Advancing Intercultural Communication Skills in Diverse Teams: An Intervention Program for Project-Based Engineering Courses

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Studies show engineering graduates lack critical skills, including the ability to communicate effectively and appropriately in diverse teams. As institutions seek effective and affordable solutions to meet ABET accreditation standards for non-technical skills, we report on an intervention program designed to advance learners' intercultural communication (IComm) skills. We adapted the UNESCO Story Circles methodology (2020) to undergraduate engineering contexts: discipline-specific prompts guide oral exchanges among students, tasking learners to practice IComm principles in teams. The 2021 mixed-method study tracked 31 students' attitudes toward teamwork and performance in project-based learning. Data sources included three survey instruments, individual project grades, and end-of-semester course evaluations. Results show strong student support for the intervention program across demographics and instructional modalities; improved learner attitudes toward teamwork in post-intervention surveys; improved 2021 end-of-semester course evaluations compared to 2019; and, higher individual grades on the team project. Findings support the use of our intervention program in project-based engineering courses and highlight the importance of guiding engineering students in the intentional practice of IComm principles.

Keywords: intercultural communication, mixed methods research, project-based learning, teamwork

INTRODUCTION

To be successful in the global marketplace, employers seek engineering graduates who possess not only disciplinary knowledge and technical skills, but also the ability to communicate effectively and appropriately in diverse teams, adapt quickly to new environments, and consider the cultural contexts of engineering solutions (AACU, 2018; IDC, 2015; ASEE, 2013; ASEE, 2018). At many universities,

however, engineering programs, faculty, and students still focus almost exclusively on developing technical skills, despite decades of scholarship and ABET accreditation standards that emphasize the need to hone non-technical skills required for well-rounded, 21st-century engineers (ABET, 2022-23, Handford et al., 2019; Jesiek, 2018; Powers, 2020; ASEE, 2017).

Above all, engineering students consistently struggle with communication and teamwork, in large measure due to curricular constraints and a lack of faculty expertise in how to effectively infuse non-technical skills development into undergraduate courses (Alford et al., 2014; Ercan & Khan, 2017; Konak et al., 2015; Leydens & Deters, 2017; Powers, 2020). Consequently, employers frequently invest resources into "training programs for new hires to augment engineering education with a broader set of skills" (Rogers & Freuler, 2015, p.1). The skills gap negatively impacts graduates' ability to function in the global workplace where communication in diverse teams is critical to success.

Recognizing the central role of intercultural communication (IComm) in closing this skills gap, select institutions have internationalized undergraduate engineering education. Five-year, dual-degree programs attract more diverse student cohorts who demonstrate significant gains in IComm skills (Berka et al., 2017; Bland, 2010; Grandin, 2013; URI, 2019). But long-term international work and study experiences, key characteristics of these programs, are not feasible at many institutions due to curricular and financial limitations (Davis & Knight, 2018; Streiner & Besterfield-Sacre, 2018), especially in the wake of the COVID-19 pandemic. Well-intentioned ad hoc initiatives, by contrast, struggle to affect long-term change. Isolated and short-duration global engineering programs and IComm interventions have been demonstrated to reinforce students' stereotypes or show only minor changes in participants' IComm abilities (Demetry & Vaz, 2010; Handford et al., 2019; Paterson et al., 2016).

Moreover, when faculty lean on standard intercultural competence workshops offered by their institution, the training is not adapted to engineering contexts. Consequently, faculty and student participants perceive prompts and activities as lacking rigor and relevance. Hence, there is a need to explore methods keyed to engineering scenarios to affect real, durable change and to address engineering students' skills gaps within the engineering curriculum itself (Handford et al., 2019; Leydens & Deters, 2017; Powers, 2020). Especially during times when resources are diminished, interdisciplinary partnerships—between engineering faculty and colleagues with expertise in IComm development, teamwork facilitation, and assessment practices—offer cost-effective and rewarding solutions that benefit both faculty and students in engineering programs (Britton et al., 2017; Paterson et al., 2016; Powers, 2020).

The literature confirms that team projects must be carefully prepared and supported (Ercan & Khan, 2017; Kusano et al., 2016, Powers, 2020). Students must be guided by faculty members in how to navigate the multi-faceted challenges entailed in team assignments. Communication issues have been identified especially in culturally and cognitively diverse teams, where performance expectations might differ and where bias, miscommunication, and conflict can arise easily (Downey et al., 2006; Khair et al., 2013; Pfeifer & Stoddard, 2018). Students must better understand how important IComm is in engineering teamwork and be afforded frequent opportunities to practice specified IComm principles if they are going to communicate effectively with colleagues and clients in the global workplace (Kusano et al., 2016; Ramaswami et al., 2014).

Our goal was to investigate the impact of an IComm intervention program in an undergraduate engineering course on learners' attitudes toward teamwork and their performance in diverse teams. We developed and tested intervention protocols that engineering faculty can employ in any course with a teamwork component and in both face-to-face and online instruction by including opportunities for intentional, iterative practice of specific IComm principles in teamwork settings throughout the course.

The COVID-19 pandemic prompted us to launch our intervention program in both online and face-to-face instruction. We welcomed its dual-modality implementation as an opportunity to prepare our students for the "new normal" in the workplace, which has shifted much collaboration and communication to remote, online settings in "geographically dispersed teams" (Gupta, 2009; Neeley, 2015). In short, if engineers of tomorrow are to succeed in global markets, they must communicate effectively in teams both in-person and online.

BACKGROUND AND THEORETICAL FRAMEWORK

Intercultural Competence (IC)

The field of intercultural competence (IC) has generated significant scholarship since its inception, arguably in the 1950s as championed by Edward T. Hall. Subsequent decades yielded numerous IC models and definitions (see Bennett, 2015; Deardorff, 2020). Our intervention program draws from Bennett's definition of IC as "a set of cognitive, affective, and behavioral skills and characteristics that support effective and appropriate interaction in a variety of cultural contexts" (Bennett, 2008, p.97). Notably, the AACU VALUE rubric for Intercultural Knowledge and Competence (2010) adopts Bennett's definition and identifies fundamental IC principles that specify requisite knowledge, skills, and attitudes. Communication features prominently in the rubric which also articulates progressive levels of competency attainment.

Deardorff's (2006) seminal study of IC definitions generated a research-based model (Deardorff, 2006, 2009) which also undergirds our project. Significantly, Deardorff's model prioritizes an individual's attitude as a starting point in the process of developing or enhancing intercultural competence. Furthermore, Deardorff's model augments previous constructs in two ways: It transcends the historical focus on the individual to include the dynamics of interactions and recognizes the iterative nature of progressive IC development in recurring, experiential learning cycles.

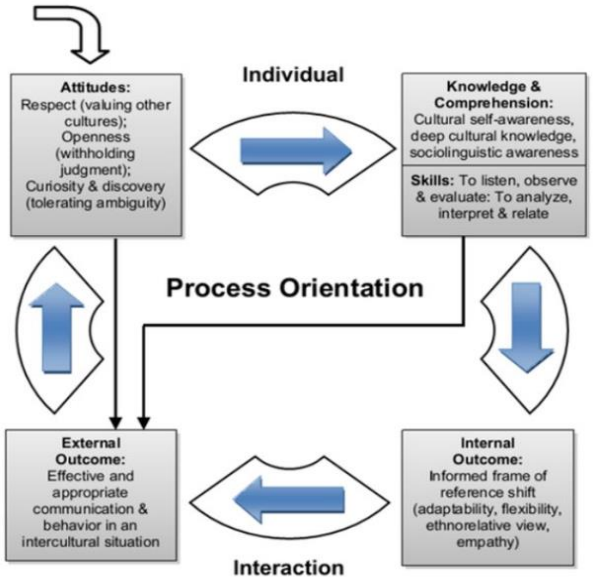
Additionally, Deardorff's emphasis on the internal outcomes of a "frame of reference shift," i.e., the ability to understand and experience a situation from a perspective other than one's own, aligns with real-world engineering work and team assignments in engineering courses: team members must explore solutions from more than one angle (Downey et al., 2006). The external outcome of effective and respectful interactions with team members (or clients) connects with the recognized skills gap in engineering students and graduates summarized above.

The concept of iteration is entailed in Deardorff's model as the recurring, cyclical, developmental process that an individual experiences with every new intercultural encounter (or team-based engineering activity) (See Figure 1). It conceptualizes IC development as a potentially life-long process and not as a goal to be reached in a semester-long course. However, communication competencies can be practiced and enhanced via intentional interventions, such as activities that prompt learners to engage in deep listening, thereby increasing cultural self-awareness and demonstrating respect and curiosity about similarities and differences with others (Deardorff, 2020).

Deardorff's *Manual for Developing Intercultural Competencies* (2020) summarizes decades of IC research and introduces the Story Circles (SC) methodology for practicing specified competencies in diverse teams. The United Nations Educational, Scientific and Cultural Organization (UNESCO) developed and tested the SC methodology in diverse settings around the world. Available as an open educational resource, the manual delineates the research-based approach to designing SC, summarizes findings, describes the facilitation of SC, and concludes that SC are effective in a variety of contexts (including university settings).

The rationale for adopting the SC method for our study was grounded in our uneven experience with standard IC training and preliminary positive experiences with SC in courses previously taught. The SC methodology seemed appropriate because it guides students in practicing IC principles deemed vital to engineers: most engineering work is conducted through collaborative teamwork, where ideas are collectively evaluated to determine optimal strategies for specific engineering designs or solutions.

FIGURE 1
DEVELOPMENTAL-RELATIONAL MODEL OF IC



Deardorff, 2006

In our study, we thus focus on specified intercultural communication competencies that participants practice during teamwork, such as deep listening and demonstrating cultural self-awareness and respect and curiosity about team members (see Figure 2). Drawing from the body of IC scholarship we define intercultural communication (IComm) competence as "the ability to communicate effectively and appropriately in diverse environments, a critical skill for the 21st-century engineer."

Teamwork

The AACU VALUE Teamwork rubric (2010), collaboratively developed and based on a review of extant scholarship about teamwork, defines teamwork as "behaviors under the control of individual team members (effort they put into team tasks, their manner of interacting with others on team, and the quantity and quality of contributions they make to team discussion)." (p.1) Like the AACU VALUE rubric for Intercultural Knowledge and Competence described above, it is a no-cost, editable tool that measures participants' behaviors according to criteria and performance levels and foregrounds attitudes and communication skills (e.g., respectful, polite, and constructive expressions and behaviors). While the rubrics help identify desireable learning outcomes, they do not, however, address best practices for attaining teamwork or IComm skills.

Numerous studies since the publication of the AACU rubrics have investigated effective facilitation and assessment of teamwork (Britton et al., 2017; Deardorff, 2011; Hughes & Jones, 2011; Kusano et al., 2016). The aforementioned authors' plurivocal advocacy focuses on advancing engineering students' "critical skills" (Britton et al., 2017, p.378) that are variously associated with the "global engineer" (Leydens & Deters, 2017, p.1). Kusano et al. (2016) summarize: "The need for collaborative work is widespread, and creating opportunities for students to practice collaboration and teamwork is imperative across disciplines." (p.2) Citing extensive literature review and direct observation in engineering curricula, Ercan and Khan (2017), as well as Khair et al. (2013), prioritize communication skills among numerous competencies. They also posit that "for modern engineers, communication needs expand [beyond written and oral skills] to good listening, visual, interdisciplinary and intercultural skills" (Ercan & Khan, 2017, p.25). And yet, communication skills development and assessment have also been widely discussed as

challenging (Britton et al, 2017; Doukanari et al., 2020; Krumm & Hertel, 2013; Kusano et al., 2016; Revilla-Cuesta et al., 2020).

Concerning learners' diversely developed communication skills, team project assignments themselves present challenges. The scholarship identifies complicating factors that arise frequently: Konak et al. (2015) document that students' lack of interest in teamwork makes the task of improving their attitude toward and performance in teams difficult. Moreover, attitudes toward teamwork can vary widely in culturally or cognitively diverse teams (Doukanari et al., 2020; Kusano et al., 2016; Ramaswami et al., 2014). Attitudes can translate into behaviors that result in undesirable team dynamics: Group assignments can privilege some group members at the expense of others. When team composition and project tasks allow individuals to eschew tasks by relying on peers, underrepresented groups feel marginalized, interpersonal team dynamics and performance are impacted, and miscommunication, member conflicts, accountability issues, and frustrations ensue (Alford et al., 2014; Ercan & Khan, 2017; Hughes & Jones, 2011; Revilla-Cuesta et al., 2020). Team assignments in which students are allowed to self-select can also negatively affect teamwork, i.e., friends choose to work with friends, and teammates who have previously worked together may dominate the group (Ercan & Khan, 2017; Revilla-Cuesta et al., 2020).

In response to these challenges, researchers recommend an intentional, process-based, multi-pronged, and research-based approach toward assigning and facilitating projects in both conventional and virtual environments. Alford et al. (2014) endorse diverse instructor-assigned teams; Hughes and Jones (2011) and Powers (2020) advocate for setting clear expectations for team behavior and project completion; Alford et al. (2014) and Thompson (2017) note the importance of crafting checklists for behavioral standards with frequent review to foster accountability. Kusano et al. (2016) summarize a set of five best practices for fostering collaboration and communication skills in teams; Ercan & Khan (2017) note the importance of team bonding; Powers (2020) emphasizes trust building; Alford et al. (2014) document that online platforms facilitate more egalitarian participation with increased contributions from women and non-native English speakers.

Developing students' communication and project management skills require considerable faculty effort, as does tracking and evaluating their teamwork via multiple criteria (Ercan & Khan, 2017, p.26). To facilitate adoption by faculty peers who lack time for or expertise in IComm training or teamwork assessment, our team drew from the findings summarized above to develop the intervention protocols in this study, i.e., by adapting the SC methodology and developing the written preamble "Guiding Principles for Professional Leadership Skills in Engineering."

INTERVENTION PROGRAM AND ASSESSMENT MEASURES

For this study, we define our intervention program as a coherent set of learning objectives, sequenced activities, and supporting resources grounded in research-based approaches and implemented in an undergraduate engineering course to improve students' attitudes towards and performance in diverse teams.

Our intervention program responds to scholarship that documents learners' attitudes as an important consideration in gauging their disposition toward developing and improving teamwork skills (AACU VALUE rubric on teamwork, 2010; Britton et al., 2017; Deardorff, 2020; Doukanari et al., 2020; Ercan & Khan, 2017; Konak et al., 2015; Krumm & Hertel, 2013; Powers, 2020). It also recognizes the importance of the iterative and intentional practice of clearly specified principles in interpersonal communication as part of teamwork (Alford et al., 2014; Deardorff, 2020; Powers, 2020). Furthermore, it acknowledges the value of multiple, varied, and integrated assessments that align with learning goals and outcomes, and opportunities for learners' reflection on specified behaviors, skills, and experiences (Deardorff & Deardorff, 2016; Deardorff & Whitehead, 2020; Hughes & Jones, 2011).

Our intervention protocols consisted of 1) facilitating the SC activity in both face-to-face and online course modalities; and 2) asking team members to meet to discuss project deliverables and interactively review written leadership principles at the outset of each team meeting. To assess the effectiveness of our intervention protocols, we adapted extant assessment instruments. We compared dozens of scales, assessment tools, and evaluation instruments to generate researcher consensus on content and format

(AACU VALUE rubric Intercultural Knowledge and Competence, 2010; AACU VALUE rubric Teamwork, 2010; Britton et al, 2017; Deardorff, 2011; Deardorff & Deardorff, 2016; Doukanari et al., 2020; Erkan & Khan, 2017; Hughes & Jones, 2011; Khair et al., 2013; Krumm & Hertel, 2013; Kusano et al., 2016; Owosu-Manu et al., 2019; Revilla-Cuesta et al., 2020). We identified a set of core themes that connect the scholarship on IC and teamwork with specified IComm principles in our intervention program. Specifically, we focused on the goals of the SC methodology and one of the documented fundamentals for successful teamwork, namely communication skills. We developed questionnaires to gauge learners' pre- and post-intervention perceptions at multiple points during the semester.

METHODS

Participants

A total of 31 undergraduate engineering students enrolled in Statistical Quality Control in spring 2021 participated in this study. Due to pandemic-induced restrictions, the class was conducted concurrently in both in-person and online modalities. Student demographic information is presented in Table 1.

Intervention Protocols

Three protocols—the SC methodology, the preamble "Guiding Principles for Professional Leadership Skills in Engineering," and the Iterative Feedback on IComm Skills—were used as the primary intervention tools to prompt students to practice IComm principles.

TABLE 1
DISTRIBUTION OF PARTICIPANT NUMBERS (PERCENTAGES) BY GENDER, RANK, ETHNICITY, CLASS MODALITY, AND CULTURAL BACKGROUND

Gender	Men	Women	Other		
	20 (65%)	11 (35%)	0 (0%)		
Modality	In-person	Online			
	9 (29%)	22 (71%)			
Rank*	Second-year	Third-year	Fourth-year		
	1 (5%)	6 (30%)	13 (65%)		
Background*	US-born	Foreign-born			
	14 (70%)	6 (30%)			
Race & Ethnicity*	White	Black or African American	Hispanic or Latinx	Asian or Asian American	Prefer not to disclose
	7 (35%)	5 (25%)	3 (15%)	5 (25%)	1

** Information does not reflect all participants due to incomplete responses.*

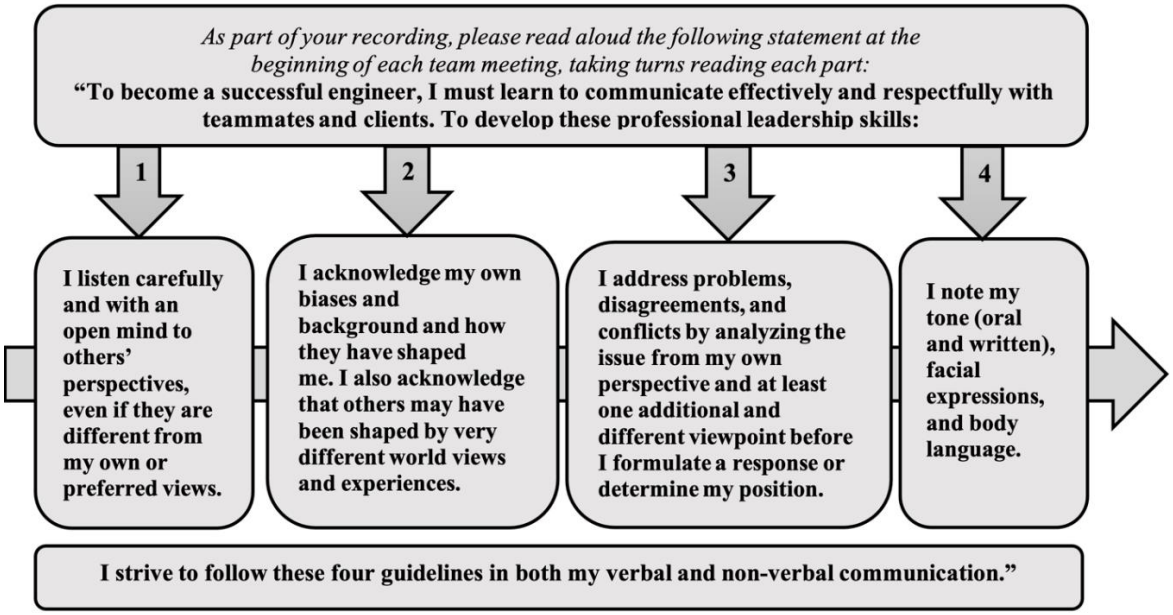
The SC Methodology

As described in the Procedures section below and Ergai et al. (2022), we adapted the SC methodology in our intervention protocol to facilitate the SC activity in the course in both modalities.

"Guiding Principles for Professional Leadership Skills in Engineering" Preamble

We drew from the SC methodology and SC activity to develop the preamble "Guiding Principles for Professional Leadership Skills in Engineering" (See Figure 2). Our decision to frame the preamble in terms of professional leadership skills was intentional: based on casual observation, we perceive that engineering students at our institution take the concept of "leadership" development more seriously than other non-technical skills development. Moreover, effective leadership requires excellent communication skills.

FIGURE 2
GUIDING PRINCIPLES FOR PROFESSIONAL LEADERSHIP SKILLS IN ENGINEERING



Iterative Feedback on IComm Skills Practice

Two Co-PIs evaluated the weekly team meeting recordings and provided students with formative feedback on their IComm skills practice. Feedback included reminders that team members practice IComm principles identified in the preamble. Typical feedback stated, for example: "Please ensure that everyone activates web cameras during the team meetings," "Please note your tone and body language," and "Please demonstrate during discussions that you are aware of at least two different viewpoints as you analyze an issue."

Assessment Measures

Multiple assessment measures were used to examine the effectiveness of the intervention program: two survey scales, student performance on team projects, and students' end-of-semester course evaluations. Both quantitative and qualitative responses were gathered to gauge students' views on the intervention protocols, the quality of the team projects, and students' overall evaluation of the course.

Story Circles Survey

To understand how students viewed the SC methodology, we developed the SC Survey for this study (available upon request). We designed the instrument collaboratively upon review of the SC manual (Deardorff, 2020, p.71), the manual's questionnaire (pp. 93–97), and recent scholarship summarized above.

The SC Survey consists of 27 items that assess students' opinions of the SC protocol concerning four aspects: attitudes, communication, culture, and teamwork. Responses were rated on a 5-point Likert-type scale with 1 indicating "strongly disagree" and 5 indicating "strongly agree." Cronbach's alpha was calculated and showed satisfactory reliability with a score of .88 (Ergai et al., 2022).

Attitudes Toward Teamwork Survey (Pre- and Post-Intervention)

To assess students' attitudes toward teams and teamwork before and after the intervention protocols, a 24-item survey questionnaire was developed (available upon request). The researchers collaboratively designed this instrument based on the recent scholarship summarized above. The questionnaire includes seven themes: communication, conflict management, diversity, instructor feedback, peer feedback, peer

evaluation, and overall experience with teamwork. Half of the statements were formulated positively and half negatively. Additionally, the items balance perceptions of own and peers' behaviors across the seven themes. An example of a positive self-perceptive prompt is: "I have had positive experiences with how I resolved disagreements or conflicts among team members when they arose." In contrast, a peer-oriented negative prompt reads: "My experiences when team members communicated with me about project work were negative." The purpose of prompting respondents from multiple angles was two-fold: to encourage learners to practice examining a topic from another perspective and to ensure the instrument's reliability and validity.

Items were rated using a 5-point Likert-type scale with "strongly disagree" and "strongly agree" as anchors with a higher score indicating stronger agreement. Cronbach's alpha was calculated and showed satisfactory reliability with a score of .94 and .97 for the pre-and post-intervention surveys, respectively.

In addition, the post-intervention survey included two open-ended reflection prompts: "Briefly describe how Story Circles was helpful/not helpful this semester" and "Briefly describe how team meetings were helpful/not helpful this semester."

Students' Performance on Team Projects

The students' final grades on the team project were used as direct evidence and as an indicator of students' performance in diverse teams based on the quality of the final product (paper and oral presentation). Students' project grades from the same course during spring 2019 were used for comparison.

End-of-Semester Course Evaluations

The generic student end-of-semester course evaluation is standardized for use in all courses within the College of Engineering. It consists of 13 multiple-choice statements and five open-ended items. The response format for multiple-choice statements is a Likert-type scale from 1 (strongly disagree) to 4 (strongly agree). The 13 statements address the course and instructor. Among the five open-ended items, three prompts ask students to comment on the course, and two invite comments on the instructor's strengths and weaknesses.

Procedure

The intervention program and assessment measures were administered in the spring of 2021 in the course Statistical Quality Control taught by the first author. The intervention program and sequence of events are outlined below (See Figure 3). Institutional Review Board approval was obtained before the beginning of the study.

In the second week of the course, students were asked to complete the Attitudes toward Teamwork survey (assessment #1 in Figure 3). The survey was available online for one week. The instructor assigned students to teams (four and five members) and according to their participation as in-person or online students (i.e., online learners were partnered with online peers). Teams reflected the diverse student body, i.e., each team included at least one woman, one international student, and one Black or African American student. Team members stayed in their assigned groups throughout the project (eight weeks).

In the fourth week, the instructor and one researcher co-facilitated the SC activity as per the SC manual (Deardoff, 2020), with modifications to enhance the relevance for engineering students (Ergai et al., 2022). Specifically, the modifications included:

1. Introduction phase: Students identify characteristics of successful individuals in diverse (engineering) environments.
2. Guided Prompts: In the breakout group, students interact in response to a discipline-specific prompt and share their experiences with teamwork: "In two minutes or less describe a time when you had a team assignment that you solved either well or that gave you issues because you were in a team with partners who were different from you."

The SC activity was facilitated simultaneously for both face-to-face and virtual-synchronous participants during a 75-minute class session and evaluated by participants via the online 27-item survey (assessment #2 in Figure 3).

During the fifth week of the course, the team project was assigned. The objective was to apply the Design of Experiments (DOE) method to improve a product or process by using the seven-step process previously introduced in the course in addition to statistical methods applied in DOE. In a departure from earlier practice, the instructor assigned completion of the project via three discrete and successive deliverables (Ambrose et al., 2010). The students had two weeks to work on each deliverable.

For each deliverable, student teams were required to meet either virtually or in-person to discuss the project and review and practice IComm principles as communicated in the preamble, "Guiding Principles for Professional Leadership Skills in Engineering." As part of the assignment, each student team meeting was recorded for at least 15 minutes, using Microsoft Teams. The preamble, with instructions for its use, was presented to students before each team meeting. Team members were asked to take turns reading the core principles aloud to focus on intentionality and remind everyone to practice specific IComm principles in team communication. Following each team meeting, students completed the post-team-meeting survey (assessment #3 in Figure 3).

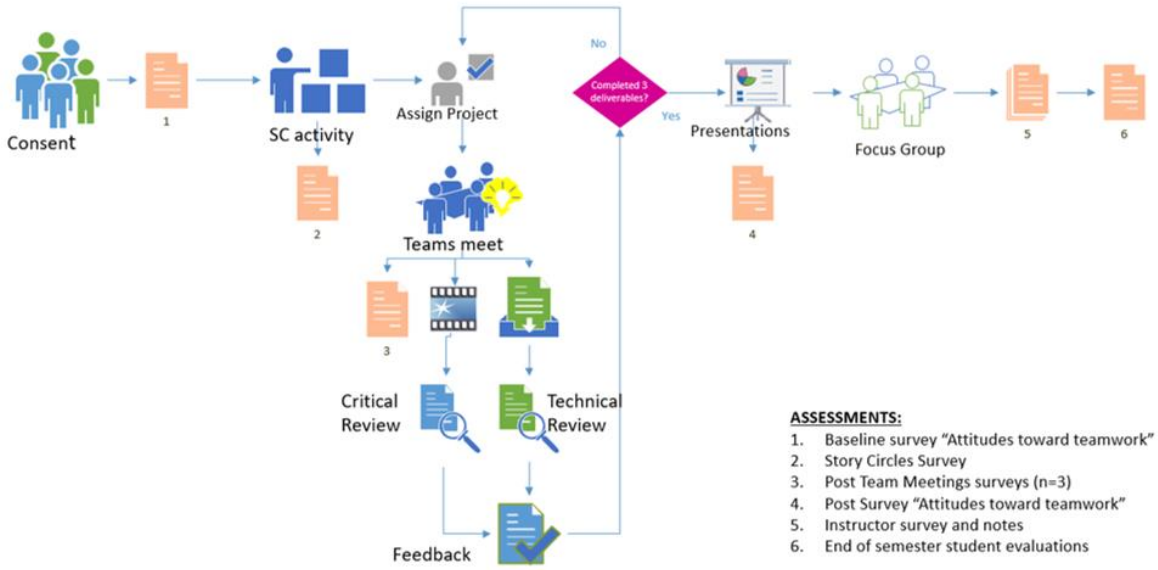
Technical and IComm-related feedback was provided to students after each meeting and deliverable: The course instructor provided technical feedback based on team submissions while the researchers reviewed the recorded meetings and provided formative feedback on IComm skills practice.

During week eleven of the semester, each team presented their project according to their course modality. Subsequently, the Attitudes toward Teamwork Survey was administered online again to obtain post-intervention data (assessment #4 in Figure 3). While the research team evaluated the project presentations with observational notes, only the course instructor assigned grades based on the quality of the project itself and the presentations (assessment #5 in Figure 3). Students were encouraged to complete the end-of-semester course evaluation (assessment #6 in Figure 3).

RESULTS

We report on results from the following four assessment instruments: Learners' Attitudes toward Teamwork surveys (pre- and post-intervention), students' views on team meetings, students' performance on team projects, and learners' end-of-semester course evaluations.

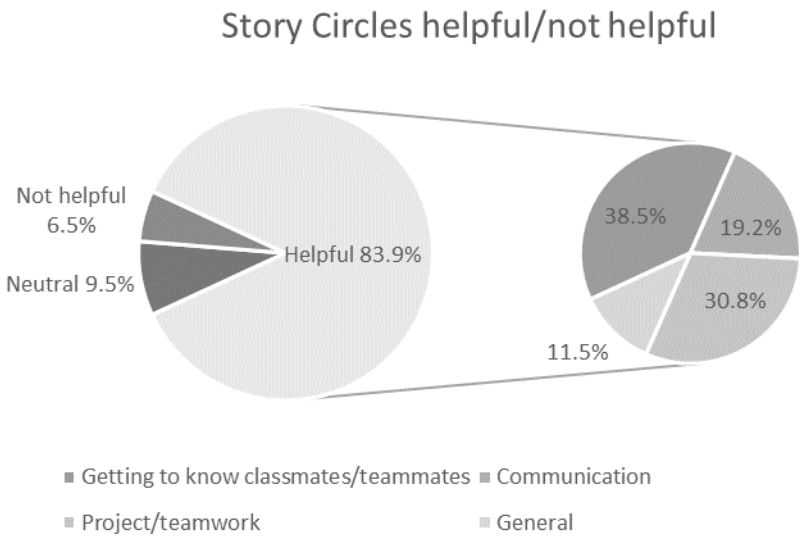
FIGURE 3
INTERVENTION PROGRAM FOR AN ENGINEERING COURSE



Story Circles

The post-intervention survey conducted approximately three months after the facilitation of the SC activity included an open-ended question on the SC methodology and yielded a total of 31 responses. The SC prompt asked students to "briefly describe how Story Circles was helpful/not helpful this semester." Analysis indicates that the majority of respondents (83.9%) described SC as helpful in various ways. Within the "helpful" category, four themes emerged. Figure 4 presents the frequency of these themes.

FIGURE 4
FREQUENCY OF THEMES IN RESPONSE TO STORY CIRCLES (N = 31*)

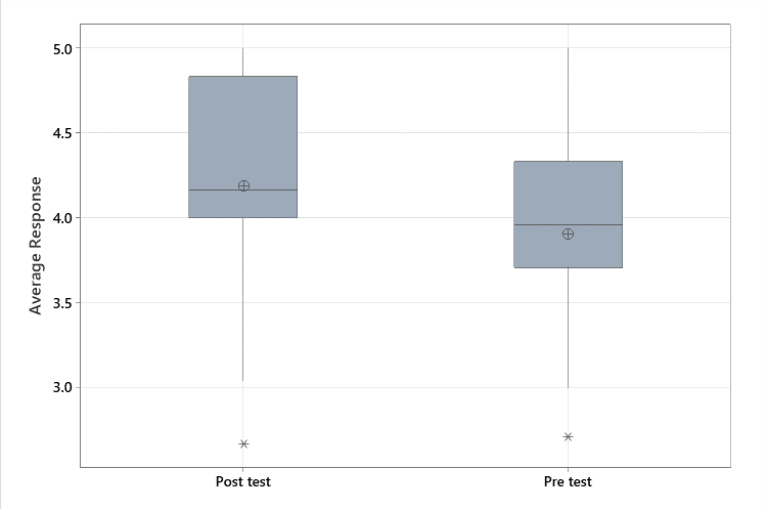


Attitudes Toward Teamwork

To examine the relationship between the intervention protocols and students' attitudes toward teamwork, responses to the pre- and post-intervention Attitudes toward Teamwork Survey were analyzed. Overall, the post-intervention Attitudes toward Teamwork Survey score (M = 4.19, SD = .67) was higher than the pre-intervention score (M = 3.91, SD = .55), but the difference is not statistically significant. However, we noticed a statistical outlier present in both pre-and post-intervention survey responses and performed an analysis with the outlier removed. The results show that the difference in means (pre: 3.96, post: 4.25) increased to approaching significance (p = .07). Figure 5 presents the box plot showing the two outliers.

An examination of gender and modality differences between pre-and post-intervention survey means indicates that women gained more appreciation than men, although the difference is not statistically significant; online students' perceptions improved more than those of face-to-face students, and the different approaches statistical significance (p = .089). The subscales results indicate that online students' post-intervention score on the "overall team experiences" subscale was significantly higher than their pre-intervention survey score, suggesting their attitudes were much more positive after the intervention program (p = .029). Table 2 presents the pre-and post-intervention results.

FIGURE 5
BOX PLOT OF POST- AND PRE-INTERVENTION RESPONSE AVERAGES TO THE ATTITUDES TOWARD TEAMWORK SURVEY



Views on Team Meetings

To examine how students viewed the three required team meetings during the project period, the post-intervention survey included an open-ended question: "Briefly describe how team meetings were helpful/not helpful this semester." Analysis indicates that a large majority (73.1%) described the team meetings as helpful in a variety of ways, 15.4% described them as not helpful, and 11.5% remained neutral.

Students' Performance on Team Projects

As a measure of generating direct evidence, students' final grades on team projects were analyzed and compared between two semesters of instruction. Taught by the same instructor, the course in spring 2019 included neither an intervention program nor a revised team project assignment. Results show that the grades were much improved in the spring 2021 intervention class (See Table 3).

End-of-Semester Course Evaluations

Students' end-of-semester course evaluations were analyzed and compared between the spring 2021 and spring 2019 classes. Response rates were comparable (25.8% vs. 22.5%). Analysis of the means on the 11 statements and the *t*-test results indicate that the overall mean (M = 3.73, SD = .19) in the spring 2021 course was significantly higher than that of the spring 2019 class (M = 2.96, SD = .29) at a p-value of 0.00. Results indicate a considerably more positive overall evaluation by students in the intervention class.

TABLE 2
PRE- AND POST-INTERVENTION MEANS AND STANDARD DEVIATIONS ON THEMES FOR ALL PARTICIPANTS, BY GENDER AND CLASS MODALITY

Theme	Gender				Modality			
	Pre (n=23)		Post (n=27)		Pre (n=23)		Post (n=27)	
	Men *n* = 14	Women *n* = 9	Men *n* = 17	Women *n* = 10	F2F *n* = 5	Online *n* = 18	F2F *n* = 10	Online *n* = 17
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Communication	3.91 (.66)	3.806 (.87)	4.10 (1.00)	4.25 (.72)	3.80 (1.01)	3.889 (.67)	3.975 (.96)	4.265 (.86)
Conflict management	3.964 (.59)	3.611 (.52)	4.088 (.76)	4.075 (.88)	3.750 (.306)	3.847 (.64)	3.857 (.97)	4.206 (.67)
Cultural diversity	4.50 (.61)	3.972 (.71)	4.324 (.70	4.20 (.63)	4.75 (.43)	4.167 (.70)	4.325 (.72)	4.250 (.65)
Instructor feedback	4.179 (.69)	3.50 (.56)	4.382 (.65)	4.40 (.52)	4.20 (.84)	3.833 (.69)	4.350 (.63)	4.412 (.59)
Peer feedback	3.946 (.63)	3.944 (.30)	4.279 (.74)	4.175 (.55)	3.65 (.58)	4.028 (.484)	4.225 (.77)	4.25 (.63)
Peer evaluation	3.786 (.78)	3.722 (.68)	4.118 (.75)	4.175 (.43)	3.90 (.84)	3.722 (.71)	3.975 (.64)	4.235 (.63)
Overall team experience	3.54 (1.03)	3.61 (1.02)	4.147 (.93)	4.1 (.84)	3.40 (1.34)	3.61 (.93) *	3.90 (1.07)	4.265 (.75)*
All Themes	3.994 (.53)	3.768 (.57)	4.196 (.72)	4.188 (.62)	3.940 (.47)	3.896 (.58)	4.083 (.73)	4.257 (.64)

** Indicates online students scored significantly higher on the post-intervention survey than the pre-intervention survey on the subscale of "overall team experience."*

TABLE 3
COMPARISON OF INDIVIDUAL STUDENTS' FINAL TEAM PROJECT GRADES

Spring 2021 *n* = 31		Spring 2019 *n* = 41	
Letter grades	**Number (percentage)**	**Letter grades**	**Percentage**
A+	28 (90.3%)	A+	15 (36.5%)
A	3 (9.7%)	A-	10 (24.4%)
		B+	10 (24.4%)
		D	6 (14.6%)
Average (SD)	99 (2)	89.5 (11.5)	

DISCUSSION

The purpose of the current study was to investigate the impact of two intervention protocols on engineering students' attitudes toward teamwork and performance in diverse teams. The objective was to provide engineering students with opportunities to practice specified IComm principles and communication skills in team settings via curricular changes to a semester-long engineering course. A review of recent scholarship on IC, IComm, teamwork, intervention programs, and assessment measures prompted us to design, pilot, and assess our intervention program during spring 2021 in Statistical Quality Control in both in-person and online modalities.

The various assessment measures generated qualitative and quantitative data and indirect and direct evidence. Results show that participants in the study responded overall very positively to the intervention program, regardless of gender and instructional modality. Some results from analysis and comparison of subscales suggest statistically significant differences.

Results from the SC Survey revealed that all learners rated the SC activity favorably (Ergai et al., 2022). Notably, students' review of the SC activity seems durable: after three months almost 84% rated the experience as helpful in the post-intervention Attitudes toward Teamwork Survey. Students' comments on the perceived merits of the SC activity (for interpersonal team relations and project-based collaboration) suggest the effectiveness of the protocol and align with recommendations in recent scholarship on the importance to facilitate team bonding (Alford et al., 2014; Ercan & Khan, 2017; Thompson, 2017).

Results from pre- and post-intervention Attitudes toward Teams Surveys revealed that all learners responded positively across the seven themes. Women participants and online students rated the experience highest, and online respondents rated their "overall team experience" significantly higher than in the pre-intervention survey. These results corroborate findings in recent scholarship: carefully designed intervention programs generate changed attitudes toward teamwork, especially in women and people of color; and in teams with a variety of interaction platforms (Alford et al., 2020; Britton et. al., 2017; Konak et al., 2015; Powers, 2020; Thompson, 2017).

Students' post-intervention comments in the open-ended prompt (on the value of team meetings as "helpful/not helpful") document that 73.1% of the participants appreciated the meetings. Responses reveal two themes, i.e., the meetings' relevance for effective and efficient project completion, and for practicing communication skills. The themes also confirm the importance of communication discussed above. As Kusano et al. (2016) demonstrate, students in diverse teams are particularly successful both in the process and with the end product of team assignments. Notably, students' favorable review of team meetings seems to endure: in end-of-semester course evaluations, 75% of the participants commented, without prompting, on their positive experience with the team project in spring 2021: they mention timing, progression, grading, and teamwork itself; students also expressed appreciation for the preamble-reading activity in open-ended questions about the course and instructor generally. In contrast, only one learner during the spring 2019 course commented on the group assignment—albeit in an extensive and entirely negative response. Students' comments on the perceived merits of the team meetings suggest the effectiveness of the intervention program and protocol as responses reflect improved perceptions of teamwork and improved experience during teamwork. These results align with findings in recent scholarship on the importance of carefully launching and supporting teamwork (Alford et al., 2014; Ercan & Khan, 2017; Doukanari et al., 2020; Kusano et al., 2016; Thompson, 2017).

A minority of participants (15.4%) described the team meetings as "not helpful" in the post-intervention Attitudes toward Teamwork Survey. Comments focus on perceived inefficiency due to long and unproductive meetings and unequal workload among teammates, so-called "free-loading." Such discontent is widely recorded in the scholarship (Ercan & Khan, 2017; Hughes & Jones, 2011; Konak et al., 2015; Pfaff & Huddleston, 2003; Revilla-Cuesta et al., 2020). Still, our findings offer overall encouraging results and suggest that in-person and virtual teamwork can be effective.

In comparing students' end-of-semester course evaluations for Statistical Quality Control in spring 2019 and spring 2021, we noted considerably higher scores for the spring 2021 evaluations across all 13 items. The items that indicated the largest improvements from spring 2021 are all related to the instructor's role and the instructor-student relationship. The high marks suggest that learners recognize and value the instructor's increased time and effort in facilitating the course and team project in spring 2021. Our finding is consistent with the scholarship, i.e., that increased instructor support during teamwork assignments is needed to generate successful team experiences for students (Doukanari et al., 2020; Erkan & Khan, 2017; Kusano et al., 2016; Powers, 2020).

Finally, the juxtaposition of students' final grades for the team project demonstrates significantly improved results in spring 2021 compared to spring 2019. With the average increase of almost 10 percentage points (from 89.5% to 99%), it is important to note that all students achieved a final grade of an "A" in spring 2021, whereas a significant number of students failed the assignment in spring 2019 (14.6%).

As Kusano et al. (2016) demonstrate, students working in diverse teams can outperform students in other modalities and are more likely to develop higher-order skills.

The spring 2021 results provide direct evidence of student success with the team project and complement the indirect evidence provided in this study—as recommended by the scholarship (Deardorff & Whitehead, 2020; Kusano et al., 2016). Students' improved performance in the team project is all the more impressive given the very challenging context of the COVID-19 pandemic in spring 2021 and its impacts on course facilitation and learners' educational experience. At a time when university programs are increasingly more intentional about addressing student success, progression, and retention, these results are encouraging.

By triangulating data points from the intervention protocols and the final grades for the team projects, we see evidence that engineering students in the spring 2021 course perceive the curricular interventions overwhelmingly in a favorable light. Minor differences among men and women as well as in-class and online participants do not significantly detract from the overall finding that intentional and iterative guidance of learners is not only effective in generating improved results in content-study-related performance (per the final grades on the project) but also in a greater appreciation of cultural diversity, teamwork, and instructor support during the learning experience. The findings of this research—both qualitative and quantitative—indicate a strong potential to enhance engineering students' attitudes toward teamwork and teamwork performance by practicing IComm principles.

Limitations

Three limitations in this study should be addressed in future research. The primary limitation is the small sample size: the number of survey responses ranged from eight (in the spring 2021 end-of-semester course evaluation sample) to 31 (in the post-intervention Attitudes toward Teamwork survey). This limitation affected the study's statistical power and our ability to verify the statistical effect. Moreover, students in Statistical Quality Control pursue their degree in Industrial and Systems Engineering, a circumstance that may suggest discipline-based bias in the results. Larger samples including different engineering majors and learners with different student standing are needed to generate information about engineering students' experiences more broadly.

The second limitation concerns confounding factors, or "mixing of effects" (Rothman, 2004). Confounding factors demonstrate an association between intervention and outcome when no true association exists. Possible confounding factors in this study include: 1) chunking of the project into three deliverables, 2) iterative feedback on deliverables, and 3) timing of the project (early-mid semester compared to, traditionally, late-semester). An experimental research design consisting of a control group and an intervention group is recommended to investigate the cause-and-effect relationship between the intervention program and outcomes.

Thirdly, a limitation presents itself in the assessment measures. We developed our pre- and post-intervention Attitudes toward Teamwork Surveys and the SC Survey. Although Cronbach's alpha scores suggest satisfactory reliability, we may consider in future studies combining our measures with modified assessment instruments that are standardized and widely used to ensure validity and reliability.

CONCLUSION

The intervention program offers a promising template for other engineering faculty who are interested in improving students' attitudes toward teamwork and performance in diverse teams through an intentional practice of IC principles. Our project adds valuable information to the existing body of literature on IC, engineering teamwork, intervention programs, and assessment measures. It is the first step in our long-term goal to meet industry needs and accreditation mandates by developing a template for curricular innovations designed to enhance critical skills in engineering students and graduates.

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