

"What I Meant to Say Was...": Unravelling the Knots of Competent Communication in Engineering Research Teams

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ABSTRACT

The escalating complexity of global challenges demands a collaborative approach in scientific research that leverages diverse expertise, cultural backgrounds, and disciplines. This paper investigates communication barriers within multicultural engineering education research teams, emphasizing competent communication in fostering effective collaboration and innovation. Using Thompson's Collective Communication Competence (CCC) Model, this study explores engineering students' experiences in a multicultural engineering education research project, aiming to identify specific challenges that hinder competent communication and propose actionable strategies for improvement. Through qualitative interviews and content analysis, the research highlights challenges in comprehensibility, team bonding, and navigating diverse disciplinary languages and cultural norms. The findings advocate for proactive measures such as early training in common language establishment, trust-building activities, and engaged reflexivity to enhance communication dynamics within multicultural research teams.

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1 INTRODUCTION

Today's world faces significant environmental and societal challenges, including climate change, population growth, disasters, and equity disparities. To tackle these challenges effectively, groundbreaking scientific and technological research among individuals with varied expertise and cultural backgrounds is essential (Aldert 2019; Leever, H 2020). Diversity of knowledge, skills, and cultural backgrounds is crucial, as it brings fresh insights and perspectives and enhances problem-solving capabilities needed to address complex challenges (Aldert 2019; Chubin, May, and Babco 2005; Euro-CASE 2020). Cultural diversity, sometimes referred to as multiculturalism, is “a system of beliefs and behaviors that recognizes and respects the presence of all diverse groups in an organization or society, acknowledges and values their socio-cultural differences, and encourages and enables their continued contribution within an inclusive cultural context which empowers all within the organization or society” (Rosado 2006). Thus, effective communication is vital in culturally diverse engineering research environments to ensure successful collaboration and knowledge exchange (Varhelahti and Turnquist 2021). This paper aims to identify factors hindering competent communication among engineering students in multicultural research project settings and proposes strategies to promote improved communication. By promoting competent communication and recognizing individual differences, engineering environments can thrive and effectively tackle complex societal and environmental challenges.

1.1 Background and Theoretical Framing

Engineering education must develop technically and professionally competent graduates to meet the ever-changing demands of engineering practice. This necessitates curriculum reform incorporating early exposure through hands-on, practical activities that reflect real engineering practices (Crawley et al. 2014). Engineering research projects provide an excellent avenue for such exposure, equipping students with essential competencies and leading to notable outcomes such as career readiness, disciplinary knowledge, and an understanding of how engineering practice functions (Seymour et al. 2004).

Supported by funding bodies like NSF and Horizon 2020 Europe (Castelpietra et al. 2020; NSF 2008), these engineering research projects involve culturally diverse teams with varied skills and expertise crucial for enhancing creativity and advancing science (Leung et al. 2008). However, this multiculturalism introduces complex communication challenges crucial to a team's success and cohesion (Varhelahti and Turnquist 2021). Cultural differences, language barriers, varying communication styles and tools, and differences in professional roles or power dynamics can lead to miscommunication and misunderstandings (Liu et al. 2021; Varhelahti and Turnquist 2021). Such challenges threaten the efficiency and effectiveness of research collaborations and risk undermining trust among team members, potentially affecting the quality of work (Walther and Sochacka 2014) and resulting in decreased performance and project failure (Marlow, Lacerenza, and Salas 2017).

Addressing these communication challenges requires a nuanced understanding of the factors influencing information exchange and comprehension within multicultural research teams. Given cultural diversity's essential role in shaping how individuals communicate and understand shared information, developing competent communication skills is crucial (Ravesteyn, Graaff, and Kroesen 2006). These skills are essential for research members to learn and carry forward into their future careers

in both academic and industrial settings (Lappalainen 2009). By fostering an environment that promotes effective communication practices, multicultural engineering research teams can leverage their diversity to overcome communication challenges and enhance collaboration (Mohanty 2018).

Competent communication within a multicultural engineering research group can be defined as interactions that effectively achieve objectives in a manner suitable to the context in which they occur (Spitzberg 1988). Employing frameworks such as Thompson's Collective Communication Competence (CCC) Model to guide competent communication practices can be beneficial. Thompson's CCC model, built originally on an ethnographic study of an interdisciplinary academic research team, stems from the understanding that interactions among group members are intertwined, necessitating appropriateness and effectiveness (Thompson 2009). This model identifies processes fundamental to and that hinder CCC, such as task talk, reflexive communication, backstage communication, spending time together, building trust, demonstrating practice, discussing language differences, and shared laughter (Thompson 2009).

This study, utilizing Thompson's model within a multicultural engineering research setting, focuses on illuminating students' experiences with competent communication, especially during the formative stages of a project, as it can provide valuable insights for improving their engagement in multicultural engineering settings. **Specifically, this research focuses on the formative stage of a multicultural engineering education research project called 'Critical Conversation.'** This team is engaged in NSF-funded research aimed at empowering Black PhD students in engineering programs to act agentic in the face of systemic and racial biases. The team consists of three engineering education faculty mentors and five engineering students, all culturally diverse and possessing at least one underrepresented identity in engineering (e.g., Black and Latine'). This study aims to identify communication challenges that may hinder or limit interactions among team members by examining the communication dynamics within this engineering education research project. The goal is to help guide engineering education research teams seeking to effectively kickstart their projects from the outset.

Research Question: What specific communication challenges do engineering students encounter when collaborating in multicultural engineering education research teams, and how do these challenges impact the team's ability to communicate competently?

2 METHODOLOGY

2.1 Context and Participants

This study is part of a broader research project investigating the agency of Black graduate students in engineering at a highly research-intensive public institution in the United States. The research project team comprises three culturally diverse subgroups collaborating to achieve the project's objectives. Each subgroup is led by the principal investigator (PI) or one of two co-investigators – each from a different department. The PIs are two self-identified Black women and one Latine' woman. Additionally, five research students are working alongside the investigators to contribute to the successful completion of the project. This study focuses on the research students involved in the project, and the authors of this paper are members of the research

project. Table 1 details the demographic information of the research students involved in the study.

Research Student's Pseudonym	Self-identified Gender	Race/Ethnicity	Discipline	Academic Level
Hassan	Man	Asian/Pakistan	Engineering Education	Ph.D.
Kim	Woman	White/Columbian	Engineering Education	Ph.D.
Kiki	Woman	Asian/not identified	Computer Science	Master's
David	Man	Hispanic/not Identified	Electrical Engineering	Undergraduate
Bima*	Woman	Black/ Nigerian	Civil Engineering	Ph.D.

Table 1: Demographic Information of Research Students

*Bima is the pseudonym of the first author conducting the research. Her demographic info is listed; however, this study does not include her interview data.

2.2 Data Collection

The data for this study was collected through qualitative interviews using a protocol designed based on the Team Effectiveness Questionnaire by the London Leadership Academy and the CIMER Mentorship Model (Law 2020; Pfund et al. 2021). Initially, semi-structured interviews were conducted to understand how an interdisciplinary, multicultural, and multidisciplinary team can effectively initiate collaboration from the project's start and identify what elements influenced this process. The preliminary findings highlighted communicating competently as a significant challenge for the research students. Consequently, follow-up semi-structured interviews were conducted to dive deeper into the engineering research students' challenge with communicating competently. The follow-up protocol was structured using the critical incident technique (Flanagan 1954; D. Simmons and Martin 2010) to identify and analyze specific communication challenges the students face, clarify meanings, and facilitate exploration of impactful incidents to improve practices and contribute to theoretical knowledge. The interviews were recorded, transcribed, and coded.

2.3 Data Analysis

The qualitative nature of the data led to using content analysis to examine the recorded and transcribed interview data (Weber 1990). This analysis involved two distinct coding processes: a deductive code employing Thompson's Collective Communication Competency Model as a conceptual framework and an inductive coding approach allowing for emergent codes from the interview data (Saldaña 2016). To generate the study findings, the first author familiarized herself with the dataset and then coded using the CCC framework. Following this, the first author ensured the validity of the findings by engaging in peer debriefing with the second author and members of her subgroup research lab. This debriefing involved scrutinizing the coding procedure and triangulating the data with other sources (i.e., memos, the first author's diary entry, and the first interview) (Creswell and Miller 2000). Once an interrater agreement was reached, the first and second authors collectively categorized the codes to answer the research questions (McHugh 2012). This approach ensured a thorough analysis of the qualitative data, allowing for interpretation within the social and cultural context and providing a deeper understanding of communication relevant to the research objectives.

3 RESULTS

3.1 Tables

Analyzing the data through the CCC model made it apparent that the research students encountered challenges in comprehensibility, team bonding, and skills gap insight while collaborating within the multicultural academic research team. These challenges resulted in deficits in the team's integrative task discourse, integrative team harmony, and engaged reflexivity. Table 2 is a structured presentation of the analytical process and findings.

Category (Impact on Team)	Description	Communication Process Codes	Exemplar Quote
Integrative Task Discourse	integrates task-focused conversations with the mindful negotiation of language differences, thereby facilitating a more cohesive and productive team dynamic	Task Talk Discussions of language differences	One project investigator sent us an e-mail requesting that research participants be contacted. However, it was not clearly mentioned which students should send the e-mail. (Kiki) I worked with [my advisor] on [research topic], and then there were two other areas [other research topics], which were very new to me. So, those are challenging for me to understand. (Hassan)
Integrative Team Harmony	holistically integrates spending meaningful time together, fostering trust (both swift and deep), and encouraging open, informal communication	Spending time together Practicing trust Backstage communication	The best way to collaborate is first by being friends. You can't have random strangers work together because they don't know how even to start the conversation and work together because they don't know each other well [...]then it's weird just communicating. (David) If I'm very near to someone, if I'm going to ask something from that person, there might be some points at which the other person or even myself will not answer those specific questions. So, you must remove those boundaries. You have to give the other person more clarity about your intentions. (Hassan) I feel like it's just a lot of behind-the-scenes things which sometimes can be hard for me to

			catch up with [...] I sometimes feel like the communication can be a little spotty. (Kim)
Engaged Reflexivity	underscores the importance of both being wholly present in collaborative efforts and maintaining an ongoing, reflective dialogue that encourages mutual trust, shared understanding, and collective growth within teams	Reflective talk Demonstrating presence	I'm an undergrad, and compared to (other teammates), they have a little more experience and knowledge of the project [...] But for me, I just try to build the best effort I can and show them the best work I can provide. (David) Qualitative analysis is something new for me right now, and at some point, I know that in the future, when we do the analysis portion, it will be a challenging part for me as well. (Hassan)

Table 2: Content Analysis: Defined Categories, Codes, and Sample Quotes

Integrative Task Discourse (ITD) relates to the dual focus required in interdisciplinary teams: concentrating on the project's tasks and objectives while acknowledging and addressing the linguistic and conceptual differences inherent in diverse academic fields. By promoting an approach that values clarity in task-related communication and sensitivity to disciplinary languages, teams can achieve a more effective and inclusive CCC, enabling them to navigate the complexities of interdisciplinary research more smoothly. Task talk is crucial to achieving ITD. However, students encountered challenges in understanding the roles delegated to them through written documents guiding the project, leading to disrupted project timelines, misaligned expectations with project investigators, feelings of being out of the loop, and unfamiliarity with the project's status. These challenges may have stemmed from the fact that the research team was in their first year or early stages of their careers, and the students were likely unfamiliar not only with the research process but also with the nuances of the products generated by the three different disciplinary strands of the project.

Moreover, addressing language differences and establishing a common language among teams in multicultural academic research settings can be highly beneficial. Students in the study struggled to comprehend the disciplinary jargon and acronyms common to the other sub-groups and the linguistic and pronunciation variances across the team, thus affecting their ability to comprehend the information they received.

Integrative Team Harmony (ITH) highlights the multifaceted approach to building a cohesive team, where each member feels valued and understood, trust is woven into the fabric of the team's interactions, and informal communication channels are recognized as vital for the team's emotional and social cohesion. This integrated approach ensures that teams are effective in accomplishing their tasks and enriched by the shared human experience, fostering a sense of unity and collective purpose. Communication processes such as spending time together are invaluable for fostering better ITH. However, students in the study faced challenges in effectively

communicating with one another, stemming from infrequent team interactions and limited time to bond. Thus, their ability to interact, build trust, cultivate shared understanding, and foster clear communication, which promotes team harmony rather than a sense of estrangement, was stymied. Students also identified trust-building, which supports team harmony, as a barrier to team interactions. Practicing trust-building helps team members overcome perceived boundaries in relationships and fosters interpersonal bonding. Additionally, backstage communication, a form of informal verbal communication, also facilitates harmony. Students recognized the benefits of backstage communication, such as one-on-one meetings with advisors and informal discussions with team members, for understanding projects and overcoming challenges. However, the students also acknowledge that such communication, especially involving discussions about project changes with specific individuals outside general team conversations, led to miscommunication and confusion regarding tasks and project developments. Additionally, the fact that all teams were not only in different disciplines but also located in different buildings posed an additional challenge.

Engaged Reflexivity (ER) emphasizes the outward actions of being present and participative and the inward reflection that enables individuals to contribute more meaningfully and cohesively to their teams. It is about creating a culture where team members are encouraged to be fully there, both physically and mentally, while also being mindful of how their contributions, behaviors, and interactions influence the collective output and team spirit. ER suggests a dynamic interplay between being present and being thoughtful, ensuring that team collaboration is vibrant and considerate, and students can successfully engage reflexivity by integrating communication processes such as reflexive talk and demonstrating presence. According to Thompson's CCC model, reflexive talk is vital in students' ability to observe, reflect upon, and ultimately effect changes within a multicultural academic research setting. The self-awareness from students' reflective talk can significantly impact their ability to demonstrate their presence and effectively communicate within the group. Students showed they were team players by supporting each other and sharing presentation responsibilities. However, their awareness of personal differences, lack of experience, and doubts about their skills posed a challenge and created perceived barriers in their interactions, leading to uncertainty about how their contributions would be received during team meetings. Therefore, understanding diversity can foster confidence and trust in group settings.

4 SUMMARY AND ACKNOWLEDGEMENTS

4.1 Summary

Using Thompson's CCC model, this study aimed to identify specific communication challenges engineering students encountered when collaborating in multicultural engineering education research teams and how these challenges impact the team's ability to communicate competently. Consistent with Thompson's CCC study, this research highlights the necessity for trust-building time, explicit conversations around disciplinary research concepts and languages, and the inclusion of social activities to strengthen research team communicative interaction (Thompson 2009). A nuanced addition to Thompson's CCC study is the need for skill training and critical conversations around the research team ethos, as many of the students' challenges stemmed from their skill gaps and unfamiliarity with the team's research process, expectations, and culture.

Engineering employers prioritize technically and professionally skilled graduates, which calls for engineering education to incorporate training instrumental for students' skill development (Simmons, McCall, and Clegorne 2020). Communication skills are essential to engineering practices because nearly all engineering activities rely on communication. Therefore, there is a need to shift from viewing communication merely as information sharing to recognizing it as a means to establish and nurture relationships (Trevelyan 2009). Engineering education research teams are encouraged to utilize models such as CIMER and CDIO (Conceive, Design, Implement, Operate), focusing on knowledge-building and facilitating professional skill development through active and experiential learning (Crawley et al. 2014; Janet, Amanda, and Amber 2020). Direct student engagement in learning contributes to lifelong learning skills and a stronger sense of responsibility (Seymour et al. 2004).

The findings of this study also call for engineering educators engaged in multicultural and interdisciplinary research to collectively uncover the hidden curriculum behind the cultural norms and expectations around communication, project, and task-related activities within their research settings. This will ensure students' alignment and enhanced comprehension for task execution (Villanueva Alarcón 2022). Competent communication is a holistic process involving both educators and students (Rosado 2006). Therefore, engineering students are encouraged to proactively seek clarification to build familiarity with the research setting and team's ethos (Ravesteijn, Graaff, and Kroesen 2006). Engineering research teams should prioritize active listening, constructive critique, and continuous learning within the team for successful engagements and collaboration, free of internal resistance and fear (Ravesteijn, Graaff, and Kroesen 2006). Based on the findings of this study, the Principal Investigators of this research project have collectively established a more defined research ethos, detailing the research process, team communication methods, frequent in-team interactions, and skill development training to help all team members communicate competently and collaborate effectively to achieve the research goals.

4.2 Limitations and Future Directions

The research findings primarily reflect students' perspectives in a multicultural engineering education research project. Future research could broaden its scope by investigating the viewpoints of the principal investigators to gain insights into the factors that may promote competent communication and cultural and disciplinary differences within research environments. The findings of this study may not be broadly transferable. This research was conducted within a research-intensive public institution in the United States; hence, future research may replicate this study in a different region and/or institution type to uncover other challenges preventing students from communicating competently within a multicultural setting.

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