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OPINION

A call to foster psychological safety to facilitate inclusive and effective engineering student teams and learning

Siqing Wei*, Yunmeng Han

Department of Engineering and Computing Education, University of Cincinnati, Cincinnati 45219, Ohio, USA

ABSTRACT

This research article presents the importance of psychological safety in engineering education. Anchoring the importance of teamwork and team-based learning, we synthesize the common issues of dysfunctional team dynamics and coping strategies based on relevant literature. Particularly, it is critical to better manage student teams and monitor student team dynamics, particularly psychological safety based on archived literature in industrial-organizational psychology and management and recent empirical studies in engineering education. Psychological safety, defined as a shared belief that a team is safe for interpersonal risk-taking, is shown to enhance team trust, communication, and collaboration. This paper presents the critical role of psychological safety in teamwork, enabling equitable participation and fostering inclusive learning environments, especially for disadvantaged students in teaming. The manuscript concludes with recommendations for approaches to enhance psychological safety by raising awareness, supporting disadvantaged students in teaming, and fostering inclusive learning environments. By fostering inclusivity and empowering all students to contribute to the teams meaningfully and effectively, psychological safety not only addresses the immediate challenges of team-based learning but also remediates students' intention to leave engineering major, ultimately leading to broader participation in engineering.

Key words: psychological safety, team dynamics, inclusion, broaden participation in engineering

TEAMWORK IN ENGINEERING EDUCATION

Team-based learning has become a popular and effective approach in modern engineering education, utilized not only to boost students' academic performance but also to foster teamwork skills.[1–3] Teamwork is regarded as a vital professional skill, as engineers must collaborate with individuals who approach problem-solving differently.[4] Students are expected to demonstrate the ability to work effectively in diverse teams, solve complex problems, and communicate with various stakeholders.[5] Through collaboration, engineering students can develop their teamwork competencies alongside essential professional skills like communication and project management.[6] In small teams, students could also practice leadership skills, as student teams are typically self-managed. Furthermore, the significance of teamwork is evidenced through its role in engineering accreditation and its conjunction with commonly adopted contemporary pedagogies in engineering education.

Role of teamwork in accreditation

Teamwork is a fundamental component of modern engineering education, reflecting the collaborative nature of professional engineering practice.[7] Accrediting bodies, such as the Accreditation Board for Engineering

***Corresponding Author:**
Siqing Wei, Department of Engineering and Computing Education, College of Engineering and Applied Science, University of Cincinnati, Cincinnati 45219, Ohio, USA.
Email: weisq@ucmail.uc.edu; https://orcid.org/0000-0002-7086-5953
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and Technology (ABET)[5] and China Engineering Education Accreditation Association (CEEAA),[8] explicitly emphasize teamwork as a core student outcome, requiring graduates to demonstrate the ability to function effectively in diverse, multidisciplinary teams. According to ABET's Criterion 3,[5] students must demonstrate: "An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. Meanwhile, according to CEEAA's standard section 4.3.8,[8] teamwork is one of the graduate outcomes: Individual and teamwork: Function effectively as an individual, team member and principal in a multi-disciplinary team. There is a consensus recognition of the importance of teamwork in engineering practice and work as contemporary engineering projects become increasingly complex in nature and scope.

The conjunction of team-based learning and project-/problem-based learning

Beyond fulfilling engineering accreditation requirements, team-based learning has become a popular pedagogy, which is closely knitted to well-adapted project-based (PjBL) and problem-based learning (PrBL). Such adaptation has been shown to better help students learn engineering skills and competencies, such as creativity and teamwork, and develop toward future engineers.[9–12] These pedagogies provide students with structured opportunities to engage in team-based problem-solving while applying theoretical knowledge to real-world challenges.[13]

Project-Based Learning: PjBL engages students in projects to enhance their engineering professional capabilities and practices,[13] either from hypothetical cases or authentic industrial problems delegated through collaboration between universities and enterprises.[14] These projects are typically complex, requiring students to analyze, design prototypes, test, improve, select cost-effective manufacturing methods, market, maintain, scrap, and redesign within a set timeframe. In addition to developing technical competencies, PjBL emphasizes interpersonal and organizational skills, such as task delegation, time management, and conflict resolution. Teams in PjBL environments experience the dynamics of shared accountability, where the project's success depends on the equitable, meaningful contributions and collective efforts of all members. A key benefit of PjBL is its ability to blend technical learning with professional skill development,[13] especially teamwork competency. For instance, students learn to manage team dynamics by negotiating roles and responsibilities, resolving disagreements, and leveraging diverse perspectives to achieve project goals. The collaborative nature of PjBL fosters a sense of ownership and accountability, helping students develop both their technical and interpersonal capabilities.[15]

Problem-Based Learning: PrBL focuses on solving open-ended problems through guided inquiry and analysis.[13] Unlike PjBL, which typically culminates in a tangible deliverable, PrBL prioritizes the process of exploration and knowledge acquisition. Students work collaboratively to identify knowledge gaps, generate hypotheses, and evaluate potential solutions, developing critical thinking and self-directed learning skills along the way.[16] Furthermore, PrBL is particularly effective at fostering adaptive teamwork as students must navigate the ambiguity of ill-structured problems, collaborate to synthesize diverse inputs, and collectively make decisions under uncertainty.[16] These activities reflect real-world engineering challenges, where teamwork and adaptability are critical to success. PrBL also cultivates team dynamics that emphasize inclusivity, as members must actively listen to and integrate each other's perspectives to address the problem effectively.[17]

From the accreditation agency's emphasis on teamwork competency to the overlap of cooperative learning with PjBL and PrBL, engineering students need authentic opportunities to learn to collaborate in diverse, team-based settings.[13] While PjBL and PrBL are designed to develop student's technical and professional skills, their effectiveness is often hindered by the challenges associated with teamwork. In other words, simply assigning students to teams to work on a team project does not guarantee their educational gains, especially in terms of developing teamwork skills.[18] Without proper instruction and support from the instructors or instructional teams, working in small teams in the context of PjBL and PrBL might raise issues, leading to unpleasant learning experiences.[19]

CHALLENGES AND COPING STRATEGIES IN TEAM-BASED LEARNING

While team-based pedagogies widely used in conjunction with PjBL and PrBL offer numerous benefits, they also present distinct challenges that can hinder their effectiveness. For instance, Bolton [20] reported differential satisfaction regarding team-based courses, where 91% of teachers were satisfied, compared to only 64% of students surveyed. Engineering educators must address these challenges to ensure that team-based learning achieves its intended outcomes. For instance, scholars have considered the integration of cooperative learning and PrBL to propose a pedagogy framework called Cooperative Problem-based Learning, the fusion of PBL and cooperative learning focusing on learning and problem-solving in the context of small student teams.[21] Cooperative learning and collaborative learning are two

forms of team-based learning; despite both requiring students to work in teams, the former focuses on achieving a specific, predetermined goal, while the latter focuses on constructing knowledge.[22] However, understanding the common challenges of teamwork and strategies for team management will better prepare teachers for team-based learning. The following subsections discuss common dysfunctions in student teams and propose strategies to manage these challenges effectively, with a focus on improving team dynamics and fostering productive collaboration.

Team dynamics and challenges

Team dynamics refer to "the influential actions, processes, and changes that occur within and between groups".[23] In engineering education, effective team dynamics are critical for promoting collaboration, fostering inclusion, and enhancing learning outcomes.[24] Positive team dynamics allow members to build trust, communicate openly, and navigate challenges constructively, creating an environment conducive to innovation and problem-solving.[25] Conversely, dysfunctional teams, characterized by the absence of trust, fear of conflict, lack of commitment, avoidance of accountability, and inattention to results, can undermine both individual and team performance, as described by Lencioni as the five team dysfunction model.[26]

Maintaining positive team dynamics can be challenging, particularly in diverse and virtual team environments,[27,28] Different from the five-team dysfunction model proposed by Lencioni[26] for organization management, we illustrate three team dysfunction issues pertinent to student teams.

Social loafing and free riding: One of the most extensively documented challenges in team-based learning is social loafing, a phenomenon wherein one or more team members exhibit a reduced level of effort, presuming that their counterparts will make up for the difference.[29] This behavior undermines the principle of shared accountability and may engender feelings of resentment among team members who are burdened with disproportionate workloads. Prior work has identified several reasons for social loafing. For instance, individuals who are more likely to loaf than others might have stronger confidence in their ability,[30] have lower cognitive demand and desire,[31] or embed lower motivation.[32] Moreover, social loafing might occur when the assigned tasks are perceived as meaningless or unrecognizable, where loafers believe their involvement and contribution won't make a difference,[33,34] Research also suggests that social loafing is particularly prevalent in large teams or in teams where individual contributions are difficult to distinguish.[35] Students who feel their effort will not be recognized or rewarded are less likely to engage fully, leading to a negative cycle that affects overall team performance and satisfaction in engineering.[1]

Marginalization: Different from social loafing, where one might intentionally opt out of an assigned portion of teamwork, marginalization typically happens when one is pushed out from normal team interactions. Marginalization of minority or underrepresented students is a pervasive issue in team-based learning environments under the predominately White male engineering culture in the United States, particularly based on gender and race.[36] Engineering education scholars explored such phenomena, such as women being ignored for their voices, devalued, and assigned gendered and non-technical roles,[37–41] and racially marginalized students reporting limited learning opportunities and exclusion from desired team roles.[40] Scholars suggest using the Microaggression theory as a lens to understand marginalization.[36] Three primary types of microaggression are characterized: microinsults demeaning one's identity), microinvalidations negating, invalidating, or diminishing one's lived experiences), and micro assaults overt attacks and avoidant behaviors.[42] Marginalization not only affects targeted students' sense of belonging for being isolated but also diminishes the team's ability to leverage diverse perspectives, which are essential for solving complex problems,[40,41]

Lack of team consensus and accountability: Effective teamwork requires shared goals, clear communication, and mutual accountability towards the common goals. However, student teams often struggle to establish these foundational elements. Misaligned expectations, conflicting priorities, and poor communication can lead to a lack of consensus on how to approach tasks or evaluate success.[43] Prior work described the stereotyped counterproductive practices of engineering students: starting work near the deadline, preferring to work alone and without a plan, neglecting assignment instruction by presuming the purpose, enjoying challenging questions, competing with others for better contributions with shorter time, and not wanting with work with technical inferior teammates.[44] Those practices inherently damper good team dynamics when enacted, which prevents building team consensus effectively. Accountability within teams is another critical issue. Likewise, those counterproductive practices compromise team accountability when students do not fully prepare for class and team meetings, rush to finish work close to the deadline or dominate the workload division to carry the whole team.[44] Empirical evidence shows that students prefer highly engaged and prepared team members over those not involved, distracted, or even disruptive to put the team's success in danger.[45]

Strategies for addressing challenges in team-based learning

To address these challenges, educators must adopt evidence-based strategies that promote equitable participation, enhance team dynamics, and foster a culture of inclusion and collaboration. We highlight four key strategies in the following four paragraphs for team management that have been shown to improve team-based learning outcomes.

Forming balanced and evidence-based teams: The composition of student teams plays a crucial role in their success. However, team formation could be a laborious process for instructors when adopting a criteria-based assignment strategy.[46] Prior work indicated that forming teams is a common issue and recommended a systematic assignment strategy rather than self-selection or random assignment, which might result in teams without diversity,[47,48] Tools like CATME (Comprehensive Assessment of Team Member Effectiveness) enable instructors to form balanced teams by considering factors such as individual characteristics, skill levels, personality traits, scheduling, and other instructor-specified criteria.[49] Taking the example of women in teams, prior literature suggests that the gender composition of a team influences student team experiences, but research findings do not converge.[50] While Layton and colleagues [49] argue for never singling out students with minoritized status based on gender and race/ethnicity. To ensure the best educational engagement and avoid marginalization, Felder and Brent recommended forming teams of three or four students for most group assignments and projects.[51] With various needs from instructors and contexts of classrooms, we contend that instructors should adopt systematic team formation strategies by listing and ranking the relevant criteria pertinent to students' success, such as demographic, major, and abilities for specific software. It is crucial to balance the technical considerations and sociocultural factors, where members bring complementary skills and perspectives while minimizing the risk of marginalization. Teams that are overly homogenous may lack the diversity needed for innovative problem-solving, while teams with extreme disparities in skills or experiences may struggle to collaborate effectively.[52]

Conducting self and peer evaluations: Regular self and peer evaluations are critical for maintaining accountability within teams. By allowing students to provide feedback on their own and their peers' teamwork effectiveness, these evaluations help identify issues such as social loafing or unequal participation early in the process, which in turn promotes student development of teamwork skills.[35] Moreover, during the process, students will also learn how to properly construct meaningful feedback and provide more consistent ratings, as a measure of rating quality.[53] Furthermore, a recent study reveals that evaluation data contains valuable information to detect instances of marginalization and biases to be leveraged to interrupt the status quo or even prevent it from happening.[36] This evaluation and feedback loop can encourage all team members to reflect on their behavior and adjust accordingly, fostering a more inclusive and productive team environment.

Setting clear expectations and monitoring team dynamics: Instructors must establish clear norms and expectations for teamwork at the outset of a project. These norms should emphasize the importance of collaboration, respect, and shared accountability, providing students with a framework for effective team behavior.[54] One possible strategy is to ask students to develop their team contracts to operationalize their own rules and coordination process.[55] Monitoring team dynamics throughout the project is equally important. Instructors can use periodic check-ins, progress reports, and self- and peer-evaluation to assess how well teams are functioning and intervene when necessary. A team might experience five ordered stages throughout their team tenure: forming, storming, norming, performing, and adjourning,[56] but it was found that engineering teams might not conform to such order, where contextual factors matter and influence their authentic teaming experiences.[57] Therefore, we advocate for proactive monitoring student team dynamics to detect any potential team dysfunctions and take action when necessary.[28]

Addressing challenges in team dynamics requires a deeper understanding of the underlying factors that influence collaboration and trust among team members. While the strategies outlined above can address many of the challenges associated with team-based learning, their success ultimately depends on the presence of psychological safety. Psychological safety is arguably the most important metric for team dynamics,[43,58] and a proxy for social inclusion in engineering classrooms.[54] By fostering an environment where team members feel safe to express their ideas, admit mistakes, and engage in open dialogue, psychological safety enhances team cohesion, inclusivity, and productivity,[59,60] In the next section, we will explore the concept of psychological safety in greater depth, examining its role in team dynamics and its importance for fostering inclusive and effective learning environments.

PSYCHOLOGICAL SAFETY

Introduction to psychological safety

Psychological safety is defined as the shared belief that a

team environment is safe for interpersonal risk-taking.[60] It allows team members to voice ideas, admit mistakes, and engage in open dialogue without fear of judgment or negative repercussions. In team-based learning environments, especially in engineering education, psychological safety fosters an inclusive atmosphere where students can freely contribute their perspectives, engage in critical discussions, and take intellectual risks necessary for solving complex problems.[54,61]

In engineering education, teamwork is often used to mirror real-world collaborative practices. However, the absence of psychological safety can exacerbate social loafing, marginalization, and unresolved conflicts, significantly hindering team performance and learning outcomes. One study showed that when within-team psychological safety was low, negative consequences of psychological safety had a higher chance of happening.[62] Conversely, teams with high psychological safety are more likely to embrace diversity, resolve conflicts constructively, and achieve higher levels of innovation and productivity.[63]

Students in psychologically safe teams are more likely to engage in constructive dialogue, which is essential for collaborative problem-solving. [63–65] Teams with higher psychological safety perform better in teamwork as team members experience fewer interpersonal conflicts, more team cohesion,[58] higher team satisfaction and effectiveness,[66] increased team potency,[67] elevated team-decision making performance,[68] and better trusting relationships.[69] When students trust that their input will be valued, they are less likely to feel defensive or competitive, leading to a more harmonious team environment.[43] Students who are marginalized or lack confidence frequently exhibit reluctance to engage in collaborative environments. The establishment of psychological safety alleviates this issue by fostering an inclusive atmosphere in which all individuals feel empowered to contribute. Teams with high psychological safety are more effective at achieving their goals. Meanwhile, promoting psychological safety also facilitates enhanced learning experiences, in terms of team learning behaviors.[70] In student teams, psychological safety has been linked to several positive outcomes in not only diverse teams but also virtual teams.

Psychological safety in diverse teams

Psychological safety plays a pivotal role in enabling diverse teams to navigate these complexities effectively. Diversity in student teams offers opportunities for richer discussions and more innovative solutions but also presents challenges that can hinder collaboration as differences in cultural orientations, communication styles, and social norms can create barriers to inclusivity and participation.[71] In the absence of psychological safety, team members from underrepresented demographics, including international students, women, and racial minorities, may experience feelings of exclusion or undervaluation.[28,53,58] It was found that only Black and international first-year engineering students perceived lower psychological safety.[72] Psychological safety mitigates these challenges by fostering an environment where all members feel valued and respected.[70] For a more in-depth discussion of the impact of individual and team characteristics on psychological safety, readers are encouraged to refer to.[43,73]

Psychological safety in virtual teams

The COVID-19 pandemic accelerated the transition to virtual learning environments, transforming how students collaborate on team projects.[28] While virtual teams offer flexibility and global connectivity, they also introduce unique challenges, such as reduced social presence and engagement, communication barriers, and difficulties in building trust and a shared mental model (a team-shared cognitive structure of interaction and coordination).[74]

In virtual teams, the absence of face-to-face interaction can impede trust development, which is essential for psychological safety. A study using a random forest algorithm characterized the relative importance of many team dynamics indicators, such as teamwork effectiveness behaviors, team conflict, team interdependence, and psychological safety, in predicting team satisfaction in a normal in-person semester and the emergency shift to a virtual instruction semester.[28] One result of this study revealed that psychological safety was the most important indicator in the in-person semester, but became less important in the emergent transition semester. Meanwhile, in the same study, another result showed that there was a 2-point drop in the 7-point Likert scale psychological safety in the COVID-19 semester with a large effect size. This decrease was argued to link to the lack of informal interactions and nonverbal communication that typically helped build rapport among team members, which made it harder to build team psychological safety in virtual teams.[74,75] Additionally, virtual settings often worsen communication issues, leading to misinterpretations or delayed responses. Students might hesitate to ask questions or share ideas, worried that their input could be misconstrued or overlooked.[28] Additionally, the literature also indicated that students in that crisis might simply not have enough dedicated time for team meetings and prefer a divide-and-conquer collaboration strategy.[76] The transition to virtual learning necessitates that students acclimate to novel technologies, workflows, and expectations. Psychological safety plays a crucial role in this acclimatization by promoting

students' willingness to seek assistance, experiment with unfamiliar tools, and adopt a growth mindset. The objective of psychological safety is to cultivate a supportive environment in which students can articulate their thoughts and feelings openly, even in asynchronous or text-based formats, to overcome unwanted teamwork behaviors. Teams with high psychological safety are more resilient to change and better equipped to overcome the challenges of remote collaboration.[70]

Psychological safety is crucial for the effectiveness of diverse and virtual teams in engineering education. In diverse teams, it fosters inclusivity, enhances communication, and reduces dysfunctional behaviors, enabling teams to leverage their diversity as a strength. In virtual teams, psychological safety builds trust, encourages interdependence, enhances collaboration, and mitigates the challenges of remote interaction. Enhancing psychological safety is vital for boosting student engagement in team-based learning. By raising awareness, assisting underrepresented students, and nurturing inclusive learning environments, educators can establish spaces where every student feels motivated to contribute. In the following section, we will delve into targeted strategies for strengthening psychological safety, emphasizing the importance of raising awareness, supporting marginalized students, and developing inclusive academic settings to enhance student involvement.

IMPROVING PSYCHOLOGICAL SAFETY TO ENHANCE STUDENT PARTICIPATION

Psychological safety is crucial in team-based learning environments, empowering students to engage actively, share their ideas freely, and learn together. However, developing psychological safety demands deliberate and focused strategies, particularly in diverse and virtual engineering education contexts. This section outlines approaches for enhancing psychological safety by raising awareness, supporting underrepresented students, and fostering inclusive learning environments.

Increasing awareness of psychological safety in team-based learning

A significant barrier to psychological safety is the lack of awareness among both students and instructors about its importance in team dynamics. Many team-based learning environments operate under the assumption that students will naturally collaborate effectively with the goal of accomplishing assigned team projects. However, studies show that psychological safety does not arise automatically, especially in diverse or high-stakes team settings.[60,70]

The team leader and instructor can address this issue by explicitly integrating psychological safety into the design and facilitation of team-based learning. At the start of a project, instructors should introduce the concept of psychological safety and emphasize its importance for effective teamwork. Wei [28] highlights the value of structured team orientations, where students learn about behaviors that promote or undermine psychological safety, such as active listening, equitable participation, and constructive feedback. These orientations not only set the stage for collaborative success but also normalize discussions about team dynamics.

Reflective practices are another critical tool for increasing awareness.[55,76] Regular team reflections or debriefing sessions provide students with opportunities to evaluate their contributions to psychological safety. For instance, a team might reflect on whether all members had equal opportunities to share their perspectives or whether feedback was delivered respectfully. These reflections encourage students to take ownership of their team's psychological climate and make adjustments as needed. Teams with regular reflective practices were more likely to maintain psychological safety, even during challenging transitions such as the shift to virtual learning environments.[28] In addition, in this article, we highlight two critical points essential to promote a psychologically safe environment in the context of team-based learning to broaden participation in engineering – identification of disadvantaged students in teams and principles of inclusive teaching practices.

Identifying and supporting disadvantaged students in teaming

Disadvantaged students, especially having multiple marginalized identities in terms of gender, race/ethnicity, and disability, as well as international students, and students with lower academic confidence, often face unique challenges in team-based.[61] One dissertation study revealed significant disparities in psychological safety among demographic groups, with international students having low levels throughout the team project period compared to domestic peers, and Asian students reporting the same level initially but dropping more rapidly relative to their White peers.[77] This finding highlights the need for targeted interventions to support disadvantaged populations in teaming – Asian students and international students. In another study, Wei and Ohland[78] investigated the role of personal cultural orientations on psychological safety, where four of eight constructs of cultural dimensions are significant: interdependence, gender equality, ambiguity intolerance, and social inequality.[78] This study showed that personal cultural orientations were an antecedent of psychological safety, which opened another door to characterize disadvantaged students in teaming beyond demographics.

For racial and ethnic minorities, especially Asian and international students who reported lower psychological safety, culturally responsive teaching practices are essential. Integrating cultural competency training into the engineering curriculum can raise awareness of biases and promote inclusivity among students.[79–81] Educators should create safe spaces where students from diverse backgrounds can share their experiences and foster mutual understanding. Mentorship training, either provided as in-class modules by instructors or conducted by dedicated school offices, is particularly effective, as they provide students with a trusted resource to navigate team dynamics and advocate for their needs in a culturally validated manner. For example, mentors can help international students adjust to cultural differences in communication styles or assist underrepresented students in asserting their ideas within a team setting. Regular monitoring of team dynamics is also critical for identifying and addressing exclusionary practices that hinder team cohesion and participation.[78] Structured participation is another effective strategy. Assigning specific roles or responsibilities to team members ensures that all students have opportunities to contribute, regardless of their confidence level, backgrounds, or culture. The significance of rotating leadership roles is paramount, as it not only fosters confidence but also mitigates power imbalances within teams.[53] These practices can help create an environment where underrepresented students feel valued and empowered to participate.

Principles of inclusive teaching practices for psychological safety

Inclusive learning spaces are essential for maximizing the potential of team-based learning.[54] Psychological safety serves as the foundation for such spaces, enabling students to engage fully and confidently in collaborative activities. Creating inclusive learning spaces begins with deliberate efforts to invite input from all team members and avoid the exclusion of students who are tentative about leaving engineering due to the chilly climate.[82] Instructors must ensure that not only historically minoritized students but also disadvantaged students in teaming feel encouraged to share their ideas and have a voice. This can be achieved through instructional practices such as establishing clear norms and expectations, providing rationales for why everyone's voices and input matter, allowing one to admit their fallibility, actively inviting everyone's input, especially disadvantaged students in teaming, and responding productively.[83] For example, an instructor might ask each team member to share their perspective during a brainstorming session, reinforcing the idea that every voice matters.

Constructive feedback is a vital part of inclusive learning environments. Teams that cultivate a culture of constructive feedback are more inclined to build trust and openness, as members are confident that their inputs will be valued and thoughtfully considered. Feedback mechanisms play a crucial role in sustaining psychological safety. By highlighting constructive, solution-oriented feedback, teams bolster trust and enhance collaboration. Such feedback is instrumental in pinpointing obstacles to progress, recognizing achievements, and promoting ongoing improvement. Resources like peer evaluations, guided reflections, and regular team assessments create opportunities for team members to proactively address concerns. For instance, CATME evaluations enable students to provide feedback in a structured and non-confrontational manner, ensuring issues are addressed constructively.[28] Teams that place a high priority on feedback as a growth tool nurture an environment of psychological safety and resilience.

Improving psychological safety in team-based learning requires a multifaceted approach, focusing on increasing awareness, supporting disadvantaged students (particularly Asian and international students), and fostering inclusivity. By implementing strategies drawn from,[83] educators can create environments where all students feel valued, respected, and empowered to participate. These efforts not only enhance team dynamics but also prepare students for the collaborative challenges of professional engineering practice.

CONCLUSIONS

Team-based learning has become a cornerstone of engineering education, reflecting the collaborative nature of the engineering profession. While pedagogies such as PjBL and PrBL leverage teamwork to enhance problem-solving, communication, and leadership skills, their effectiveness hinges on the dynamics within student teams. This article stresses the critical role of psychological safety in fostering effective and inclusive team-based learning environments, addressing challenges such as social loafing, marginalization, and disengagement. Psychological safety provides a foundation for trust, openness, and collaboration, enabling all students to engage fully and contribute meaningfully to team efforts. Its importance is especially pronounced in diverse and virtual teams, where cultural, linguistic, and contextual differences often introduce additional barriers to participation. Psychological safety is not an inherent feature of student teams but rather a construction that must be deliberately cultivated through targeted strategies. These include increasing awareness of its importance, providing structured support for disadvantaged students, and fostering inclusive practices that celebrate diversity and promote equity. Educators can improve team dynamics and foster equitable,

supportive learning environments by using strategies like evidence-based team formation, reflective practices, and mentorship programs. This approach aims to boost student participation. Moreover, these efforts align with broader educational goals, preparing students to navigate the collaborative demands of their professional careers.

Despite much of the literature framing psychological safety as an emergent property of teams,[84] recent empirical studies suggest that it is more relevant at the individual level, reflecting a person's belief about their comfort in taking interpersonal risks.[73,77] These studies demonstrated that psychological safety is primarily influenced by differences among individuals rather than by team dynamics. This suggests that individuals within the same team may perceive psychological safety differently, leading to a lack of consensus regarding its level within the team. In the context of engineering education, instructors need to pay extra attention to disadvantaged students in teaming and embrace inclusive teaching practices.

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Author contributions
Wei SQ: conceptualization, writing – revising and editing. Han YM: writing – drafting and editing. All authors have read and approved the final version of the manuscript.

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