From Classroom to Workplace: Exploring Beliefs About Effective Collaboration in Engineering Teams- RFE (EEC-2217523)

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Underperformed Behaviors in Engineering Student and Practitioner Teams, RFE (EEC-2217523)

Introduction

Collaboration is fundamental to engineering practice, as engineers routinely communicate with their teams to tackle complex problems and achieve shared goals [1]. While engineering education emphasizes technical skills, effective collaboration is equally critical for addressing multidisciplinary challenges in both academic and professional settings [2]. This paper is part of a larger project that identifies which of the desirable collaborative behaviors are performed least by engineering students and practitioners working in design teams, and explores why these behaviors are not performed. This paper reports the least performed behaviors by capstone engineering students and engineering practitioners, it also seeks to explore the perceived consequences of performing those behaviors. Understanding collaborative behaviors dynamics is crucial for improving how students transition to the workforce and how practitioners engage in lifelong learning [3].

Our larger study, divided into three phases, is titled "Collaboration in Engineering Student and Practitioner Teams: A Study of Beliefs about Effective Behaviors" and funded by RFE (EEC-2217523). This paper focuses on phases 1 and 2 of the study. In phase 1, we designed a Q-sort activity to identify the least performed behaviors among engineering students and engineering practitioners which will help us identify gaps in collaboration. In this study, the collaborative behaviors under investigation are referred to as target behaviors. We utilized the CATME-B (Comprehensive Assessment for Team-Member Effectiveness- BARS) version which is a well-established framework designed to evaluate and improve team dynamics, focusing on individual contributions and collaborative behaviors to enhance teamwork [4]. Our contribution is revealing which behaviors associated with effective collaboration, as identified in the CATME-B instrument [4], are reported as least frequently performed by engineering capstone students and engineering design practitioners. In phase 2, we explored the participants' perceptions of the positive and negative consequences of performing the target behaviors, focusing on the most anticipated consequences and how these perceptions differ between students and practitioners. Finally, in phase 3, we will investigate why certain target behaviors are systematically underperformed by analyzing the data collected in phases 1 and 2 using the lens of Reasoned Action Approach theory.

Literature Review

Assigning students to teams is often mistaken for fostering collaborative skills. However, previous research shows that building such skills requires additional measures, such as mentoring [3] and peer assessments [4]. Challenges to effective collaboration in engineering practice include environmental barriers, gaps in teamwork skills, and resistance to change.

Collaborative behaviors in engineering education

Collaboration is fundamental to engineering practice, yet engineering students' collaborative skills often lag behind their technical skills [2]. This skill gap often leaves students ill-equipped for the teamwork integral to professional engineering [5]&[6]. Also, merely assigning students to teams does not guarantee effective collaboration. Therefore, programs must focus on interdisciplinary teamwork [7]. Analyzing collaborative behaviors allows educators to design interventions, identify struggling teams, and improve assessments [5].

CATME-B framework [4], provides a structured approach to evaluating teamwork in student teams. It categorizes collaborative behaviors into five key areas: contributing to the team's work, interacting with teammates, keeping the team on track, expecting quality, and possessing relevant knowledge, skills, and abilities (KSAs). For instance, "Contributing to the team's work" includes actions such as doing a fair share, attending meetings on time, and assisting teammates in need. CATME-B employs a Likert-scale to assess these behaviors reliably, offering educators a comprehensive tool to evaluate and enhance teamwork capabilities in engineering education.

Collaborative behaviors in engineering practice

Teamwork in professional environments faces various challenges that hinder its effectiveness. A key issue is the mismatch between academic training and the real-world complexities of workplace collaboration. Navigating organizational hierarchies, informal communication, and diverse expectations often prove challenging for new engineers [1] & [3]. Many professionals also struggle with interpersonal communication, particularly in adapting their style to suit multicultural and multidisciplinary teams [1] & [6]. Academic programs frequently emphasize formal tasks, such as presentations, while neglecting informal interactions, self-directed learning, and adapting to workplace cultures[3]. Additionally, emotional intelligence and cultural sensitivity are often insufficiently developed [6].

Resistance to collaborative practices, fueled by organizational shortcomings, further complicates teamwork [8]. Gaps in leadership skills and the ability to manage power dynamics hinder inclusive and effective collaboration [9]. Resistance to change poses another barrier, with traditional work practices favoring individual efficiency over collaboration, causing employees to revert to old methods and stifling innovation [8]. Due to the presence of barriers to collaboration, it is important to examine both students and practitioners in engineering team settings to understand their current behaviors. This project identifies gaps in collaborative practice by examining the least performed collaborative behaviors, with the goal of informing changes that enhance collaboration and improve outcomes.

Theoretical Framework

The Reasoned Action Approach (RAA), developed by Fishbein and Ajzen [10], is a social–psychological framework used to explain and predict behavior by examining the beliefs that precede action. RAA proposes that behavior is primarily driven by behavioral intention, which is shaped by three forces: attitudes, subjective norms, and perceived behavioral control. Attitudes are shaped by anticipated positive or negative consequences, subjective norms capture social expectations and common practices, and perceived behavioral control refers to individuals' beliefs about their ability to perform the behavior. In collaborative and team-based contexts, RAA offers a useful lens for understanding how beliefs impact behavior. Specifically, collaborative behaviors may be underperformed not because of a skill gap, but because individuals hold unfavorable attitudes toward the behavior, perceive limited social support for performing it, or doubt their ability to perform it effectively, or all three. In this study, RAA informs our examination of the beliefs underlying the least performed collaborative behaviors and guides our interpretation of why such behaviors may persistently remain underperformed in team settings.

Data Collection

A survey was developed using QuestionPro software and completed by 107 students enrolled in interdisciplinary capstone courses at two different R1 public universities. Additionally, the survey was completed by 27 engineering practitioners from diverse engineering companies, representing varying years of experience. The survey structure leverages the list of effective behaviors from the CATME-B survey. The survey asked participants to place the 16 behaviors from CATME-B on a grid, where each position on the grid corresponds to a specific frequency of performance. The grid includes 16 positions: 4 for "somewhat frequently," 3 each for "sometimes" and "rarely," 2 each for "often" and "very rarely," and 1 each for "always" and "never." This Q-sorting activity prompts participants to consider the relative frequency of collaborative behaviors. Our Q-sorting approach builds on our prior pilot investigation of capstone students' collaborative behaviors using a similar CATME-B–based sorting methodology, which revealed meaningful variation in collaborative practice [11]. For Phase 2, we designed a protocol to guide our 60-minute interview process. The interview questions included a section for the most commonly anticipated consequences of the least performed behaviors identified in Phase 1. Interviewees were also asked to rate the likelihood of these consequences occurring on a scale from 1 to 7, where 1 represents "not likely at all" and 7 represents "extremely likely". The other sections of the interview explored the normative and control beliefs of participants about the target behaviors.

Current Findings

A descriptive statistical approach was used in phase one to summarize all participants' ratings of the frequency of 16 collaborative behaviors. The averages provided a clear overview of the general perceptions and helped identify underperformed behaviors in collaborative settings, helping us answer: What are the least performed behaviors among student and practitioner teams? For each collaborative behavior, the average score was calculated using weighted frequencies of perceived performance. The weights assigned to the response categories—always, often, sometimes, somewhat, rarely, very rarely, and never—were 3, 2, 1, 0, -1, -2, and -3, respectively. The behaviors were then sorted in descending order based on their frequency of perceived performance. Descriptive results indicated that Behaviors A, B, and C were the least frequently performed across both student and practitioner teams. Additionally, a t-test revealed a significant between-group difference for Behavior D. Accordingly, these four behaviors were selected as the target behaviors for further analysis:

- Behavior A: Noticing changes that influence the team's progress
- Behavior B: Knowing what everyone should be doing and noticing problems
- Behavior C: Having the ability to perform some of the tasks normally done by other team members
- Behavior D: Having sufficient knowledge, skills, and abilities to contribute to the team's work

After analyzing the interviews in phase 2, the consequences of the four behaviors were revealed. Perceived consequences differ slightly between students and engineering practitioners. For students, Behavior A supports ongoing assessment and strategic adjustment but can lead to challenges in team dynamics while Behavior B promotes workflow efficiency and productivity yet it may cause conflicts within the team. Behavior C encourages flexibility and efficiency but similarly risks team dynamics issues, and Behavior D results in effective contributions and overall project success. For practitioners, Behavior A enhances productivity but may also create poor team dynamics. Behavior B supports problem-solving, decision-making, and collaboration when team dynamics are good, yet can contribute to team friction if dynamics are poor. Behavior C ensures flexibility and continuity of operations but carries the risk of overstepping and negative team interactions. Finally, Behavior D leads to insightful contributions and successful project outcomes. Overall, while both students and practitioners benefit from these behaviors in terms of productivity, contribution, and flexibility, the recurring challenge across both groups is maintaining positive team dynamics.

Discussion

This study sought to identify which collaborative behaviors are least frequently performed in engineering student and practitioner teams and to explore the perceived consequences of those behaviors as seen by engineering students and practitioners. Overall, our findings reveal consistent gaps in process-oriented and situational awareness behaviors, alongside mixed perceptions of the benefits and risks associated with performing them. In the sections that follow, we interpret these results by first examining the nature of the observed collaboration gaps and then considering the perceived consequences that may shape participants' willingness to enact these behaviors.

Gaps in collaboration in engineering teams

Before interpreting the main findings, it is important to recognize that the frequencies reported in this study are based on participants' ratings of collaborative behaviors rather than on direct observation. Drawing on the Theory of Rating [12], ratings are shaped by recall, bias, and contextual constraints. Therefore, behaviors identified as underperformed may reflect true performance gaps, measurement-related influences, or both. With this interpretive lens in mind, we now turn to what these findings suggest about the nature of collaboration in team settings. Effective collaboration requires strong situational awareness and active engagement, both of which are often challenging for teams. Prior research highlights these issues in practitioner settings, while our findings extend this understanding to student teams, emphasizing the need for targeted interventions to address gaps in collaborative behaviors. Nahar and colleagues [13] identify situational awareness—such as monitoring roles and noticing changes—as a significant challenge faced by practitioners in collaborative networks. Similarly, our findings highlight a lack of situational awareness among both student and practitioner teams, particularly in behaviors like noticing changes (Behavior A) and monitoring roles (Behavior B). This alignment underscores the importance of improving situational awareness to enhance collaboration.

Mejía and colleagues [14] also report significant challenges related to engagement in teams due to lack of support and insufficient training which coincides with our findings related to Behavior C (has the ability to do some of the tasks normally done by other team members). Most of our participants mentioned how the lack of training hinders team members from supporting each other with difficult tasks or at difficult times. Notably, while both Nahar et al. [13] and Mejia et al. [14] focus on practitioner teams in their respective studies, neither explicitly examines student teams. Our findings also align with the observations of Ger in [15] regarding reduced situational awareness. Ger's work emphasizes structured interventions—such as role clarity, trust-building, and peer evaluations—to address these issues. Murzi et al. [16] revealed that, prior to participating in the study, students viewed collaboration primarily as a requirement for degree completion rather than as a crucial skill needed for their careers. Students also initially held mixed or limited views regarding the importance of collaboration; however, their beliefs evolved positively after experiencing structured teamwork training and working on a real-world project. In sum, the reported pattern is consistent with prior findings in capstone teams, where technical contributions were commonly observed while process-oriented and interpersonal behaviors occurred less frequently and showed greater variability [11].

Consequences of performing the target behaviors

Building on Murzi et al.'s work [16], our findings move beyond treating collaboration as a single, broad construct by examining the perceived positive and negative consequences of specific collaborative behaviors. In particular, we focused on the least performed behaviors and the positive consequences associated with them. Students reported positive consequences such as increased workflow efficiency, productivity, and strategic adjustment, as well as negative consequences, including challenges in team dynamics. Our findings regarding engineers' perceived negative consequences of collaborative behaviors—particularly concerns about team conflict and poor team dynamics—align with prior work by Buch and Andersen [17], who argue that engineering professionalism is strongly oriented toward individual performance and accountability rather than collective achievement. Within such a professional culture, collaborative behaviors may be perceived as disruptive to established roles, responsibilities, and performance expectations, thereby increasing the likelihood of interpersonal tension and conflict.

Future Research

After completing the first and second phases of our project, summarized in this paper, our research team will shift focus to the third and last phase. We will explore the underlying beliefs held by student and practitioners about collaborative behaviors by analyzing interviews with participants. These interviews will provide qualitative insights into participants' motivations, challenges, and contextual factors influencing their actions. Additionally, we will apply the Reasoned Action Approach (RAA) to analyze their responses, enabling us to systematically interpret the interplay between beliefs, actions and intentions. This combined approach will provide a more holistic understanding of current practices in both engineering education and professional engineering contexts.

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References

[1] J. D. Ford, M. Paretti, D. Kotys-Schwartz, S. Howe, and R. Ott, "New Engineers' Transfer of Communication Activities From School to Work," *IEEE TRANSACTIONS ON PROFESSIONAL COMMUNICATION*, vol. 64, no. 2, 2021.

[2] J. Trevelyan, "Transitioning to engineering practice," *European Journal of Engineering Education*, vol. 44, no. 6, pp. 821–837, Nov. 2019, doi: 10.1080/03043797.2019.1681631.

[3] C. Gewirtz *et al.*, "New Engineers' First Three Months: A Study of the Transition from Capstone Design Courses to Workplaces," in *2018 ASEE Annual Conference & Exposition Proceedings*, Salt Lake City, Utah: ASEE Conferences, Jun. 2018, p. 30838. doi: 10.18260/1-2--30838.
[4] M. W. Ohland *et al.*, "The Comprehensive Assessment of Team Member," *Academy of Management Learning & Education*, 2012.
[5] M. Besterfield-Sacre, M. F. Cox, M. Borrego, K. Beddoes, and J. Zhu, "Changing Engineering Education: Views of U.S. Faculty, Chairs, and Deans," *J of Engineering Edu*, vol. 103, no. 2, pp. 193–219, Apr. 2014, doi: 10.1002/jee.20043.
[6] F. Munir, "More than technical experts: Engineering professionals' perspectives on the role of soft skills in their practice," *Industry and Higher Education*, 2021.
[7] 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," *J of Engineering Edu*, vol. 102, no. 4, pp. 472–512, Oct. 2013, doi: 10.1002/jee.20023.
[8] A. Buch and V. Andersen, "Team and Project Work in Engineering Practices," *NJWLS*, vol. 5, no. 3a, p. 27, Nov. 2015, doi: 10.19154/njwls.v5i3a.4832.
[9] T. S. Woodson and S. Cozzens, "Teaching Community Engagement to Engineers via a Workshop Approach," *J. Prof. Issues Eng. Educ. Pract.*, 2019.
[10] M. Fishbein and I. Ajzen, *Predicting and Changing Behavior*, 0 ed. Psychology Press, 2011. doi: 10.4324/9780203838020.
[11] M. Gerhardt, M. Madboly, N. Pitterson, E. Dringenberg, and B. Ahn, "Collaborative (in)decision: A Preliminary Investigation of the Differences in Undergraduate Engineering Capstone Students' Collaborative Behaviors".
[12] M. Madboly and N. P. Pitterson, "Enhancing Teaching Evaluation in Engineering Education: An Exploration of the Theory of Rating," in *2024 ASEE Annual Conference & Exposition*, 2024.
[13] N. Nahar, S. Zhou, G. Lewis, and C. Kästner, "Collaboration challenges in building ML-enabled systems: communication, documentation, engineering, and process," in *Proceedings of the 44th International Conference on Software Engineering*, Pittsburgh Pennsylvania: ACM, May 2022, pp. 413–425. doi: 10.1145/3510003.3510209.
[14] J. A. Mejia, R. A. Revelo, and A. L. Pawley, "Thinking about Racism in Engineering Education in New Ways [Commentary]," *IEEE Technol. Soc. Mag.*, vol. 39, no. 4, pp. 18–27, Dec. 2020, doi: 10.1109/MTS.2020.3031776.
[15] Y. Ger, "Sustaining teamwork and interaction in higher education," 2023.
[16] H. G. Murzi, T. M. Chowdhury, J. K. Ek, and B. C. R. Ulloa, "Working in Large Teams: Measuring the Impact of a Teamwork Model to Facilitate Teamwork Development in Engineering Students Working in a Real Project".
[17] A. Buch and V. Andersen, "Team and Project Work in Engineering Practices," *NJWLS*, vol. 5, no. 3a, p. 27, Nov. 2015, doi: 10.19154/njwls.v5i3a.4832.