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Collaborative (in)decision: A Preliminary Investigation of the Differences in Undergraduate Engineering Capstone Students' Collaborative Behaviors

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This study investigates differences in collaborative behaviors among undergraduate engineering capstone students through a behavioral sorting methodology. Using the Comprehensive Assessment of Team Member Effectiveness Behaviorally Anchored Rating Scale (CATME-B), 25 students from a senior-level interdisciplinary engineering capstone course sorted collaborative behaviors according to their observed frequency in collaborative experiences. The sorting revealed patterns worth further investigation across technical/task-oriented, process-oriented, and interpersonal/social dimensions of collaboration, with variations emerging between demographic groups. Technical behaviors showed consistent observation across the sample, while process-oriented and interpersonal behaviors exhibited notable variability. The initial results suggest that collaborative behaviors may be influenced by sociocultural dynamics, with students adapting their engagement strategies in response to identity-related and culturally situated contexts. This preliminary investigation indicates the need for further research to examine how students' perceptions and attitudes toward collaborative behaviors influence their engagement in engineering group work; particularly focusing on the relationships between individual beliefs, group contexts, and behavioral choices. Such understanding could inform theoretical models of engineering collaboration and guide the development of evidence-based approaches to collaborative learning.

Keywords: collaborative behaviors; capstone projects; collaborative effectiveness; collaboration dynamics; CATME; Reasoned Action Approach (RAA)

1. Introduction

Engineering is a fundamentally social and collaborative discipline. A so-called "large collaboration performance" [1, p. 240], engineering necessitates interdisciplinary collaboration from diverse expertise. Modern engineering challenges exacerbate the need for collaborative-minded engineers, as their complexity and growing global footprint demand working across cultures, systems, and disciplines [2]. To illustrate this point, ITER, the ongoing international effort to build the largest tokamak fusion generator, has members from 33 countries, speaking over 40 languages [3]. Such problems and large-scale projects require engineers to be comfortable negotiating group dynamics and socially influenced environments.

Recognizing this need, collaboration has received significant attention in engineering education. Accreditation requirements, including ABET, emphasize collaborative competencies, requiring accredited programs to increase their focus on such experiences in engineering curricula [4]. Cultivating collaborative skills and behaviors often manifests in project- and group-based learning experiences, such as capstone design projects and design teams [5]. These experiences provide students with learning opportunities beyond those emphasized by traditional technical course material, helping students develop their engineering identities and real-world skills [6]. To assess this development, researchers have investigated collaborative behaviors as the skills demonstrated by an individual group member that contribute to the functioning of a collaborative engineering project. Engineering collaborative behaviors are specific, observable actions that include both task-oriented and interpersonal/social behaviors, and are typically assessed via peer evaluations and self-report measures [7]. One such measure, the Comprehensive Assessment of Team Member Effectiveness Behaviorally Anchored Rating Scale (CATME-B) [8], is a widely used tool designed to assess individual contributions to collaboration. CATME-B consists of five dimensions of team member effectiveness: contributing to the team's work, interacting with teammates, keeping the team on track, expecting quality, and having relevant knowledge, skills, and abilities. Each dimension is identified by concrete behavioral descriptors at varying perfor-

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mance levels, making abstract concepts of collaborative effectiveness more tangible for evaluation.

Framing collaboration as specific, observable behaviors provides clear anchors for assessment and developmental feedback. However, collaborative behaviors, like all behaviors, are highly dependent on context and the individuals involved. For instance, various setting, situation, and personal-related factors influence the words we use and the arguments we offer. These varied contextual elements influence how behaviors are perceived and enacted [9], making it crucial not only to consider *what* constitutes a collaborative behavior but also *who* is demonstrating it and *why*. There is a need to explore students' perceptions of collaborative behaviors and the importance of considering the problem and contexts that locate and shape them. Current assessment methods often overlook the individual's role in and perspective on collaboration, presenting an opportunity for a more nuanced analysis of specific behaviors, particularly regarding students' perceptions and the impacts of those behaviors.

This preliminary study asks whether students from a single senior-level engineering capstone course report differences in how frequently various collaborative behaviors occur within their groups. Accordingly, we posed the following research question to guide our investigation: "*Do senior-level capstone engineering students perceive differences in the frequency of collaborative behaviors within their collaborative groups?*" To address this question, students were asked to complete a behavioral sorting task (adapted from a Q-Sort approach) in which they arranged a set of collaborative behavior statements according to how often they had observed each behavior in their capstone group experiences. We then analyzed the sorting results to identify patterns in both frequently observed and infrequently observed behaviors. By investigating the relationship between individuals and collaborative behaviors, this study provides initial insights and motivates further research to understand the perception, influence, and effects of these behaviors; insights with implications for curriculum design and collaboration-based learning strategies.

2. Literature Review

In this study, we explored students' experiences of collaborative behaviors in engineering, recognizing that collaboration is highly contextual and dynamic. This approach diverges from traditional assessments of collaboration by emphasizing the students' perceptions of collaborative behaviors and recognizing the influence of the task, group composition, and prior experience in shaping students' behavior. In this section, we first review collaborative behaviors: the skills and actions enacted by students during collaboration. We then consider how collaborative behaviors are typically evaluated and how many of these approaches inadequately consider students' perspectives and the broader collaborative environment.

2.1 Collaborative Behaviors in Engineering Education

Collaboration is central to engineering practice, which itself has been conceptualized as a "large collaboration performance" [1, p. 240]. However, much of engineering teaching and learning concerns developing technical knowledge and expertise, despite engineering practice's fundamental dependency upon successful collaboration [6]. In this respect, engineering education often emphasizes technical skills at the expense of developing collaborative capabilities. Educators similarly must recognize that simply placing engineers in groups does not guarantee effective collaboration [10]. Engineering programs, therefore, must intentionally prepare students for the collaborative demands of their future careers, where they will need to engage in life-long learning, work across disciplines, and address ill-structured, complex problems [11, 12]. To develop engineering students as effective collaborators, researchers have suggested possible group-related behaviors that contribute to successful collaboration. These "collaborative behaviors" are specific, observable actions that enhance a group's effectiveness [7]. They encompass both task-oriented activities and social interactions, reflecting the multi-dimensional nature of engineering collaboration in real-world practice. For example, identifying the collaborative behaviors performed by different students in a group could reveal those who are poorly functioning or students who need extra support. In this sense, framing students' group-based interactions through the lens of collaborative behaviors can guide interventions and inform the design of assessments for collaboration [8, 13, 14].

Researchers have identified many behaviors necessary for effective collaboration among engineering students and practitioners. The CATME framework [7] provides a starting point for examining these behavioral patterns, and was organized through an extensive review of teamwork literature. It includes five key categories of team member effectiveness that each contain several sub-items: (1) Contributing to the team's work, (2) Interacting with teammates, (3) Keeping the team on track, (4) Expecting quality, and (5) Having relevant knowledge, skills, and abilities (KSAs). For example, "Contributing to the team's work" includes items such as, "Did a fair share of the team's work," "Arrived on time for team meetings," and "Helped teammates who were having difficulty." Similarly, some items from the category "Expecting quality" were, "Cared that the team produced high-quality work" and "Wanted the team to excel at its work." The CATME instrument thus provides an empirically-based framework for evaluating team member effectiveness across multiple dimensions, with each dimension measured by multiple items on a Likert scale to ensure reliability and capture different aspects of collaboration.

Building on this foundation, Ohland and colleagues [8] enhanced CATME's practical utility by developing behaviorally anchored rating scales (BARS). The BARS format defines specific behaviors at different levels of proficiency, allowing assessments based on observable actions. They defined three performance levels for each CATME dimension: 1 – poor/unsatisfactory performance (common complaints about poor group members), 3 – satisfactory performance (typical/average group member contributions), and 5 – excellent performance (going above basic requirements). Levels 1, 3, and 5 contain multiple items per collaborative behavior dimension, resulting in a range of tangible behaviors students have likely seen before. To illustrate, for the category "Interacting with teammates," a level 1 performer "Complains, makes excuses, or does not interact with teammates. Accepts no help or advice." A level 3 performer "Communicates clearly. Shares information with teammates. Participates fully in team activities." A level 5 performer "Improves communication among teammates. Provides encouragement or enthusiasm to the team." Levels 2 and 4 do not have explicitly specified behaviors but are provided as "in-between" options for students. This tiered behavioral description allows students to evaluate themselves and their peers with a clear understanding of how different tangible behaviors reflect different levels of collaborative effectiveness.

2.2 Assessment of Collaborative Behaviors

Assessing collaborative behaviors and collaboration in engineering education has utilized both qualitative and quantitative methods to capture the complexity of group dynamics. These assessments examine both the processes and outcomes of collaboration among engineering students. A common approach is self- and peer assessment where students reflect on their contributions and evaluate their groupmates' performances. Such assessments typically use structured questionnaires or rating scales to measure aspects of collaboration, such as communication effectiveness, leadership, responsibility, and conflict resolution. As mentioned, the CATME-B scale [7] provides defined dimensions of contributions that students can reference when evaluating themselves and others. Similarly, the Team Process Check (TPC) instrument focuses on group function, covering areas such as communication, task management, decision-making, and conflict resolution [15]. Researchers have also drawn from other disciplines to assess collaborative skills among undergraduate engineering students (e.g., [16]). These standardized instruments are administered to evaluate perceptions of collaboration and are valuable for capturing subjective experiences and identifying areas for improvement in collaboration.

Besides self- and peer-report approaches, researchers have directly observed student-group interactions to investigate collaboration. Observational methods often involve recording, identifying, and categorizing behaviors during collaborative tasks to identify patterns and assess the quality of interactions. For example, Han et al. [17] utilized automated digital data collection to identify students' collaborative problem-solving behaviors. This computer-based assessment system recorded students' actions and response times during collaborative tasks, providing process data alongside performance outcomes. While such approaches may not capture richer qualitative data like body language and tone, they enable an analysis of how students approach collaborative tasks. Other observational techniques include structured protocols to systemically record and analyze collaborative behaviors during collaborative activities [18] and real-time observational tools, such as the Co-Measure instrument [19], which focuses on dimensions including communication, cooperation, and coordination.

Advances in technology have also introduced tools that facilitate collaborative assessment. Garcia et al. [20] found a variety of approaches have been used to support collaborative learning in software engineering education, including web platforms, communication and documentation applications, and hardware, including interactive tabletops and tablets. While not all the reviewed studies directly measured collaboration, this research direction shows a shift toward computer-mediated technologies to support student interactions. Many such tools feature interactive elements that facilitate communication, provide scaffolding for collaboration, and integrate mechanisms for individual and group learning. Additionally, advances in natural language processing (NLP), the technology driving generative AI chatbots like ChatGPT, open new avenues for assessing collaboration by analyzing group communications and other collaborative artifacts robustly and quickly [21–23]. The growth of these technologies, as well as emerging student-AI collaboration (SAC) contexts, continues to push the boundaries of collaboration assessment in engineering education.

Common among these approaches is an emphasis on the products of collaboration whether behavioral or material. Self-report measures focus on reported collaborative actions and outcomes, asking students to rate how the quality of behavioral performance and/or their impact on the group. Observational techniques, whether in-person or mediated by technology, similarly emphasize visible collaborative actions and outputs. These two broad approaches, while valuably providing insight into *how* collaboration operates and *what* it produces, often fail to capture the nuances of *why* collaboration might differ between participants. Collaboration operates at the intersection of the self and group, yet existing approaches tend to scrutinize only the observable manifestations of collaboration while overlooking the underlying psychological and social dynamics that shape collaborative engagement.

2.3 Perceptions of Collaboration

Collaboration within engineering student groups is influenced by various factors, leading to differing perceptions and experiences among group members. For example, research suggests that students' perception of collaborative value depends on their prior work experience. Bayerlein [24] found that more experienced students generally perceived deeper professional value in collaborative work than less experienced students, who often needed subsequent workplace exposure to fully appreciate the collaborative aspects of their education. Ford and colleagues [25] examined new engineers' transitions from academic to professional environments, with attention paid to challenges they experienced related to teamwork, communication, self-directed learning, and identity development. The vast majority of their participants who reported self-directed learning challenges reported drawing on their capstone experiences to address these issues, as did most who faced teamwork and communication challenges. These findings support the value of capstone courses for engineering students, but they do not help explain why participants recalled and used behaviors learned in these courses. For example, one participant specifically notes how their capstone professor encouraged them to "jump into it" rather than wait for instructions, which prepared them for workplace environments where they needed to take initiative [25, p. 2005]. Experience assisted this young professional, understanding why this approach was recalled and deemed appropriate for the participant's new workplace requires further investigation.

In this regard, student perceptions of collaboration can vary with identify-related factors outside those based on prior experience. Studies suggest that gender, race, ethnicity, and other aspects of social identity can influence collaborative experiences, provided that students' experiences are fundamentally mediated through campus cultures, power relations, and identity categories [26]. For instance, students with prior negative collaborative experiences or those from underrepresented groups may be more attuned to certain group dynamics (such as being excluded from decision-making or stereotyped into specific roles), which in turn may affect how they perceive collaborative behaviors. Tonso [26, 27] noted that campus culture and engineering identity impact how students engage in collaborative practices, and Rodriguez and Blaney [28] highlighted that women of color in STEM often face unique challenges in group settings that influence their sense of belonging. Such factors suggest that two students in the same collaborative group might experience it very differently, potentially creating additional cognitive and emotional labor that impedes learning [29]. These insights motivate an approach that looks beyond just *what* behaviors occur to understand *whose* perspectives are being represented and *how* personal and contextual factors shape those perspectives.

In summary, while much research investigates which collaborative behaviors are desired in engineering groups, less focuses on understanding students' subjective experiences of those behaviors. Our pilot study takes an initial step toward addressing this gap by examining students' perceptions of collaborative behaviors. That is, how frequently they observe various behaviors during collaboration by examining differences across student groups. By doing so, we aim to uncover not only the patterns of collaboration but also potential underlying reasons for those patterns related to student identity and context.

3. Positionality Statement

We approach this research informed by our diverse experiences with collaboration across education and industry, which have shown us how group compositions and interpersonal dynamics fundamentally shape collaborative outcomes. Through both positive and negative collaborative experiences, we have observed how inclusive and exclusive cultures emerge and impact individual participation. This firsthand knowledge motivates our interest in understanding the psychological factors that influence collaborative behaviors in engineering. While our varied backgrounds provide valuable insights, we acknowledge that our experiences as educators and researchers may differ from those of undergraduate engineering students. Additionally, our roles in collaborative settings may have limited our exposure to certain collaborative challenges faced by others. Therefore, we designed this research to center student perspectives and experiences, allowing us to examine how collaboration is perceived and enacted by engineering students themselves rather than imposing our preconceptions. In this regard, we acknowledge the historical significance of collaboration for engineering education research and practice; particularly, the significance placed in maximizing its effectiveness [30]. We support these efforts as well as those that promote more student-centered and individualized learning experiences in engineering.

4. Methods

4.1 Data Collection

To investigate students' perceptions of collaboration, we employed an online sorting task that asked students to sort collaborative behavior statements according to how frequently they were observed in the students' capstone engineering groups. This approach was influenced by Q methodology, a mixed-methods approach used to investigate individuals' subjective viewpoints by having participants rank or sort a set of statements about a topic. In our context, the Q-Sort style sorting allowed us to identify areas of consensus and divergence among the behaviors students reported.

4.1.1 Defining Collaborative Behaviors

We designed a behavioral sorting task using QuestionPro, an online survey-making tool. This sorting constituted the pilot phase of a larger investigation that will use Q methods to more comprehensively understand how and why engineering students and practitioners prioritize collaborative behaviors. In this pilot, we focused solely on senior-level engineering undergraduate students from a single capstone course to evaluate the presence of behavioral variations and the efficacy of the sorting process.

Our sorting task was heavily influenced by the Q-Sort component of the Q methodology, which, as noted, is a mixed-methods approach to probe individuals' thoughts about a topic [31]. Q methodology has been utilized in various fields including higher education (e.g., [32–35]), and increasingly in engineering education (e.g., [31, 36–38]). Methodologically, Q methodology entails an initial quantitative item sorting phase followed by a qualitative inquiry (often semi-structured interviews). Participants first sort a set of items (e.g., statements about a topic) into a forced distribution, typically along a continuum (e.g., from "most agree" to "most disagree"). Researchers then identify patterns in how the items were sorted, and follow-up interviews help explain why participants sorted items the way they did. This mixed-methods combination allows researchers to reveal participants' viewpoints and how similarly or differently groups of participants think [39]. In our study, the sorting task captures students' viewpoints on collaborative behaviors, making it possible to see if certain behaviors are consistently viewed as more frequent or infrequent across participants.

Desing and Kajfez outline five key steps in using Q methodology for engineering education research: "(1) determining the Q Concourse, (2) developing the Q-Set, (3) selecting the P-Set, (4) conducting the Q-Sorts, and (5) analyzing and interpreting the data" [31, p. 4]. The Q Concourse is the "universe of statements" [31, p. 5] about the topic and typically involves comprehensively collecting all possible statements about it from multiple perspectives. To define this set, we leveraged the behaviors specified in the CATME-B scale because of our interest in concrete, real-world collaborative performance [8]. The scale provided 46 behaviors across three different performance levels and five contribution areas, but we focused on a single performance level – level 5 – to have a manageable subset for sorting. Table 1 shows the full list of level 5 CATME-B collaborative behaviors that formed our Q-Set, which includes 16 behavior statements spanning the five CATME dimensions (with the "Interacting with Teammates" category containing four behaviors and the others containing three each). We initially assumed these level 5 behaviors would be appropriate for capstone students; however, as we will discuss later, this proved optimistic. We elaborate on this in the Limitations section, and future research will use level 3 behaviors which are more aligned with average collaborative performance.

4.1.2 Context and Sample

We identified our P-Set – the study participants who sort the Q-Set statements – as senior-level capstone engineering students at a large public research university in the southeastern United States. Typically, Q methodology uses non-random, purposive sampling with a representation of expected viewpoint variations. However, given the pilot nature of this study, our sample was more limited and context-specific. Participants were recruited from a single senior-level interdisciplinary engineering capstone course in the Fall of 2022, where students from multiple engineering disciplines collaborate

Table 1. CATME-B level 5 collaborative behaviors

Area	Behavior
Contributing to the Team's Work	Does more or higher-quality work than expected
	Makes important contributions that improve the team's work
	Helps to complete the work of teammates who are having difficulty
Interacting with Teammates	Asks for and shows an interest in teammates' ideas and contributions
	Improves communication among teammates
	Provides encouragement or enthusiasm to the team
	Asks teammates for feedback and uses their suggestions to improve
Keeping the Team on Track	Watches conditions affecting the team and monitors the team's progress
	Makes sure that teammates are making appropriate progress
	Gives teammates specific, timely, and constructive feedback
Expecting Quality	Motivates the team to do excellent work
	Cares that the team does outstanding work, even if there is no additional reward
	Believes the team can do excellent work
Having Relevant Knowledge, Skills, and Abilities (KSAs)	Demonstrates the KSAs to do excellent work
	Acquires new knowledge or skills to improve the team's performance
	Able to perform the role of any team member if necessary

Note: Behaviorally anchored descriptions of excellent team-member performance in each area.

Table 2. Sample demographic information

Characteristic	Category	N (%)
Gender	Male	15 (62.5%)
	Female	8 (33.3%)
	Prefer not to answer	1 (4.2%)
Race/Ethnicity	White	14 (58.3%)
	Non-White	7 (29.2%)
	Prefer not to answer	1 (4.2%)
	Prefer to self-describe	2 (8.3%)

on comprehensive design projects. The course instructor distributed our voluntary survey to the students, and 24 completed the sorting task (Table 2 summarizes the sample's demographics). To protect participant privacy given the small cohort, we consolidated some demographic categories (e.g., combining all non-White ethnicities into a single "Non-White" category) to prevent individual identification while still providing meaningful context. This aggregation was necessary for the pilot, but future research with larger samples will enable a more granular analysis of how students' intersecting identities and characteristics influence their collaborative experiences and behaviors.

4.1.3 Behavior Sorting Task

Following Q methodology conventions [31], we designed our Q-Sort as a quasi-normal distribution for the sorting task. In a Q-Sort, the number of items that can be placed at each point on the scale follows a roughly normal distribution (fewer items at the extremes, more in the middle). As shown in Fig. 1, our Q-Sort grid ranged from –3 to +3, corresponding to the statements "I ALWAYS observe this behavior" (assigned value –3 for always) through to "I NEVER observe this behavior" (+3 for never). The grid had as many total slots as there were behavior statements (16), with

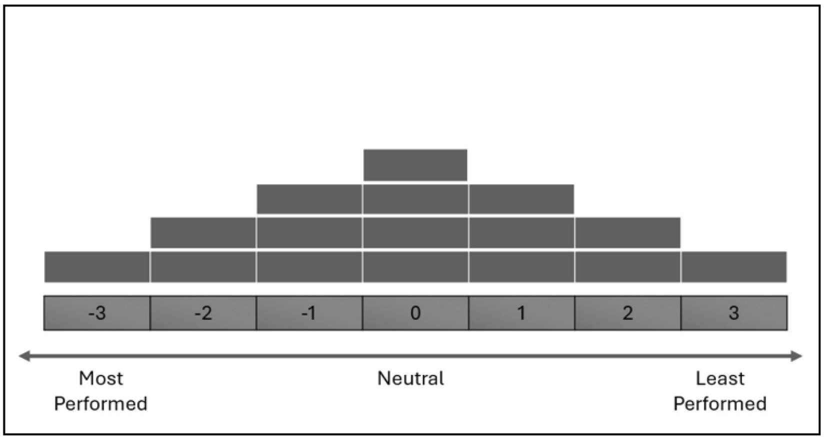

Fig. 1. Q-Sort grid used for behavior sorting (symmetric from –3 to +3 with a quasi-normal distribution of slots) shape.

the most slots near the middle (neutral) and the fewest at the extremes, reflecting the expectation that participants would identify only a few behaviors as extremely frequent or extremely infrequent, with most behaviors falling in between.

Each student received instructions describing the sorting task and the meaning of the scale. They were required to place all 16 behavior "cards" into the Q-Sort grid, meaning they had to rank the behaviors relative to one another from most frequently observed in their groups (which they placed in the –3 column) to least frequently observed (placed in the +3 column), filling all slots in the prescribed distribution. Students were asked to "sort the cards below (descriptions of team member behaviors) into categories you think best represent how often you have seen them performed by members of your team (including yourself) in [an] engineering design experience." Using the forced-ranking approach ensured they had to prioritize some behaviors as more common and others as less common, rather than rating all behaviors similarly. Additionally, by using the structured distribution, we can compute a rank-order score for each behavior per participant based on where it was placed (e.g., a behavior placed in the +1 column gets a value of +1). Summing or averaging these scores across participants then represents the collective ordering of behaviors. Since we assumed students might not feel extremely polarized about most collaborative behaviors, we opted for a relatively "flat" distribution (fewer extreme slots) rather than a very peaked one [38]. The distribution ranged from "I ALWAYS observe this behavior" to "I NEVER observe this behavior," mapped to scores of –3 and +3 respectively. Background information and instructions in the survey clarified the process, and an example was provided to familiarize participants with the idea of forced ranking. Ultimately, this Q-Sort-inspired approach allowed us to investigate differences in students' perceptions of collaborative behaviors by comparing how behaviors were positioned in the forced distribution across participants.

4.2 Data Analysis

Traditionally, the final steps of the Q methodology involve factor-analyzing the Q-Sort data to identify groups of participants with similar sorting patterns, followed by interviews to interpret those patterns. However, because this was a preliminary investigation with a small sample, we did not conduct factor analysis or interviews at this stage. Instead, our analysis focused on establishing whether discernible differences existed in how students sorted the behaviors, which would inform subsequent, more in-depth studies.

To analyze the sorting results, we first converted each participant's sorted data into numerical values: for each behavior, an "Always" placement was coded as –3, "Never" as +3, and intermediate positions accordingly. We then calculated an overall average score for each behavior across all participants, as well as average scores within key demographic subgroups (by gender and by race). A negative average score for a behavior indicates that, on the whole, students ranked that behavior toward the "frequently observed" end of the spectrum; a positive score indicates the behavior was ranked toward the "infrequently observed" end. We used Excel to compute these averages and to compare scores between groups, which were mainly descriptive in nature; we did not perform statistical significance testing, as the data were not sufficient for robust inferential analysis. Instead, we looked for notable differences in scores (for example, if one subgroup's average for a behavior was on the opposite side of the scale or substantially different from another's). This approach allowed us to identify patterns in collaborative behavior engagement as reported by the students. By examining group differences (Female vs. Male; White vs. Non-White), we explored whether certain behaviors were perceived as more or less frequent in different subgroups. Although future studies will employ more typical Q methodology analyses (including factor analysis and participant interviews), this pilot analysis departs from common collaborative assessment methods by delving directly into students' beliefs and attitudes about collaboration through their observed behavior frequencies.

5. Findings

The analysis revealed notable patterns in how engineering students perceive and report collaborative behaviors in capstone groups. These patterns can be described in terms of areas of consensus (behaviors that all students or subgroups reported at similar frequency levels) and areas of divergence (behaviors that different demographic subgroups reported at different frequency levels). While our sample does not allow for the broad generalization of these findings, they do suggest differences in how collaboration is perceived and enacted by these engineering students. Table 3 provides the full list of level 5 collaborative behaviors, sorted from least frequently observed to most frequently observed based on the students' responses. Behaviors at the top of the list have positive scores (indicating they were, on average, reported as less frequently seen), whereas those at the bottom have negative scores (indicating they were reported as more frequently seen). For each behavior, we calculated an aggre-

Table 3. CATME-B Level 5 behaviors sorted by reported frequency

Behavior	**Score**
Able to perform the role of any team member if necessary	1.27
Gives teammates specific, timely, and constructive feedback	1.08
Asks teammates for feedback and uses their suggestions to improve	0.38
Improves communication among teammates	0.38
Watches conditions affecting the team and monitors the team's progress	0.35
Cares that the team does outstanding work even if there is no additional reward	0.23
Motivates the team to do excellent work	0.23
Asks for and shows an interest in teammates' ideas and contributions	0.19
Provides encouragement or enthusiasm to the team	–0.04
Helps to complete the work of teammates who are having difficulty	–0.12
Does more or higher quality work than expected	–0.15
Acquires new knowledge or skills to improve the team's performance	–0.19
Makes sure that teammates are making appropriate progress	–0.62
Makes important contributions that improve the team's work	–0.81
Believes that the team can do excellent work	–1.04
Demonstrates the knowledge, skills and abilities to do excellent work	–1.15

Note: Behaviors are sorted from least observed to most observed. A negative score indicates the behavior was generally placed toward the "Always" end of the spectrum (frequently observed), while a positive Score indicates placement toward the "Never" end (infrequently observed).

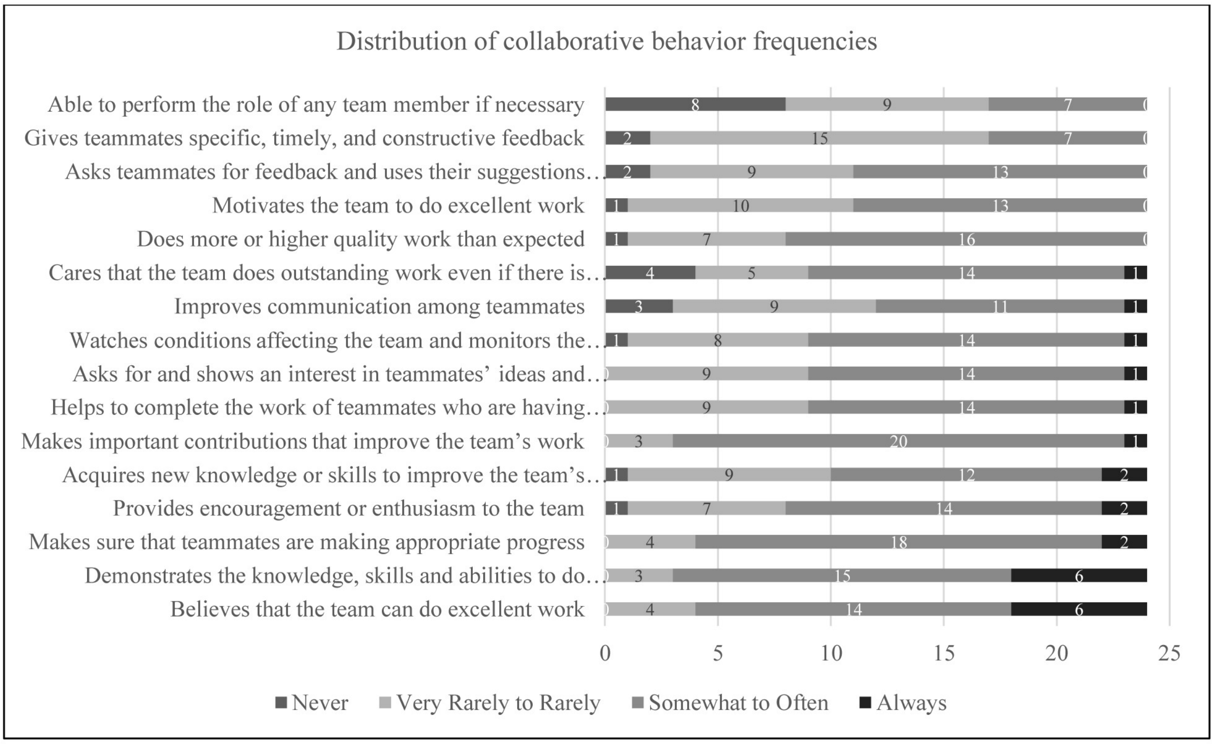

Fig. 2. Distribution of student-reported frequencies for each collaborative behavior.

gate frequency score (where more negative = observed more frequently, more positive = observed less frequently). To illustrate the spread of responses for each behavior, Fig. 2 presents a histogram of how many students placed each behavior in each frequency category ("Always" through "Never").

Across all subgroups (see Tables 4 and 5), students converged in reporting certain behaviors as frequently performed and others as rarely performed. For instance, all groups consistently observed some technical/task-oriented behaviors very often. "Demonstrates the knowledge, skills, and abilities to do excellent work" was among the most commonly observed behaviors for every subgroup (White: –1.27, non-White: –1.43, Female: –1.25, Male: –1.13). Similarly, "Believes that the

Table 4. Gender differences in collaborative behaviors (average behavior scores by subgroup)

Behavior	Female	Male
Does more or higher quality work than expected	0.25	–0.31
Makes important contributions that improve the team's work	–1.25	–0.44
Helps to complete the work of teammates who are having difficulty	–0.50	0.13
Asks for and shows an interest in teammates' ideas and contributions	0.63	0.00
Improves communication among teammates	0.63	0.31
Provides encouragement or enthusiasm to the team	0.13	–0.38
Asks teammates for feedback and uses their suggestions to improve	–0.38	0.63
Watches conditions affecting the team and monitors the team's progress	0.50	0.06
Makes sure that teammates are making appropriate progress	–1.38	–0.44
Gives teammates specific, timely, and constructive feedback	0.88	1.13
Motivates the team to do excellent work	0.88	0.06
Cares that the team does outstanding work even if there is no additional reward	0.75	0.06
Believes that the team can do excellent work	–0.63	–1.13
Demonstrates the knowledge, skills and abilities to do excellent work	–1.25	–1.13
Acquires new knowledge or skills to improve the team's performance	–0.38	0.00
Able to perform the role of any team member if necessary	1.13	1.44

Table 5. Racial differences in collaborative behaviors (average behavior scores by subgroup)

Behavior	White	Non-White
Does more or higher quality work than expected	–0.20	0.00
Makes important contributions that improve the team's work	–1.20	–0.29
Helps to complete the work of teammates who are having difficulty	–0.40	0.00
Asks for and shows an interest in teammates' ideas and contributions	0.20	–0.57
Improves communication among teammates	0.33	0.14
Provides encouragement or enthusiasm to the team	–0.27	–0.43
Asks teammates for feedback and uses their suggestions to improve	0.20	0.00
Watches conditions affecting the team and monitors the team's progress	–0.07	0.29
Makes sure that teammates are making appropriate progress	–0.73	–0.57
Gives teammates specific, timely, and constructive feedback	0.73	1.00
Motivates the team to do excellent work	0.33	0.14
Cares that the team does outstanding work even if there is no additional reward	0.60	–0.14
Believes that the team can do excellent work	–1.27	–0.57
Demonstrates the knowledge, skills and abilities to do excellent work	–1.27	–1.43
Acquires new knowledge or skills to improve the team's performance	–0.20	–0.43
Able to perform the role of any team member if necessary	1.20	0.86

team can do excellent work'' was reported at high frequency by both racial and gender groups (White: –1.27, non-White: –0.57, Female: –0.63, Male: –1.13). The relatively negative consistency in these values (in some cases strongly so) suggests that students generally see these behaviors happening regularly in their groups. In practical terms, technical competence and a shared confidence in the group's capability were visible across the board. This convergence likely reflects the strong emphasis on technical skills in engineering education and the relatively observable nature of technical contributions; everyone can recognize when a groupmate has the necessary skills and is applying them effectively.

A similar agreement was found for some of the least frequently observed behaviors. For example, ''Able to perform the role of any team member if necessary'' had consistently positive scores (White: +1.20, non-White: +0.86; Female: +1.13, Male: +1.44), indicating that students across all groups rarely saw groupmates swap roles or cover each other's roles completely. Likewise, ''Gives teammates specific, timely, and constructive feedback'' was rated as infrequent by all subgroups (White: +0.73, non-White: +1.00; Female: +0.88, Male: +1.13). These consistently positive scores suggest that certain idealized collaborative behaviors (e.g., fully interchangeable roles, frequent detailed peer feedback) were seldom realized in practice for any of the students. Students may tend to stick to their defined roles and may not often engage in explicit feedback, which could imply that while technical tasks get done, deliberate collaborative process behaviors (e.g., giving feedback) receive less attention. In summary, the areas of consensus imply that technical/task-oriented behaviors were commonly observed, whereas some process-oriented behaviors (especially those indicating highly proactive or versatile collaboration) were not.

On the other hand, students diverged in their perceptions of several collaborative behaviors, with notable variations between demographic groups. One such area of divergence was in communication and encouragement behaviors. For example, "Improves communication among teammates" showed a difference between groups: White students on average reported it less frequently (White: +0.33) than non-White students (Non-White: +0.14), and there was an even larger gender gap (Female: +0.63, Male: +0.31). In this case, female students reported observing this communication-improvement behavior much less often than male students did. This could reflect different expectations or awareness of communication efforts, or possibly different experiences; for instance, female students may have wished for more communication improvement than they witnessed, or male students might perceive normal communication as "improvement." Similarly, "Provides encouragement or enthusiasm to the team" showed variations across both gender and racial lines. White and non-White students' averages were fairly close (White: –0.27 vs. Non-White: –0.43, both indicating it was seen as a relatively frequent behavior by those groups), but the gender difference was more pronounced: Female: +0.13 vs. Male: –0.38. In this case, male students generally saw group encouragement as a frequent occurrence (negative score), whereas female students on average did not see it as frequently (slightly positive score). This suggests that male students might either be receiving or noticing more encouragement in their groups or perhaps female students have higher expectations for encouragement that are not being met. Non-White students, interestingly, rated encouragement as even more frequent than White students did (more negative), hinting that group encouragement dynamics may vary by cultural or group norms.

There were also divergences in task-related behaviors. For instance, "Makes important contributions that improve the team's work" showed one of the largest gaps in our dataset: White students reported this behavior much more frequently (White: –1.20) than non-White students did (Non-White: –0.29), and similarly, female students reported it more frequently (Female: –1.25) than male students (Male: –0.44). In other words, White and female students tended to see a groupmate making important contributions as a very common occurrence, whereas non-White and male students were less likely to report seeing such contributions as frequently. This could imply that underrepresented students (non-White, and in this specific case also male students) might sometimes feel that major contributions are not happening as visibly or that they are not in positions to make those contributions as often. Prior research has noted additional participatory barriers that underrepresented students can face during engineering collaboration (e.g., being pigeonholed into certain roles or having their contributions undervalued), which might explain why non-White students in our sample didn't observe "important contributions" as routinely; perhaps because they were not always in a position to make those contributions or did not see their contributions recognized.

Another divergent behavior was "Makes sure teammates are making appropriate progress." Here we saw essentially opposite experiences: White students on average indicated this behavior was infrequent (White: +0.73), whereas non-White students indicated it was frequent (Non-White: –0.57). Similarly, there was a stark gender difference (Female: –1.38, Male: –0.44, with females seeing this monitoring behavior far more frequently than males). This suggests that female students and non-White students were more likely to report that someone in their group was checking on their progress regularly, whereas White students (and to a lesser extent male students) reported this behavior as happening less often. One interpretation could be that in groups with diverse composition, perhaps underrepresented members took on (or noticed) the role of monitoring progress more diligently, or that in groups lacking such monitoring, it was more apparent to certain students. The female vs. male difference might indicate that female students either engaged in more collaboration-checking behaviors or were more aware of those behaviors when they occurred. Alternatively, students' judgments of their peers may inform how they distribute work, with those deemed "less competent" requiring more frequent monitoring [26].

Taken together, these findings suggest that collaborative behaviors are performed and perceived differently by different students, with some behaviors being more common for everyone and others varying by group. Although our data are exploratory and we did not calculate statistical significance (given the small sample size) or examine intersectional identities in-depth, these commonalities and differences are notable and warrant further investigation. The variability observed, especially in process-oriented and interpersonal behaviors, highlights that factors like gender and race may influence how collaboration unfolds during student group work. For example, certain supportive behaviors (e.g., encouraging the group) might be plentiful in some and lacking in others, possibly affecting group cohesion and individual student experience. Before interpreting these differences further, we emphasize that these results are preliminary. With only 24 participants, we cannot draw definitive conclusions about cause-and-effect or generalize to all engineering students. However, the patterns observed raise important questions. They suggest that while all students in our sample valued and experienced core technical contributions, the social and process aspects of collaboration (communication, encouragement, feedback, leadership in keeping on track) showed more variability. This variability might stem from differing group cultures, individual dispositions, or the roles students adopt during collaboration, and underscores the importance of considering student demographics and context when studying collaboration. In the following sections, we discuss these findings in light of existing literature and outline directions for future research to delve deeper into these dynamics.

6. Discussion

Our preliminary investigation suggests patterns in student collaborative behaviors across three dimensions: technical/task-oriented, process-oriented, and interpersonal/social engagement. However, additional research with larger and more diverse samples is required to validate these initial observations and consider them in broader engineering contexts. In our sample, the technical/task dimension demonstrated consistent observation across all demographic subgroups, whereas process-oriented and interpersonal/social behaviors showed substantial variability in their reported frequencies. These variations manifested most prominently in gender-based comparisons, with additional notable differences across racial categories. The observed differences imply that collaborative behaviors are influenced by the sociocultural dynamics of the collaborative environment, with students continuously adapting their collaborative strategies in response to identity-laden and contextual aspects of the experience.

Given these findings, exploring students' personal experiences and interpretations of their collaborative environments is essential for developing a robust theoretical understanding of engineering collaboration. In particular, it is important to examine how identity-based factors and cultural dynamics shape collaborative learning processes. Our results hint that factors such as who is in the group (in terms of demographic composition), how roles are assumed, and what prior experiences students bring can all impact which behaviors flourish or falter in a collaborative setting. To truly understand why certain behaviors are frequent or infrequent, we must delve into students' phenomenological experiences: how they perceive their group interactions and why they behave as they do. This line of inquiry can help researchers build theories of engineering collaboration that account for individual attitudes and social context, not just normative group processes. Below, we discuss the key patterns in each of the three dimensions of collaborative behavior identified, relate them to existing literature, and suggest implications.

6.1 Patterns in Collaborative Behaviors

6.1.1 Technical/Task Behaviors

Our analysis identified a set of behaviors related to technical contribution and task execution that students across demographics reported observing frequently. These include demonstrating strong KSAs (knowledge, skills, abilities), making quality contributions to the group's work, and acquiring new knowledge for the project. This aligns with Trevelyan's [40] view of engineering practice as inherently a technical-social endeavor where technical competence underpins effective collaboration. Stevens and Campion's "planning and task coordination KSAs" for collaboration [41] also emphasize that core technical abilities enable meaningful contributions. The consensus we saw on technical behaviors likely reflects the centrality of technical competence in engineering education [6]. Engineering programs heavily emphasize developing students' technical skills, and by the senior year (capstone), students may share a baseline expectation that everyone will contribute technically. Furthermore, most students have had limited formal exposure to collaborative training beyond early project experiences [5], so they may default to focusing on technical tasks as their main contribution. Prior work by Hirshfield and Chachra [10] notes that simply having students do group work does not automatically build advanced collaboration skills; without explicit scaffolding, students often revert to dividing the technical work and working in parallel. Our findings that technical behaviors were consistently high-frequency across groups might be a manifestation of this phenomenon: all groups, regardless of composition, ensured the technical work got done, even if higher-level collaborative processes were less developed.

Interestingly, we observed a slight trend where non-White students reported some technical contribution behaviors (e.g., "Makes important contributions. . .") as less frequent than White students did. For example, "Makes important contributions that improve the team's work" had a notably lower frequency for non-White students. This echoes findings by Cross and Paretti [42] that underrepresented students can face participatory barriers in engineering collaboration, such as being stereotyped into less central roles or not having their contributions valued equally. It is possible that non-White students in our sample experienced groups where their potential contributions were underutilized or less visible, leading them to rate that item as not occurring as often. Addressing such disparities is crucial: if some students are not fully included in the technical dialogue, they miss opportunities to contribute and learn, and the group misses out on their ideas.

6.1.2 Process-Oriented Behaviors

Process-oriented behaviors (those related to managing the collaborative process and project progression) showed much more variability. This framing draws from the "Big Five" framework [43], particularly its emphasis on behavioral markers that facilitate group coordination and adaptation. These markers serve as critical mechanisms enabling groups to maintain effectiveness across varying conditions and challenges, such as observable indicators of communication, behaviors that establish mutual trust, and working toward shared understanding. Behaviors like monitoring progress, giving constructive feedback, and keeping the group organized were generally less frequent overall, and where they did occur, they often differed by subgroup. Our results suggested that female students and some non-White students took on (or observed) more of these process-management roles than their counterparts. For instance, female students reported more frequent occurrences of "makes sure groupmates are making progress" than male students. One interpretation is that female students during engineering collaboration, perhaps due to a heightened sense of responsibility or to counteract anticipated issues, might proactively monitor the group's processes. This could tie into broader literature on gender roles: some studies have found that women often perform more organizational or "housekeeping" roles in group work to ensure success, even if not formally recognized [10, 26, 44, 45]. This relates to the notion of "task vs. maintenance roles;" some students may adopt maintenance (process/people-oriented) roles to help the group function when those roles are not otherwise filled. However, not all process behaviors were taken up. Across all groups, giving specific, timely feedback was rare. This might indicate a general discomfort among students in providing peer feedback, possibly due to lack of training or fear of causing conflict. It suggests an area where educational intervention could be needed: students may benefit from guidance on how to exchange constructive feedback during collaborative experiences.

6.1.3 Interpersonal/Social Behaviors

The interpersonal dimension included behaviors focused on communication, encouragement, and idea-sharing. These behaviors relate to Stevens and Campion's [41] "collaborative problem-solving KSAs:" actions directed toward facilitating problem-solving and improving collaborative culture. Here we saw some of the clearest differences: male students reported higher frequencies of group encouragement and communication improvements than female students did, while non-White students reported slightly higher frequencies of encouragement than White students. This could reflect differences in group culture or climate that correlate with its makeup. Wolfe and Powell [46] have shown that biases in group communication can cause the same behavior to be perceived differently depending on who performs it. It is possible that during collaboration with mixed genders, for example, female students might not experience as much encouragement or open communication, perhaps due to subtle exclusion or communication styles that do not resonate with them. Alternatively, male students might perceive normal banter or coordination as "encouragement" more readily. Another interesting finding is that non-White students reported "provides encouragement or enthusiasm" slightly more frequently than White students. This could be due to smaller group sizes of non-White students often banding together or supporting each other in groups, or cultural differences in how encouragement is expressed and noticed. It might also be that groups with non-White members made conscious efforts to be inclusive and encouraging. This speculation would need qualitative follow-up to understand.

In summary, our pilot data suggest that engineering capstone groups reliably engage in technical work, but the extent to which they engage in process and interpersonal behaviors can vary. Some students report high rates of communication and mutual support, while others experience relatively transactional interactions focused on tasks. These differences align with certain demographic lines in our sample, implicating underlying social dynamics, and underscoring the importance of not treating student teams as homogeneous entities. Factors, including prior experience, group composition, and individual dispositions likely modulate how collaboration unfolds.

6.2 Contextual Influences on Behavioral Patterns

Ultimately, we argue that collaborative behaviors emerge from complex interactions between educational structures, group contexts, and individual beliefs. Our preliminary findings suggest that while students do perceive differences in collaborative behavior performance, further research is needed to understand the underlying attitudes and experiences driving these behaviors.

6.2.1 Educational Structures

The environment in which students learn can shape which collaborative behaviors they prioritize. Limited collaborative experiences before capstone (e.g., if collaboration is only introduced in a significant way during senior projects), an educational emphasis on technical competence over collaborative skill development, and grade-centric evaluation systems that reward technical output might all influence the behaviors students focus on. For example, if meeting project technical requirements is tied directly to grades but process quality is not, students may understandably prioritize task completion at the expense of process improvement or collaborative skill development. We observe hints of this in our data: technical behaviors such as "demonstrates knowledge and skills" had high frequency (e.g., average score was –1.15), whereas a process behavior such as "gives constructive feedback" had a much lower frequency (e.g., score average +1.08). This disparity reflects how the educational context may encourage students to invest their effort. If delivering a working prototype or report is what counts, students might implicitly agree to "just get the job done" and not spend time on peer feedback sessions or group retrospectives.

The curriculum design also plays a role. If collaborative experiences are isolated (as in a single capstone course or a few project courses) rather than woven throughout the curriculum, students have limited time to develop sophisticated collaboration strategies. Many will rely on what worked in earlier projects: divide and conquer the technical parts. This can reinforce patterns where interpersonal growth is stunted. Our findings of uniformly high technical engagement and low process engagement may be a symptom of this common educational approach.

6.2.2 Group Composition and Dynamics

The makeup of the group (in terms of skills, personalities, and demographics) can significantly influence observed behaviors. In some groups, a natural leader may emerge who keeps everyone on track and encourages others, in which case all members might report high frequencies for those behaviors. In others, leadership may be diffuse or lacking, so those behaviors might be reported as low frequency. Our study's subgroup differences suggest that who is in the group (and perhaps who takes on certain roles) matters. For instance, groups with female members might only see progress-checking happening if a female student steps into that role (as suggested by female students' reports), whereas groups of all males might neglect it. Collaboration dynamics can also be affected by implicit biases or stereotype threats. If a student feels their contributions are undervalued (perhaps a common experience for some underrepresented students [47]), they might disengage or contribute less, which in turn could lead their groupmates to not see those contributions (a vicious cycle). Alternatively, those students might be working harder to gain credibility, possibly explaining why non-White students rated "demonstrates KSAs" as occurring more frequently than White students: they may be going above and beyond to demonstrate competence, a phenomenon some have termed "culturally compelled coping" [48, 49].

6.2.3 Individual Beliefs and Attitudes

Students' personal beliefs about collaboration undoubtedly influence their behavior [9]. Some students genuinely believe in its value and will naturally encourage groupmates, seek input, and coordinate efforts. Others may have had negative collaborative experiences or simply prefer to work alone, causing them to engage less in collaborative behaviors (beyond what's necessary). Understanding these mindset differences was beyond the scope of our survey data, but it is an important next step. For instance, do students who frequently encourage groupmates hold stronger pro-group attitudes or higher confidence in collaboration? Are students who rarely observe feedback possibly those who do not believe peer feedback is useful? Our future work, including qualitative interviews, will aim to probe such questions.

6.2.4 Interpretation of Differences

The differences we observed by gender and race could be interpreted through frameworks including social role theory or stereotype threat. Social role theory [50] suggests that people enact behaviors consistent with societal expectations for their demographic. Women might take on more communal roles (support, organization) while men focus on agentic roles (individual tasks) because of ingrained norms, which may be particularly salient in an engineering collaboration. This can happen subconsciously. Stereotype threat [51, 52] might cause, for example, women to avoid being too assertive (hence maybe not pushing communication improvements) or other underrepresented students to avoid asking for help (hence not receiving adequate feedback or encouragement). While speculative, such mechanisms could underlie our observations and deserve targeted study.

6.2.5 Implications for Engineering Education

If collaborative behaviors indeed vary with these factors, engineering educators and program designers should take note. There may be a need for more explicit instruction and practice in collaborative processes, to ensure all students engage in central, real-world collaborative practices, such as feedback and regular multi-person communication, regardless of group composition. Additionally, awareness training could help students recognize and counteract biases in collaboration (e.g., ensuring labor is evenly distributed and not falling along gender lines stereotypically). Tools including CATME itself can be used not just for assessment but to prompt discussions among students about balancing contributions and roles. Finally, it is worth noting that although our findings are specific to one course context, they resonate with broader calls to improve collaborative training in engineering education [53]. By highlighting even preliminary differences in collaborative behavior perceptions, we underscore that how students collaborate can depend on context and identity, meaning one-size-fits-all approaches to teaching collaboration may miss the mark. Tailoring activities to encourage inclusive and effective collaboration for diverse groups could help address some of the disparities hinted at in this study.

7. Limitations

Throughout the paper, we have detailed our thinking and process for this investigation, but readers should be aware of several limitations when considering the applicability of our findings in alternative contexts. Firstly, our sample size is quite limited. Students were surveyed from a single instructor's capstone engineering course and asked about their capstone projects, which were unique in their interdisciplinary focus. Whether these findings are also present for more diverse populations is an open question, which we aim to address in subsequent investigations. Ideally, these samples will also be more representative of all undergraduate engineering students and ask them to refer to any engineering collaborative experience, not just their capstone projects. These aspects of the sample significantly restrict the generalizability of our results because the patterns we observed may be specific to this particular course context, institution, or student cohort. Additionally, with such a small sample, we cannot make claims about the statistical significance of the observed differences between demographic groups. These limitations form the basis for our characterization of this work as preliminary and exploratory, establishing groundwork for future larger-scale and more in-depth investigations.

Several methodological limitations are also present, including the efficacy of self-report measures, the lack of consideration of group composition, and the rigidity of the sorting method. Our instrument asked students to sort behaviors according to the frequency as performed by themselves or others. Consequently, the sorting captures biases between students' perceptions of themselves and others. It is possible that students inflated certain "positive" behaviors when evaluating themselves, leading to a distribution that does not accurately reflect their experiences. Variations between students' survey responses and their actual collaborative experiences may also arise because of our choice to use CATME-B level 5 collaborative behaviors. While level 5 behaviors capture what would ideally be performed by capstone-level engineering students, given the lack of scaffolding and support provided to students during their undergraduate careers regarding effective collaboration [54, 55], it is more likely that lower levels, namely level 3 CATME-B collaborative behaviors, are more realistic [8, p. 614]. As a result, future work will use the other CATME-B levels of collaborative behaviors to assess students' perceptions of collaboration. Regardless of the level used, however, the CATME-B scale is behaviorally anchored, allowing students to differentiate between the quality of collaborative performances when evaluating themselves and others. Using a single level in our survey may prevent students from recognizing how the same behavior manifests differently depending on how strongly it is performed. Some participants noted this discrepancy in their responses to a survey question asking for feedback, noting that behaviors exist that negatively impact collaboration, such as last-minute contributions to group work or complete non-participation over the semester. Such behaviors are technically included in the CATME-B scale because of its behavioral anchoring: students that inhibit collaboration through their actions are performing collaborative behaviors, albeit poorly performed. Nonetheless, these comments point to students' understanding that problematic behavior impacts collaborative effectiveness, and we hope to capture this nuance in the qualitative interviews in future investigations.

Our instrument did not question students about their group's composition because, as a pilot, we sought to determine whether collaborative behaviors are performed differently. Future investigations will delve deeper into how group composition impacts collaborative dynamics and the performance of behaviors. In addition, using a predefined and rigid sorting system limited students' sorting abilities. One student noted that none of the behaviors were "never" performed, so they placed less frequent behaviors arbitrarily. Similarly, it is possible that a student in an exemplary group could observe multiple behaviors very frequently but would have been limited by the set distribution. While a pre-defined Q-Sort distribution is a key feature of Q methods [31], future investigations will critically assess whether the distribution used in this preliminary investigation warrants a wider or narrower spectrum. Future investigations could ask students to sort the behaviors however they wish, providing additional insight into how the Q-Sort distribution impacted their sorting. This could be coupled with a contextualizing question about whether the collaborative experience was "good" or "bad," helping probe how dynamics and outcomes inform students' choices.

This investigation contributes to our understanding of engineering collaboration through its emphasis on the perceptions of collaborative behaviors. Although several aspects of this pilot should be considered when assessing its transferability, we see them as guideposts for future investigations.

8. Conclusion

Our findings suggest that collaborative behaviors are highly contextual and individualized. While our small sample prevents drawing definitive conclusions, it highlights the need for more robust research into how and why engineering students engage differently in collaborative settings. These behavioral differences have deep philosophical roots. Plato theorized that human behavior originates from the interplay between desire, emotion, and knowledge [56]. In engineering contexts, we therefore might ask: how do disciplinary norms, group compositions, and project characteristics influence these drivers of behavior? Current research predominantly documents *what* engineering collaborative behaviors exist rather than investigating *why* they are performed. This distinction is crucial; understanding the motivations behind collaborative behaviors provides insights into both how students perceive collaboration and how they engage with it in practice. Future research should build on this study by examining these patterns with larger, more representative samples across multiple institutions and program types. Understanding students' perceptions of and attitudes toward collaborative behaviors is a vital aspect of both theoretically defining engineering collaborative behaviors and developing effective educational approaches. Subsequent work should explore how beliefs, attitudes, and abilities interact to shape engineering collaboration, with particular attention to how individual and group dynamics influence these elements in collaborative settings.

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