students, strove for social fit (respect from peers) and self-concept fit (affirming that their self-concept as an engineer was valid despite stereotypes) by pressuring themselves to perform at the highest levels.

Social and identity determinants affected students' feeling of fit during teamwork. Within engineering team environments, students who had difficulties meeting teammates' expectations about meeting availability (due to non-academic time commitments) or contributing equally to project budgets (due to economic restrictions) experienced a lack of social fit. Social and self-concept fit was threatened when students' identities did not match their peers or engineering stereotypes—of which students were acutely aware. Women had social or self-concept fit issues that depended on their intersectionality. Most women had at some point experienced exclusion, disrespect or microaggressions within teams. Sexual interest from male teammates made heterosexual women uncomfortable, while queer women felt invisible. Muslim women felt that their unwillingness to drink alcohol interfered with their social fit. Gay men often chose not to disclose their sexuality or to participate fully in teams in order to socially conform. Minoritized racialized students were hyper-aware of their differences from their peers and self-concept divergence from the stereotypical engineer, so either avoided teamwork or felt extra pressure to perform. In contrast, the collaborative atmosphere within successful teams enhanced some women's goal fit, increasing their motivation and satisfaction.

The accumulation of challenges to fit during teamwork made many students wary of potential social or self-concept fit barriers in future engineering workplaces and they voiced their uncertainty about pursuing engineering careers after graduation.

To address inequitable team experiences that interfered with fit, we propose a comprehensive set of interventions. We suggest imposing group selection that balances diversity with ensuring teams included allies. We suggest facilitating social interactions with identity-matched peers and mentors as early as possible with the help of well-supported student affinity groups. We encourage assigning and rotating technical and non-technical roles within teams, providing in-class time for team meetings and setting modest project budget caps. We also suggest providing students training on inclusive team behavior, diversifying engineering faculty, students and role model representation and using asset-based reflections.

By using fit to frame engineering teamwork choices, experiences and outcomes, we provided an actionable set of teamwork best practices that we believe will nudge future choices by providing diverse students a sense of fit within engineering team environments.

Data availability statement

The datasets presented in this article are not readily available because our ethics approval did not allow sharing of focus group transcripts because of privacy issues. Requests to access the datasets should be directed to Kim Jones, kjones@mcmaster.ca.

Ethics statement

The studies involving humans were approved by McMaster Research Ethics Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SE: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis. MM: Writing – review & editing, Project administration, Methodology, Investigation, Conceptualization. EB: Writing – review & editing, Methodology, Investigation, Conceptualization. KJ: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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