

Theme Work on Teamwork: Mapping Student Teaming Experiences in Design Projects

Dr. Sara Beckman
Haas School of Business
University of California, Berkeley
Berkeley, CA, USA
<https://orcid.org/0000-0001-9536-2108>

Krina Patel
Department of Mechanical Engineering
University of California, Berkeley
Berkeley, CA, USA
<https://orcid.org/0009-0000-0949-9280>

Qiuquan Gu
Haas School of Business
University of California, Berkeley
Berkeley, CA, USA
<https://orcid.org/0009-0000-9544-7654>

Shang Zhu
Department of Mathematics
University of California, Berkeley
Berkeley, CA, USA
joanna.zhu@berkeley.edu

Alexander Cui
University of California, Berkeley
Berkeley, CA, USA
alexmcui@berkeley.edu

Jacob Yim
Department of Electrical Engineering and Computer Sciences
University of California, Berkeley
Berkeley, CA, USA
jacobyim@berkeley.edu

Abstract— This innovative practice paper presents an analysis of data collected from the implementation of a teaming curriculum, Teaming by Design (TxD), across design and innovation courses. The study examines the successes and challenges identified by both undergraduate and graduate students in their teamwork experiences. The analysis draws on written reflections from 2,621 students enrolled in 47 design and innovation courses at the University of California, Berkeley. The identified themes from student reflections were compared with those derived from a comprehensive review of the teaming literature to pinpoint overlaps and gaps. Our findings reveal opportunities for refining project-based course structures and enhancing teaming pedagogy, with the goal of better equipping students with the essential teamwork skills they will need in their professional careers.

Keywords— *team dynamics, teamwork training, design projects*

I. INTRODUCTION

Teaming, defined as the collaboration of diverse individuals for mutual benefit, is crucial for addressing complex problems by integrating unique skills and enhancing social intelligence [1], [2]. In both educational and interdisciplinary settings, effective teamwork is characterized by interdependent behavior, shared objectives, and the development of collaborative competence, which together lead to more efficient and effective outcomes [1], [2], [3], [4], [5], [6]. Unlike working groups, where individual accountability is prioritized, teams emphasize shared goals, skills, and collective accountability [7].

The importance of team-based learning as a core skill for students is widely recognized. For instance, the ABET accreditation criteria for engineering programs highlight the ability to work effectively in a team as a critical outcome for future engineers [8]. Effective teamwork pedagogy includes not only training in teamwork skills but also addressing common challenges such as social loafing and intragroup conflict [4].

Various models and frameworks exist to guide team learning, including the Input-Process-Outcome model for understanding team processes [9], the Input-Mediator-Output-Input model for understanding the cyclical nature of teams [10], and the Knowledge, Skills, Abilities, and Other framework designed to help team members acquire teamwork competencies [4]. In higher education, fostering teamwork skills and collaborative activities has been shown to enhance academic achievement [4] and critical thinking abilities [11]. These skills are increasingly vital in the context of Industry 4.0, where effective collaboration in hybrid environments and strong interpersonal skills are essential [12]. Despite the emphasis on teamwork in engineering education, there is still a lack of consensus on the specific attributes that contribute to its effectiveness. Our research aims to bridge that gap.

At the University of California, Berkeley, classes in the engineering school employ a Teaming by Design (TxD) curriculum (www.teamingxdesign.com) to cultivate teamwork skills among engineering students. The TxD curriculum is a module designed to be integrated into courses with team-based work. It includes collaborative planning exercises to launch teams, as well as feedback assessments administered during and after the team's work. These assessments provide students and faculty with data to help teams iteratively refine their shared goals, coordination strategies, and interpersonal relationships. The learning outcomes of the TxD framework emphasize purpose, coordination, and trust. At the start of a project, teams identify both shared and individual goals, which are revisited throughout the project. Teams establish norms for effective decision-making, assign roles based on expertise and individual goals, and focus on establishing behavioral norms to enhance and ensure psychological safety within the group. Periodically, students engage in written self-reflection on both overall team performance and the individual contributions of team members. These reflections are summarized and fed back to students to

build self-awareness and develop a shared understanding of how to improve team collaboration and leadership skills. They are also provided to faculty to enhance their understanding of team dynamics and facilitate their coaching and teaching students to become better team members and team leaders.

This paper examines the written reflections of 2,621 students from 47 undergraduate and graduate courses that implemented the TxD curriculum between 2015 and 2023. Through thematic analysis, we identified key themes related to team dynamics as perceived by students. We utilized Large Language Models and Generative AI to assist in managing the extensive qualitative data set and compared these AI-generated themes with those identified with manual tagging of a subset of the data. By analyzing these results relative to themes extracted from existing literature on team dynamics, we highlight areas of alignment and discrepancy in student perceptions of effective teaming. These insights offer guidance for refining project-based course structures and teaming instruction to better prepare students for the collaborative challenges they will face in their professional careers.

II. IDENTIFYING TEAMWORK THEMES

Our research was conducted in two parallel phases. One focused on the academic literature on teaming with the aim of extracting a set of attributes of effective teaming. That work entailed a comprehensive literature review that is summarized here and will be published in a fuller form elsewhere. The other phase focused on the student reflection data and involved extracting themes from that data. The two phases came together as we compared themes from the literature with what students identified as important in their teaming experiences. This section describes our approaches to each of the two phases.

A. Teaming Literature

Our goal was to identify the core attributes of effective team practice through a comprehensive review of the existing literature. This paper summarizes a portion of that review, with plans to present the full scope of our findings in a future publication. We conducted a literature review of teamwork, examining 136 papers, including both original studies and reviews. Through an inductive thematic coding process [13], we distilled the themes from these papers into the 20 most salient ones. Two researchers independently reviewed and coded the literature, capturing definitions and examples from each paper. The shared language across these themes facilitated the grouping of the most common ones, allowing for a clear synthesis of key teamwork attributes.

For this paper, we specifically focused on literature related to engineering [5], [8], [12], [14], [15], [16], [17], [18], [19] and higher education [6], [20]. Our sources included six literature reviews, three journal articles, one dissertation, and three conference proceedings. From there, we refined the 20 initial topics down to the 12 most prominent ones within the engineering and higher education fields, counting their occurrences to identify key trends.

The identified themes are presented in the frequency chart in Figure 1. Conflict and conflict resolution emerged as the most prevalent theme, appearing in all 11 papers. This was closely followed by team goal setting and communication, each

identified in eight papers. These findings suggest that conflict resolution, team goal setting, and effective communication are critical areas requiring focused attention in educational and engineering contexts to foster effective teamwork.

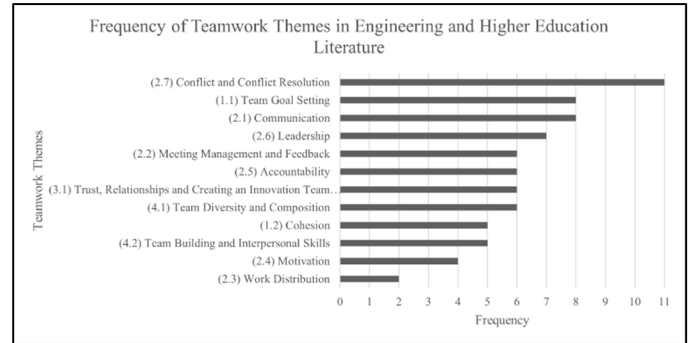


Fig. 1. Frequency Chart for Emerging Teamwork Themes in the Engineering and Higher Education Literature

B. Thematic Coding using ChatGPT and Manual Coding Processes

To capture an understanding of how students viewed important attributes of good and poor teaming, we analyzed data from 2,621 students across 47 classes who participated in the TxD assessments within engineering and design courses at UC Berkeley between 2015 and 2023. Each team consisted of approximately three to seven students and completed between one to five check-ins. The data included student responses to two open-ended questions about their team's performance:

1. "Name one concrete and specific thing that your team is doing well so far that you would like to continue." {DidWell}
2. "Name one concrete and specific thing that you would like your team to do differently." {DoDiff}

The dataset includes 1,421 responses to the {DidWell} question and 1,397 responses to the {DoDiff} question. The difference in response numbers compared to the total number of students is due to partial survey completions. We used SpaCy v2.x (<https://spacy.io/models>) to de-identify personal and sensitive information, and three researchers manually reviewed the resulting dataset to ensure accuracy and prevent any inadvertent alterations.

ChatGPT has been shown to improve the efficiency of thematic analysis, a method used to identify and interpret patterns in qualitative data [21]. Given the large dataset, we leveraged ChatGPT-4 to complement previous manual coding efforts. The {DidWell} and {DoDiff} responses were analyzed separately, with the model identifying 25 unique and distinguishable themes for each set of responses. Each theme was characterized by a one-sentence definition and five exemplary survey responses.

While ChatGPT can enhance research efficiency, it may sometimes "hallucinate" or generate outputs unrelated to the input [21]. To minimize inaccuracies, we carefully reviewed the identified themes. We removed themes unrelated to teamwork attributes such as those speaking to tools taught in class, such as "user interviews" and "prototyping," or to specific project

outcomes such as “reducing homelessness.” We also removed themes related to “professionalism” and “training,” for which the identified survey responses were better aligned with other themes. Cross-checking the AI-generated themes with manual coding increased our confidence in the accuracy of the final themes.

Through an iterative process of refining the themes using both ChatGPT and manual review, we reduced the number of themes from the student responses to 10 (Table 1). Three of the themes – Cohesion (1.2), Motivation (2.4), and Teaming Building and Interpersonal Skills (4.2) – were identified through manual coding and the other seven through interaction with ChatGPT. While we are confident in the quality of these identified themes, we determined that ChatGPT was not reliable enough for accurately tagging individual responses to obtain a frequency count.

TABLE I. TEAMWORK THEMES IN THEMATIC CODING OF STUDENT RESPONSES

<i>Teamwork Theme</i>	<i>Manual Thematic Coding of Student Responses</i>	<i>GPT Thematic Coding of Student Responses</i>
(1.1) Team Goal Setting	X	X
(1.2) Cohesion	X	
(2.1) Communication	X	X
(2.2) Meeting Management and Feedback	X	X
(2.3) Work Distribution	X	X
(2.4) Motivation	X	
(2.5) Accountability	X	X
(2.6) Leadership	X	X
(3.1) Trust, Relationships and Creating an Innovation Team Climate	X	X
(4.2) Team Building and Interpersonal Skills	X	

III. MAPPING TEAMWORK THEMES

Now we turn to examine the similarities and differences between our two sets of data – the themes identified in the literature review (Figure 1) and those extracted from student responses (Table 2). First, we note that student responses did not reflect two themes that were prominent in the teaming literature: Conflict and Conflict Resolution (2.7) and Team Diversity and Composition (4.1). In the case of team diversity and composition, students often do not control team assignments, so cannot influence the composition of the teams.

In the following sections, we unpack each of the themes, comparing what the literature says about each with student comments. The unpacking is presented in three sections that mirror the TxD curriculum: purpose or goal setting (themes 1.1-1.2); coordination, including communication, roles and responsibilities, and work distribution (themes 2.1-2.7); and trust or psychological safety (theme 3.1). Themes 4.1 and 4.2 are not explored in this study, as student responses did not clearly reflect these themes. We hope to explore these themes further in future studies.

TABLE II. TEAMWORK THEMES IN THEMATIC CODING OF STUDENT RESPONSES

<i>Teamwork Theme</i>	<i>Themes from Student Responses</i>	<i>Themes from Literature Review</i>
(1.1) Team Goal Setting	X	X
(1.2) Cohesion	X	X
(2.1) Communication	X	X
(2.2) Meeting Management and Feedback	X	X
(2.3) Work Distribution	X	X
(2.4) Motivation	X	X
(2.5) Accountability	X	X
(2.6) Leadership	X	X
(2.7) Conflict and Conflict Resolution		X
(3.1) Trust, Relationships and Creating an Innovation Team Climate	X	X
(4.1) Team Diversity and Composition		X
(4.2) Team Building and Interpersonal Skills	X	X

A. Team Goal Setting (1.1) and Cohesion (1.2)

The teaming literature suggests that, for effective teamwork, teams should have a common goal and be clear about their purpose within the team [22]. Team members should clearly understand their roles and responsibilities while ensuring everyone agrees on the shared objectives, values, and beliefs [6], [22], [23], [24]. Shared commitment to achieving the team’s goals and objectives and working together increases team cohesion, the degree to which team members bond and connect [25]. Prior research on the dataset used for this paper shows that while students highly rate their team’s agreement on a shared goal, they rarely concur when asked to state those goals [18]. Teams with a more equitable work distribution were more likely to achieve their shared goals and have team cohesion than teams with inequitable workloads [26].

In reflections on their overall team performance, students identify the need for clear goals, particularly related to the quality of their output. Some identify the benefits of navigating goal congruence, saying that the team effectively: “narrowed down what our final project was going to be and started working on it without too much back and forth on what we should create.” Others recognize the need to get better and “be more clear about our direct, short-term goals and objectives,” while some focus on the future, suggesting, “we need to come up with a solid long-term plan for the next 3 weeks.” Thus, although goal congruence among their stated goals is low [18], they recognize the need for managing goals on their teams.

B. Coordination

Coordination involves setting team norms and procedures for communication, including meeting management, work allocation and associated accountability, and decision-making, including conflict resolution and establishing roles and responsibilities, which may evolve over time.

1) Communication (2.1) and Meeting Management (2.2)

Teaming literature shows that teams that collectively share information both online and in person enhance the team's collective knowledge and help with decision-making [27], [28], [29]. Consistent information sharing and a better understanding of the team's shared goal also improve the team's coordination [29]. Team members can effectively utilize team meetings, whether informal or formal, to share information and discuss team progress [30]. However, by having well-structured meetings that promote adaptability and effective decision-making, team members' productivity can be significantly improved [6], [30].

Students regularly identify communication as a team challenge without the nuance described in the literature. General statements, such as "in future teams, I would like to have more communication overall in the team, not just when deadlines are approaching," recognize communication challenges but do not have a detailed understanding of different purposes of communication or connection of purpose to mode of communication. A frequent response to what they would do differently is simply "communicate better" or "communicate." Although not analyzed in this paper, we note that communication is often highlighted in the individual feedback students give to one another, in which they request more responsiveness, transparency, and clarity in individual communications from their teammates.

Students recognize the value of regular and consistent meetings, including effective brainstorming, discussion, and respectful and understanding attitudes. They also seek equal participation among team members and more effective meeting management. Some explicitly recognize the connection between meetings and team performance: "we should establish a more regular meeting time outside of class to create a better teaming and communicative experience." Others indirectly acknowledge the value of "hav[ing] more in-person meetings."

2) Work Distribution (2.3), Motivation (2.4), and Accountability (2.5)

Effective work distribution within a team involves allocating tasks among members to balance individual demands and optimize team performance, especially under uneven workload conditions [31], [32]. An optimal distribution of work enhances teamwork by ensuring all members are adequately supported and utilized, thereby facilitating improved communication, coordination, and overall team dynamics [32]. Commitment within a team is defined by members investing time and effort to achieve shared objectives, often setting aside personal interests to enhance team performance [6], [33]. This commitment is crucial for the team's success. It is supported by accountability measures that ensure each member actively contributes to the team's goals, with strategies such as strict supervision, engaging group talks, and documenting roles to prevent free-riding and boost morale [5], [24], [32], [33]. Additionally, creating an environment that recognizes individual contributions can further enhance motivation within the team, fostering a positive cycle of engagement and productivity [16], [24].

Work distribution is a big topic on student teams. When done well, they highlight clear role definition, efficient

communication, collaborative teamwork, positive attitudes, support for one another, and meeting deadlines. One student writes, "we made sure to spread the work as evenly as possible and check on each other." Another comment, "we did a good job of allocating based on skill and interest and not just assigning parts randomly." When they struggle, they highlight poor time management, inappropriate task distribution, and the need for more proactive engagement and better collaboration. Some make concrete suggestions such as having more open discussion and "starting a table with each assignment's work split up so that everyone gets a chance to contribute every time."

Unlike many work environments they will experience post-graduation, student teams must negotiate work distribution among themselves. Thus, time management is a big issue, often due to their competing priorities. Some teams manage time well and describe their teams as "...consistently organized and prepared for deadlines well ahead of time" and "completing tasks promptly." But, many emphasize the need to "start things earlier" and "plan ahead more." Others wish for more organization, suggesting that the team "create more of a timeline so things are done in a timely manner creating less pressure" and "be more clear on what has to get done by a certain time."

We note that while free-riding is highlighted in the literature [5], TxD survey results suggest a more nuanced interpretation is merited and that free-riding is rarely the student's express intent. Teammates of students who are seen to be contributing less than their fair share often describe those underperforming teammates as having challenges of some sort and are willing to step in and support them. Unbalanced or unequal contributions are often rebalanced by the end of a project as shown by a more equal distribution of points across student teams.

3) Roles and Responsibilities, Including Leadership (2.6)

Effective team leadership is essential as it establishes and nurtures team norms that foster an environment of open communication, mutual respect, and shared accountability. At the same time, organizational support creates a holistic ecosystem that sets the tone of daily interaction and provides the necessary infrastructure for collaborative endeavors to thrive [6]. Rotating the leadership role has resulted in higher levels of cooperation and performance on student teams by helping students understand expectations, encouraging individuals to contribute fairly, and enabling students to experience group work as more rewarding and productive [11]. Teams must understand their roles and relationships [34], [35] recognizing team members' diverse strengths, facilitating effective work division, and highlighting individual contributions to the team's success.

Students acknowledge teammates who show leadership in project management roles or task-related outputs. Some students recognize their team's responsibility and role assignment strategy: "one person to lead each assignment" and "team leads that guide each meeting and assign roles." Other students hope the team can improve by "set[ting] up a leader," and "tak[ing] initiative more often in guiding the project." Interestingly, one student suggests, "make one person the permanent leader rather than a rotational leader," while another hopes "everyone can practice contributing and leading." They implicitly acknowledge leadership in speaking to their teammates'

proactivity (or lack thereof). In other data gathered through the TxD assessments, there are frequent instances of teams for which all team members identify one specific individual as the team leader, and that individual identifies someone else. The dynamics of student teams suggest that students prefer not to take on the role of “leader” among their peers.

In their collaborative plans, students often say that they will designate roles on the team based on the strengths of individual team members. Rarely do they suggest that they will allocate based on the desired learning outcomes of team members. One student comments, “we concretely distribute roles amongst the team and provide a clear guideline on what our tasks are.” Another student points out that the team should “support each other whenever we can and not be strictly confined to ‘roles.’” Another student recommended that the team have “more integration and collaboration across separate roles.”

4) Decision Making and Conflict Management (2.7)

Teams can experience various types of conflicts related to interpersonal relationships, tasks, and processes [36], [37]. When teams constructively manage their disagreements, they improve their teamwork skills, particularly problem-solving [6]. Existing research suggests in-person communication is the most effective way to resolve conflict [5]. Furthermore, teams can develop norms and strategies in the beginning for managing future conflicts in a productive manner [17].

Despite its importance in the literature, our analysis of student feedback did not surface conflict management as one of the overall themes. A search for the term conflict in the raw data surfaced only eight entries, among which five refer to “time conflict.” The small number of mentions did acknowledge positively that the team “resolves conflicts quickly” and, conversely, a need to “communicate about conflicts/challenges more proactively.” A related search on the use of the terms “agree” and “disagree” yielded 18 entries. One participant writes, “we seem to agree on many things and not argue very much,” while another participant says they “try to be less frustrated when I disagree with the group.”

C. Trust, Relationships, and Creating an Innovation Team Climate (3.1)

Psychological safety, essential for effective teamwork, enables team members to take interpersonal risks without fear of backlash [10]. Psychological safety is bolstered by mutual support and proactive communication, key elements in fostering trust and respect, especially within engineering education [8], [22], [32]. The resulting sense of social cohesion promotes interdependence and learning, which are critical for enhancing team dynamics and performance [38], [39]. Effective team-building strategies focusing on camaraderie and interpersonal interactions contribute significantly to a team's effectiveness [40]. An innovation climate is a shared commitment to novel solutions, emphasizing the collective belief systems and operational methods underpinning innovative endeavors [41]. This climate is about generating ideas and their execution towards impactful outcomes. Autonomy, impact, competence, and meaningfulness promote team members' deep engagement, creating a fertile environment for innovation and enhancing team performance [41].

Extracting themes from the student data yields no category related to psychological safety. A manual review of the data reveals that a small number of student responses include related words such as “trust,” “relationship,” and “camaraderie.” One student commented, “our team is supportive of one another's ideas and has a high amount of trust in one another.” Another student hoped their team could “better encourage and trust team members to do more things that could further improve our project.” Elsewhere in the TxD assessment, students provide individual feedback to one another, and they allude to relationship issues in those responses. However, there are few references in the overall team performance data.

Creativity does arise because the teams in the classes that use the TxD curriculum are engaged in design and innovation projects. Students speak directly to the team's creativity, explicitly addressing the many aspects where creativity is applied. For example: “we have creative and unique ideas,” “our project idea and mechanism are creative and meaningful,” [we employ] “creative process and skills,” and [we] “develop creative solutions to the problems we ran into.” They also identify ideation and brainstorming as activities with a positive team dynamic: “we are able to generate great ideas and next steps forward whenever we discuss among ourselves.” They include references to inclusivity in the creative process: “I think we are very good at listening to each other's ideas and bundling them in the brainstorming process. I never feel like I would be judged for contributing even if it's a bad idea” and “we had good idea sharing, and everyone contributed to ideation.”

IV. DISCUSSION

We have compared teamwork themes captured in a review of the teaming literature with teaming elements that surfaced in teaming assessments administered to students in engineering and design courses. The gaps in student representation of salient elements of good teaming represent opportunities to consider ways to reimagine the teaming curriculum and enhance the pedagogy in team-based courses in general. We summarize identified gaps and associated opportunities here.

Goal setting (1.1): Student comments suggest agreement that goal setting is important, but they struggle to achieve goal congruence [18]. More explicit attention by faculty to goal setting as teams are launched, including identifying different types of goals (e.g., achievement-focused, learning-focused, project outcome-focused), facilitating identification of shared versus individual goals, connecting goals to class learning outcomes, and then engaging students to revisit goals throughout a project as a new understanding of the project context is surfaced will ultimately support improved team cohesion and performance [22].

Communication (2.1): While students are facile in finding various communication channels (e.g., WhatsApp, Google Drive), they lack nuance in their comments concerning connecting modes of communication to desired outcomes for that communication. The teaming literature provides frameworks around elements such as information sharing and perspective-taking that might be introduced to students at team launch and/or used to help teams that surface communications issues in team assessments [8].

Work distribution (2.3), role designation, and leadership (2.6): Student experiences with these categories may vary substantially from team experience in practice. Unlike in practice, students prefer to work non-hierarchically [43] without a designated leader [44], and allocate work through relatively democratic processes [6]. Our data shows they struggle with work distribution and associated accountability. From a pedagogical perspective, this raises questions about whether team-based courses should be structured in ways that better mimic practice, such as enforcing the adoption of leadership roles and providing concrete means of ensuring accountability on a team. Conversely, as our data analysis shows and, as in practice [34], students often allocate work based on individual strengths. From a learning perspective, however, it might be best if faculty encouraged more peer-to-peer learning by having students take on tasks in which they lack strength and then teach skills to one another.

Conflict management (2.7): Conflict is ubiquitous and critical to team performance [6]. Students' minimal mention of conflict raises broader questions about why [19]. Students might be better armed with both acknowledgment that conflicts will arise and are important to the creative process and with tools for de-escalating and coping with conflict.

Psychological safety (3.1): Creating psychological safety is, perhaps, the “fuzziest” of the team performance attributes and, thus, the least likely to be addressed directly by faculty [45] and students (as evidenced by our data). While it might appear to faculty that taking time away from the content of the course or the tasks to be done is problematic, staging short exercises during class related to building trust and letting students get to know one another better can show students that faculty value these elements of teaming and proffer significant dividends in improved team cohesion and performance [44].

In all these areas, one might also leverage AI to support faculty in evaluating team performance and enhancing student learning about teaming. It might be used, for example, to evaluate a goal-setting exercise as students capture their individual and team goals and get both evaluative feedback and suggested improvements, with the logic behind those suggestions, in real time.

Our dataset represents just one university, so it may have sample bias from the perspectives of both the students and researchers. The focus of our paper was limited to examining the answers provided by students to two open-ended questions in the check-in surveys. To get a comprehensive understanding of the students' teamwork experiences from different viewpoints, we suggest conducting future studies that involve cross-referencing the self-reported responses to those of their teammates and using a mixed-method approach to avoid bias from the researchers. Although we have triangulated data from manual coding, various LLMs, and generative AI, there may be errors in identifying themes in the literature review and student data analysis.

This research might go in many directions. First, it opens the door to brainstorming alternative interventions that might be made to increase student exposure to the under-identified teaming constructs captured here. Second, it begs a deeper dive into some elements, such as why conflict resolution is not fully

represented in their feedback. Third, several opportunities exist to triangulate the data analyzed for this paper with other data in the survey, such as Likert-scale evaluations of team performance and individual feedback provided to other teammates. In all cases, the objective is to improve our understanding of how teaming can be learned in classes where the topic is not the primary focus of the class. We seek to improve student learning in as many team-based classes as possible, including allowing students to scaffold that learning longitudinally across multiple team experiences.

V. CONCLUSION AND FUTURE PLAN

Our study highlights the discrepancies between students' teaming experiences and the existing literature on teamwork, highlighting the need for diverse approaches to teamwork assessment. Additionally, project-based course structures and teaming pedagogy may need to be revised to better align with student needs and serve as guidelines for educators to prepare engineering students for the demands of a team-based workplace. To address these issues, the TxD team is researching the application of Artificial Intelligence to analyze student feedback from check-in surveys, both quantitative and qualitative, to extract deep insights that can be directly provided to educators and students. This approach addresses the deficiencies in implementing teaming pedagogy in engineering classrooms by offering actionable recommendations to educators and students.

ACKNOWLEDGMENT

We thank members of the Teaming by Design research and teaching team, both past and present, without whom this paper would not have been possible.

REFERENCES

- [1] J. A. Bruce and K. G. Ricketts, “Where’s All the Teamwork Gone? A Qualitative Analysis of Cooperation between Members of Two Interdisciplinary Teams,” *Journal of Leadership Education*, vol. 7, no. 1, pp. 65–76, Jun. 2008, doi: <https://doi.org/10.12806/v7/i1/rf3>.
- [2] S. M. Fiore, “Interdisciplinarity as Teamwork,” *Small Group Research*, vol. 39, no. 3, pp. 251–277, Jun. 2008, doi: <https://doi.org/10.1177/1046496408317797>.
- [3] A. Volkov and M. Volkov, “Teamwork and Assessment: A Critique,” *E-Journal of Business Education & Scholarship of Teaching*, vol. 1, no. 1, pp. 59–64, 2007.
- [4] L. Riebe, A. Girardi, and C. Whitsed, “A Systematic Literature Review of Teamwork Pedagogy in Higher Education,” *Small Group Research*, vol. 47, no. 6, pp. 619–664, Sep. 2016, doi: <https://doi.org/10.1177/1046496416665221>.
- [5] M. F. Ercan and R. Khan, “Teamwork as a fundamental skill for engineering graduates,” *2017 IEEE 6th International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, Dec. 2017, doi: <https://doi.org/10.1109/tale.2017.8252298>.
- [6] C. Newell and A. Bain, *Team-Based Collaboration in Higher Education Learning and Teaching: A Review of the Literature*. Springer, 2018.
- [7] J. R. Katzenbach and D. K. Smith, *The Wisdom of Teams : Creating the high-performance Organization*. Boston, Massachusetts: Harvard Business Review Press, 1993.
- [8] T. Chowdhury and H. Murzi, “Literature review: Exploring teamwork in engineering education,” in *Proceedings of the Conference: Research in Engineering Education Symposium*, Cape Town, South Africa, 2019, pp. 10–12.

- [9] R. Knapp, "Collective (Team) Learning Process Models: A Conceptual Review," *Human Resource Development Review*, vol. 9, no. 3, pp. 285–299, Jun. 2010, doi: <https://doi.org/10.1177/1534484310371449>.
- [10] A. Edmondson, "Psychological safety and learning behavior in work teams," *Administrative Science Quarterly*, vol. 44, no. 2, pp. 350–383, Jun. 1999, doi: <https://doi.org/10.2307/2666999>.
- [11] C. J. Finelli, I. Bergom, and V. Mesa, "Student Teams in the Engineering Classroom and Beyond: Setting up Students for Success. CRLT Occasional Paper No. 29," *ERIC*, 2011. <https://eric.ed.gov/?id=ED573963>
- [12] T. M. Chowdhury and H. Murzi, "The Evolution of Teamwork in the Engineering Workplace from the First Industrial Revolution to Industry 4.0: A Literature Review," in *2020 ASEE Virtual Annual Conference Content Access*, 2020.
- [13] J. Saldaña, *The Coding Manual for Qualitative Researchers*, 4th ed. Los Angeles: Sage, 2021.
- [14] M. AL-Rawi and A. Auckaili, "Literature review: Effective teamwork and team diversity in engineering education," *Australasian Association for Engineering Education*, 2020.
- [15] P. L. Hirsch and A. F. McKenna, "Using reflection to promote teamwork understanding in engineering design education," *International Journal of Engineering Education*, vol. 24, no. 2, pp. 377–385, Apr. 2008.
- [16] E. Kim, "A Systematized Literature Review of the Characteristics of Team Mental Models in Engineering Design Contexts," in *Proceedings of the 2019 ASEE Annual Conference & Exposition*, Jun. 15, 2019.
- [17] M. Borrego, J. Karlin, L. D. McNair, and K. Beddoes, "Team Effectiveness Theory from Industrial and Organizational Psychology Applied to Engineering Student Project Teams: A Research Review," *Journal of Engineering Education*, vol. 102, no. 4, pp. 472–512, Oct. 2013, doi: <https://doi.org/10.1002/jee.20023>.
- [18] S. Beckman, A. Jian, A. Sabharwal, and K. Goucher-Lambert, "EXAMINING GOAL CONGRUENCE ON ENGINEERING DESIGN AND INNOVATION STUDENT TEAMS," *The ASME International Design Engineering Technical Conferences*, 2021.
- [19] K. Patel and K. Jablow, "Conflict in the Classroom: An Exploration of the Role of Conflict in Engineering Teams," *The Pennsylvania State University*, 2022. <https://catalog.libraries.psu.edu/catalog/38042002>
- [20] B. Mennecke, J. Bradley, and M. Mcleod, "The impact of group process training and role assignments on the performance and perceptions of student iS project teams," *Journal of Informatics Education and Research*, vol. 1, no. 1, pp. 30–36, Oct. 1999.
- [21] V. Lee, S. van der Lubbe, L. H. Goh, and J. M. Valderas, "Harnessing ChatGPT for thematic analysis: Are we ready?," *Journal of Medical Internet Research*, vol. 26, pp. e54974, 2024.
- [22] M. F. R. Kets. De Vries, "High-performance teams: Lessons from the pygmies," *Organizational Dynamics*, vol. 27, no. 3, pp. 66–77, Dec. 1999, doi: [https://doi.org/10.1016/s0090-2616\(99\)90022-0](https://doi.org/10.1016/s0090-2616(99)90022-0).
- [23] D. Francis, D. Young, and Internet Archive, *Improving work groups: a practical manual for team building*. San Diego, Calif. : University Associates, 1979.
- [24] W. Ziegler, "Teaching and Assessing Teamwork: Including a Method (That Works) to Determine Individual Contributions to a Team Introduction," in *2003 ASEE Annual Conference*, Jun. 2003, doi: <https://doi.org/10.18260/1-2--11593>.
- [25] E. Salas, R. Grossman, A. M. Hughes, and C. W. Coultas, "Measuring Team Cohesion," *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 57, no. 3, pp. 365–374, Apr. 2015, doi: <https://doi.org/10.1177/0018720815578267>.
- [26] S. B. Feichtner and E. A. Davis, "Why Some Groups Fail: a Survey of Students' Experiences with Learning Groups," *Journal of Management Education*, vol. 9, no. 4, pp. 58–73, Nov. 1984, doi: <https://doi.org/10.1177/105256298400900409>.
- [27] G. Stasser and W. Titus, "Pooling of unshared information in group decision making: Biased information sampling during discussion," *Journal of Personality and Social Psychology*, vol. 48, no. 6, pp. 1467–1478, Jun. 1985, doi: <https://doi.org/10.1037/0022-3514.48.6.1467>.
- [28] G. Stasser and W. Titus, "Effects of information load and percentage of shared information on the dissemination of unshared information during group discussion," *Journal of Personality and Social Psychology*, vol. 53, no. 1, pp. 81–93, 1987, doi: <https://doi.org/10.1037/0022-3514.53.1.81>.
- [29] J. R. Mesmer-Magnus and L. A. DeChurch, "Information sharing and team performance: A meta-analysis," *Journal of Applied Psychology*, vol. 94, no. 2, pp. 535–546, 2009, doi: <https://doi.org/10.1037/a0013773>.
- [30] J. E. Mroz, J. A. Allen, D. C. Verhoeven, and M. L. Shuffler, "Do We Really Need Another Meeting? The Science of Workplace Meetings," *Current Directions in Psychological Science*, vol. 27, no. 6, pp. 484–491, Oct. 2018, doi: <https://doi.org/10.1177/0963721418776307>.
- [31] C. O. L. H. Porter, C. Itir Gogus, and R. C.-F. Yu, "When Does Teamwork Translate Into Improved Team Performance? A Resource Allocation Perspective," *Small Group Research*, vol. 41, no. 2, pp. 221–248, Feb. 2010, doi: <https://doi.org/10.1177/1046496409356319>.
- [32] K. A. Smith, *Teamwork and Project Management*. McGraw-Hill Education, 2013.
- [33] P. Brackin and J. Williams, "Teaching And Assessing Teaming Skills In A Senior Level Design Course," in *Proceedings for the ASEE Annual Conference and Exposition*, Jun. 24, 2001.
- [34] P. R. Harris and K. G. Harris, "Managing effectively through teams," *Team Performance Management: An International Journal*, vol. 2, no. 3, pp. 23–36, Sep. 1996, doi: <https://doi.org/10.1108/13527599610126247>.
- [35] B. S. Gardner and S. J. Korth, "A Framework for Learning to Work in Teams," *Journal of Education for Business*, vol. 74, no. 1, pp. 28–33, Sep. 1998, doi: <https://doi.org/10.1080/08832329809601657>.
- [36] K. A. Jehn and E. A. Mannix, "The Dynamic Nature of Conflict: A Longitudinal Study of Intragroup Conflict and Group Performance," *Academy of Management Journal*, vol. 44, no. 2, pp. 238–251, Apr. 2001, doi: <https://doi.org/10.5465/3069453>.
- [37] F. R. C. de Wit, L. L. Greer, and K. A. Jehn, "The paradox of intragroup conflict: A meta-analysis," *Journal of Applied Psychology*, vol. 97, no. 2, pp. 360–390, 2012, doi: <https://doi.org/10.1037/a0024844>.
- [38] J. T. Scarnati, "On becoming a team player," *Team Performance Management: An International Journal*, vol. 7, no. 1/2, pp. 5–10, Feb. 2001, doi: <https://doi.org/10.1108/13527590110389501>.
- [39] M. A. Campoin, G. J. Medsker, and A. C. Higgs, "Relations between work group characteristics and effectiveness: Implications for designing effective work groups," *Personnel Psychology*, vol. 46, no. 4, pp. 823–847, Dec. 1993, doi: <https://doi.org/10.1111/j.1744-6570.1993.tb01571.x>.
- [40] C. Klein et al., "Does Team Building Work?," *Small Group Research*, vol. 40, no. 2, pp. 181–222, Jan. 2009, doi: <https://doi.org/10.1177/1046496408328821>.
- [41] M. A. West, "The social psychology of innovation in groups," in *Innovation and creativity at work: Psychological and organizational strategies*, Eds, Chichester, England: John Wiley & Sons, 1990, pp. 309–333.
- [42] B. Kirkman, G. Chen, and J. Mathieu, "Improving employee performance by developing empowering leaders & companies," *Behavioral Science & Policy*, vol. 6, no. 1, pp. 23–36, 2020.
- [43] C. L. Outcalt, S. K. Faris, K. N. McMahon, and A. W. Astin, *Developing non-hierarchical leadership on campus : case studies and best practices in higher education*. Westport, Conn.: Greenwood Press, 2001.
- [44] J. E. Mathieu, M. R. Kukenberger, L. D'Innocenzo, and G. Reilly, "Modeling reciprocal team cohesion–performance relationships, as impacted by shared leadership and members' competence," *Journal of Applied Psychology*, vol. 100, no. 3, pp. 713–734, 2015, doi: <https://doi.org/10.1037/a0038898>.
- [45] S. Wei and M. W. Ohland, "The Relative Importance of Team Dynamics in Predicting Effective Teamwork Behaviors," *IEEE Xplore*, Oct. 01, 2021.