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Why do capstone students choose to perform behaviors? Differing prevalence in collaborative choices

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This project explores the collaborative skills occurring within engineering education and practice. While technical competence is crucial, collaborative skills are paramount in engineering enterprises, and current evidence suggests working in teams does not ensure the development of effective collaboration behaviors among engineers. Yet, lifelong learning requires engineers to navigate complex interactions within diverse design teams, emphasizing the need for a nuanced understanding of collaboration. To address this gap, our study aims to identify the least-performed effective collaboration behaviors in engineering capstone teams and explore the reasons behind this occurrence. This investigation is part of a larger study that employs the Reasoned Action Approach[1] where we seek to uncover individual beliefs and factors influencing the performance of target behaviors. These insights serve as tools for engineers, students, educators, and managers to assess and enhance collaboration skills, fostering effective teamwork in engineering settings. Ultimately, this overarching goal of advancing professional formation in engineering distills into the key question: Why do individuals exhibit variations in performing effective collaboration behaviors in engineering teams?

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Background and Motivation

Engineering is a fundamentally collaborative profession and can be conceptualized as a "large collaboration performance."[2(p. 202)] Despite this recognition, current engineering education disproportionately prioritizes technical proficiency, sidelining the interconnectedness of technical competence and effective collaboration.[3] Research indicates that engineers working together does not guarantee successful collaboration or the development of collaborative behaviors.[4] Further, developing essential collaborative skills necessitates dedication to practice and learning beyond formal education.[5,6] Consequently, the disproportionate emphasis on technical proficiency at the expense of collaborative skills compromises the development of engineers at both the student and practitioner levels.

Analysis of collaborative dynamics within engineering requires understanding the behaviors contributing to effective collaboration. While research has identified behaviors in engineering team settings[7–10], a notable gap exists in understanding the differential frequency of these behaviors. Variations are likely due to individual differences, contextual factors, and varying abilities, influencing the uneven performance of behaviors associated with effective collaboration.[1] The underdeveloped understanding of how these collaborative behaviors are differentially enacted within engineering design teams encourages exploration of the determinants influencing individuals' engagement in collaborative behaviors. Addressing this gap can inform engineering collaboration, facilitating more targeted and effective training for students and practitioners, and fostering a culture of effective collaboration in the field.

This paper explores the variances in effective collaborative behaviors within capstone engineering teams. The following sections will outline the methodology employed, the preliminary findings, and discuss the potential implications of this investigation.

Methodology

As a component of a broader investigation into the determinants and factors influencing behavioral choices within collaborative engineering environments (NSF Award: EEC – 2217523, VT IRB: 22-584), this initial pilot study utilized participants enrolled in an interdisciplinary senior capstone engineering course taught at a large, land-grant institution and recruited by their instructor. The pilot study aimed to unveil variations among individuals concerning the performance of specific behaviors in collaborative settings.

Theoretical Framework

Existing research on teamwork and collaboration in engineering education has focused on understanding the dynamics within design teams or capstone courses, exploring team members' experiences and assessments of team effectiveness, and identifying team behaviors correlated with effectiveness.[11–13] However, fewer investigations have delved into the reasons behind the likelihood of engineers performing effective collaboration behaviors, which prompted this investigation.

To address this gap, our approach is grounded in the Comprehensive Assessment of Team Member Effectiveness (CATME) Behaviorally Anchored Rating Scale (BARS), a research-based compilation of explicit behaviors associated with effective collaboration in engineering contexts.[14] In line with the larger study's overall objective of examining and supporting engineering students and practitioners, the CATME-B scale incorporates behaviors validated by experts and college students. Table 1 provides the list of the 16 specific CATME-B behaviors indicative of "typical or average team-member contributions." [14(p. 614)]

Table 1. Behaviors associated with effective collaboration from the CATME-B scale[14(p. 626)]

Contributing to the team's work: 1) does more or higher quality work than expected; 2) makes important contributions that improve the team's work; 3) helps to complete the work of teammates who are having difficulty.
Interactions with teammates: 4) asks for and shows an interest in teammates' ideas and contributions; 5) improves communication among teammates; 6) provides encouragement or enthusiasm to the team; 7) asks teammates for feedback and uses their suggestions to improve.
Keeping the team on track: 8) watches conditions affecting the team and monitors the team's progress; 9) makes sure that teammates are making appropriate progress; 10) gives teammates specific, timely, and constructive feedback.
Expecting quality: 11) motivates the team to do excellent work; 12) cares that the team does outstanding work even if there is no additional reward; 13) believes that the team can do excellent work.
Having the relevant knowledge, skills and abilities: 14) demonstrates the knowledge, skills and abilities to do excellent work; 15) acquires new knowledge or skills to improve the team's performance; 16) able to perform the role of any team member if necessary.

Instrumentation

This study sought to determine whether specific behaviors were performed more frequently than others within engineering teams. To achieve this, a questionnaire was developed using QuestionPro software[15] and subsequently administered to the sample of engineering capstone students whose makeup is detailed in Table 2. Of these students, 26 completed the pilot with the rest opting out of participating. The survey instrument prompted participants to recall a past engineering team experience[16] and were tasked with sorting the CATME-B behaviors based on the frequency of their occurrence, either by themselves or by others in their groups.

Table 2. Capstone course composition by major

Major	Number of Students
Mechanical Engineering	44
Computer Engineering	19
Electrical Engineering	16
Industrial Systems Engineering	10
Computer Science	8

Q-Sort

In conducting the behavior sorting, participants were tasked with distributing cards, each featuring a single behavior, based on their observed frequency in their engineering design teams. This Q-sort approach serves to capture participants' perspectives on their experiences[17,18] and had categories, or "bins," that

ranged from "I NEVER observed this behavior" to "I ALWAYS observed this behavior." Each bin was assigned an allowable number of cards to maintain a balanced distribution of behaviors. In line with the methodology, the median selection allowed for more choices, while the extremes permitted fewer selections.

The survey instructions explicitly underscored that the scale was relative and not absolute, urging participants to sort behaviors relative to each other. Additionally, participants had the flexibility to introduce their own cards, and sort them accordingly, if they deemed a behavior critical to engineering design collaboration that was not included in the original set of 16 behaviors from CATME-B.

Discussion

Employing the Q-sort method, specific weights were assigned to the bins housing the distinct CATME-B behaviors, followed by a sum-product procedure to generate a single score representing each behavior's relative ranking. The outcome of this process revealed notable disparities in the observed frequency of CATME-B behaviors, as detailed in Table 3, which presents the complete list ranked from least to most frequently observed. The item, "Provides encouragement or enthusiasm to the team" received a score approximately equal to the mean for all the items. In addition, though the survey included seven possible frequencies, the values for "ALWAYS" and "NEVER" are included to illustrate the range of responses.

Table 3. CATME-B behaviors results ranked from least to most frequently observed

Behavior	n_{ALWAYS}	n_{NEVER}
Able to perform the role of any team member if necessary	0	8
Gives teammates specific, timely, and constructive feedback	0	2
Asks teammates for feedback and uses their suggestions to improve	0	3
Improves communication among teammates	1	3
Watches conditions affecting the team and monitors the team's progress	1	1
Cares that the team does outstanding work even if there is no additional reward	1	4
Motivates the team to do excellent work	0	1
Asks for and shows an interest in teammates' ideas and contribution	1	0
Provides encouragement or enthusiasm to the team	2	2
Acquires new knowledge or skills to improve the team's performance	2	1
Does more or higher quality work than expected	0	1
Helps to complete the work of teammates who are having difficulty	1	0
Makes sure that teammates are making appropriate progress	2	0
Makes important contributions that improve the team's work	2	0
Believes that the team can do excellent work	7	0
Demonstrates the knowledge, skills and abilities to do excellent work	6	0

These findings underscore the unequal observation of behaviors by senior capstone engineering students within design teams. This outcome aligns with the Reasoned Action Approach (RAA)[1] model for predicting behavioral choices, which emphasizes that behavioral choices are influenced by factors such as one's background, the perceived environment and context, social norms, and actual ability to perform the behavior. These results support the RAA because students are likely to encounter variations in their abilities and team dynamics, contributing to differences in their behavioral choices. However, the Q-sort methodology employed merely signifies variations in the frequency of behaviors, thus limiting a more nuanced understanding of the reasons behind participants' ranking decisions. As such, we plan to leverage the RAA in the larger investigation to better understand why students choose to perform some behaviors over others.

Conclusion

The variations in the prevalence of collaborative behaviors within engineering design teams underscore the nuanced nature of engineers' experiences, influenced by their inherent individuality, perceptions of their environments, contexts, and interactions with teammates. These diverse factors shape behavioral choices, potentially impacting a team's potential and effectiveness. The implications of these findings support the need for a deeper investigation into the underlying reasons, or *why*, for the differing performance of behaviors in engineering teams. Such insights hold the potential to inform the development of more targeted and effective training programs and pedagogies aimed at enhancing the overall effectiveness and success of engineering collaborations.

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