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Training Future Engineers to Become Better Communicators: The Effects of Engineering-specific Communication Courses on Student Attitudes and Identity

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Engineering identity and communication outcomes: Comparing integrated engineering and traditional public speaking courses

Abstract:

This research study compares engineering identity and communication outcomes (such as attitudes towards communication, motivation, and intentions to engage in communication) between students enrolled in an Integrated Engineering Public Speaking (IEPS) class and a Traditional Public Speaking (TPS) class. Findings indicate that intentions to engage in communication and engineering identity improved for students in IEPS and TPS classes. Attitude towards communication only improved for those in the IEPS classes. Motivation was high for IEPS students even before classes started, and while they improved for only those in the TPS classes, those in the IEPS classes continued to have higher motivation after classes than those in the TPS classes. Overall, comparing IEPS and TPS classes revealed that attitudes towards communication, motivation, and engineering identity improved significantly more for those in the IEPS classes compared to those in the TPS classes. The paper concludes by discussing future directions for research in engineering instruction/communication.

Introduction:

This research paper assesses outcome differences between a traditionally taught public speaking course and one integrated with engineering specific content. Communication underpins the evolution of every field of science [1], [2], and plays a central role in the process of science—not only in sharing the findings upon which scientists build knowledge, but also in formulating questions and hypotheses, justifying theories and methods, and arguing the relevance and significance of results. Innovative thinking is meaningless without the ability to communicate an idea in a meaningful way. Future innovators and entrepreneurs must be armed with the skills to communicate with their colleagues and peers as well as with decision-makers if they are to promote their work effectively.

Given the growing societal impacts of scientific research, STEM practitioners have a responsibility to communicate to the general public and enhance understanding of science [3], [4]. Public skepticism is increasingly directed at science based issues appearing to conflict with some public values or religious beliefs. Targeted training of STEM students in effective communication skills for all audiences can lead to intelligent public conversations that allow for informed decisions in national and international debates involving science and technology [5]. Understanding how to frame technical information so that it is relevant to a variety of audiences, however, is a skill for which too few STEM students receive formal training [6]. As the American Association for the Advancement of Science points out, traditional education in STEM disciplines does not prepare students to be effective communicators outside academia [7], despite the inclusion of communication skills as a component of many accreditation criteria. This is particularly true in regard to both oral [8] and visual communication [9].

An approach that has held promise for addressing these deficiencies in traditional STEM education is Communication Across the Curriculum (CXC), the integration of oral, visual, and electronic communication in all disciplines. CXC was initially developed in the 1970s and has seen some success in a variety of fields. Many CXC initiatives have been criticized, however, for being overly compartmentalized, focusing too much on discipline-specific skills training and having missed opportunities to encourage broad-minded thinking. CXC, traditionally applied, has not been viewed by the National Communication Association (NCA) as a substitute for basic instruction provided by departments of communication [10].

This project aimed to return to Deanna Dannels' and Housley Gaffney's [11] call for a commitment to empirical rigor in CXC research. We have addressed critiques of CXC by developing pedagogy with a cross-disciplinary team of experts from communication and engineering with the goal of improving outcomes advocated for by both NCA and The Accreditation Board for Engineering and Technology (ABET), but in a context focusing on the specific needs of the engineering discipline. The goal of the pedagogy was to engage students' personal and professional interests more thoroughly in what was still fundamentally, however, a communication classroom. Research has suggested that integrating oral communication with discipline-specific content enhances learning and allows students to take a more active role in the classroom because students are "communicating to learn" [12].

Engineering takes place in a fundamentally oral environment where communication skills are the "lifeblood of a practicing engineer" [13]. ABET reinforces the importance of communication to the field, making "an ability to communicate effectively" an expected student outcome in their criteria for accrediting engineering programs [14]. Such lessons face inherent hurdles in the engineering classroom, however. Data has indicated students have been resistant toward the inclusion of pedagogy regarding fundamental oral communication skills in their engineering classes [15].

The integration of communication and engineering courses has previously proven successful in teaching essential writing skills to STEM students [16], [17]. Oral communication has been integrated into some of these courses, but has often played a subordinate role to writing pedagogy [18]. A truly integrated engineering and oral communication course has not previously been thoroughly assessed.

Complimenting previous work in CXC, identity-based motivation theory describes motivation and goal pursuit, explaining when and how individuals' identities motivate them [19], [20]. The theory suggests that people prefer to make sense of situations and act in identity-congruent ways consistent with their self-perceptions. This happens in a context specific manner, where the context shapes what identities come to mind. It is reasonable to suspect that offering students a context that connects communication skills to their engineering identity may have a variety of positive student outcomes.

This study explored the following hypotheses:

H_1: An integrated engineering and communication course will improve student course affect relative to a traditionally taught communication course.

H_2: An integrated engineering and communication course will improve student attitude toward communication relative to a traditionally taught communication course.

H_3: An integrated engineering and communication course will improve student course motivation relative to a traditionally taught communication course.

H_4: An integrated engineering and communication course will improve student intentions toward communication behaviors relative to a traditionally taught communication course.

H_5: An integrated engineering and communication course will improve student engineering identity relative to a traditionally taught communication course.

Course design:

Three college of engineering faculty worked with five faculty from the department of communication over the course of several months to develop an integrated engineering and communication course for this project. Two sections of the integrated engineering and communication were piloted in the spring 2017 semester at the study institution. Communication faculty and engineering faculty again worked together to refine the course and the course assignments before full implementation in the spring 2018 semester. This class was designed to fit as seamlessly as possible within existing curriculum at the study institution. At this institution students are required to complete an oral communication general education requirement. To meet this requirement, the institution teaches a large number of traditionally taught public speaking classes. These classes follow what could be considered a typical public speaking course template; the classes are standardized around a single text book, meet in person three hours a week, and include introduction, ceremonial, informative, and persuasive speeches as well as a group project (and at least one speech of the instructor's choice). The integrated class was created to meet that same general education requirement, but specifically for engineering students. The course was designed to be taught by existing faculty and with the same number of students per section as existing classes, i.e. zero additional resources after initial development. The integrated engineering and communication course, while designed hand-in-hand with engineering faculty, was created to be taught by communication faculty. For this reason, as well as to ease the integration of the class into existing curriculum, the class was modeled very closely on the traditionally taught public speaking class. The integrated course taught foundational concepts covered in traditionally taught classes, including but not limited to ethics, communication apprehension, listening, analyzing an audience, and supporting ideas. Each of these concepts was taught, however, though an engineering lens. Instructors employed specific examples from the engineering discipline to clarify these concepts for the students and encouraged the students to supply examples of their own.

Furthermore, traditionally taught public speaking classes are organized in part around the assignments the students work their way through as the class progresses. Assignments build off one another as students obtain mastery of their skills. This course followed that same model, constructing assignments that mirrored assignments in the traditionally taught class. These assignments were placed, however, in an engineering context to help students identify connections between the assignment and their goals as an engineering professional. These assignments looked to address both NCA and ABET desired student outcomes and are outlined briefly in Table 1[1].

Method:

Assessment of this course was conducted through a test and control group quasi-experiment. Three communication faculty, all of whom were involved in course development, were identified to each teach one section of the integrated course as well as three sections each of traditionally taught public speaking, for a total of twelve class sections. Class times for both test and control groups were distributed throughout the day and week to the degree possible. Students registered for these sections blind, without knowing if they were registering for a traditionally taught or integrated class.

Advising staff at the study institution manipulated course caps so that only college of engineering students were allowed to enroll in the integrated engineering and communication classes (test group). They similarly manipulated course caps so that college of engineering students were roughly evenly distributed across the study's nine traditionally taught classes (control group). At the start of the spring 2018 semester 70 college of engineering students were

[1] Full assignment descriptions are available upon request from the corresponding author.

enrolled in the control group and 57 were enrolled in the test group. The remaining 110 class seats available in the control group were filled by students in the general population.

Procedures and instrumentation:

All engineering students were asked to take part in pre-test and post-test survey. Research received prior approval from the study institution's institutional review board. Willing participants took a pre-test survey in the first regular week of class and a post-test survey in the last regular week of class. For each survey, students were directed by their instructor to an online informed consent document. After indicating consent, each participant was directed to an online survey. Participants were asked to complete a series of instruments (see below) to evaluate their attitudes regarding the course. Several instruments were adapted somewhat to change language so that they applied specifically to the engineering discipline rather than general sciences. Note, individual items as well as alpha reliability coefficients for each instrument are given in Tables 2-6. No reward or inducement was employed to encourage participation but surveys did take place during regular class time.

Affective learning: Affective learning and teacher evaluation were measured using McCroskey's [21] measure of affective learning. This measure explored participants positive affect for the course and for the instructor. Participants completed two 7-point, 4-item bipolar scales reflecting their attitudes on the course, the instructor, and the likelihood of taking each again. Higher numbers indicated a higher level of affective learning.

Attitude toward communication: Attitudes regarding communicating about engineering were measured using an adapted version of Poliakoff and Webb's instrument [22]. This measure explored participants positive or negative attitudes toward communicating about engineering related topics in various contexts. Participants completed 18 items, each with a 7-point bipolar scale reflecting the participants' attitudes about engaging in communication regarding engineering.

Motivation: Student motivation was measure using Christophel's [23] student motivation scale. This measure explored the participants degree of motivation to put forth effort in the current class. Participants completed 16 items, each employing a 7-point bipolar scale reflecting participants' feelings toward their current class.

Intended behavior: Intended behavior was measured were measured using an adapted version of Poliakoff and Webb's [22] instrument. This measure explored participant attitudes regarding their confidence to engage future engineering communication related activities in various contexts. Participants completed 16 items, each employing a 7-point bipolar scale reflecting participants' beliefs regarding their own future behavior.

Engineering identity: Engineering identity was measured using an adapted version of Hanauer, Graham, and Hatfull's [24] college student persistence in the sciences (PITS) survey. This measure explored the degree to which participants identify themselves as part of the engineering discipline. Participants completed 11 items, each on a 7-point Likert scale from "strongly disagree" to "strongly agree." Items reflected participants' beliefs about their own attitudes and ideas.

Results

Sample: There were 41 engineering students randomly assigned to an Integrated Engineering Public Speaking (IEPS, condition 1) class, 43 engineering students randomly assigned to a Traditional public speaking class (TPS, condition 2), and 87 students who were randomly assigned to a traditional public speaking class (TPS, condition 3) and who completed both the pre-survey and post-survey. Given how we cannot control the number of students who are likely to enroll into public speaking classes any given semester, the number of students who would add/drop the course during the semester, and be willing to participate in pre-survey and post-survey, the researchers were limited in ensuring all three conditions remain equally distributed. However, measures were taken to ensure that at least conditions 1 and 2, the ones used for analyses in the study were closely matched in numbers. An a-priori power analysis for t-tests with matched pairs using the typical criteria of alpha set to 0.05, power to 0.80, and medium effect size of 0.5 indicated a sample size of 34. We ensured conditions 1 and 2, used for our analyses, had a sample size approximately close to 34. Again, as the researchers are unable to ensure exactly 34 students be enrolled in conditions 1 and 2, the researchers feel confident that a sample size of 41 and 43 in each condition is close enough to detect medium effects.

Among the 171 students in the study, mean age of the sample was 19.27 (SD=1.42). There were 94 males and 77 female students. There were 12 female engineers in the IEPS class, 11 female engineers in the TPS class, and 54 non-engineer females in the TPS class. The sample had 146 students identify themselves as White, 11 as Black or African-American, 8 as Asian, and 6 as other. Among those who identified themselves as White, there were 34 engineers who identified themselves as White in the IEPS class, 40 engineers who identified themselves as White in the TPS class, and 72 non-engineers who identified themselves as White in the TPS class. There were 76 students who indicated being freshmen, 74 sophomores, 15 juniors, and 6 seniors. In the GSPS class, there were 7 freshmen, 26 sophomores, 6 juniors, and 2 seniors. In the TPS class of engineers, there were 8 freshmen, 25 sophomores, 6 juniors, and 4 seniors. In the TPS class of non-engineers, there were 61 freshmen, 23 sophomores, 3 juniors, and no seniors.

Random assignment was checked for engineering students assigned to an IEPS class (condition 1) and TPS class (condition 2) using analysis of variance. There was no significant difference in gender ($F(1,82) = 0.14$, $p=0.709$) or age ($F(1, 81) = 0.725$, $p=0.397$). Since the sample was mostly white, analysis of variance was only conducted with students who identified themselves as white and no significant difference in conditions was found ($F(1, 82) = 2.041$, $p=0.157$). Since the sample was also mostly sophomores, analysis of variance was only conducted with students who indicated being sophomores and no significant difference in conditions was found ($F(1, 82) = 0.24$, $p=0.626$). Thus, we can conclude that engineering students were randomly assigned to either the GSPS or TPS condition and there is no need to additionally control for gender, age, ethnicity, and class in the following analyses.

Measures: Tables 2-6 describe reliable measures for course affect towards course content and instructor (McCroskey, 1994), attitude towards communication (Poliakoff & Webb, 2007), motivation (Chrisophel, 1990), intentions towards behaviors (Poliakoff & Webb, 2007), and engineering identity (Hanauer, Graham, & Hatfull, 2017) analyzed in this study. Only scales found reliable were used in analyses. Due to the low reliability of course affect (see Table 2), no inferential statistics were performed with this measure. Given how our study is about those in conditions 1 and 2, our scores in the tables exclude individuals from condition 3.

Analyses: Paired sample t-tests were performed to assess if there were significant differences between pre-class and post-class tests in each condition across all variables and Welch two sample t-tests was performed to assess if there were significant difference in student outcomes before IEPS and TPS classes and after IEPS and TPS classes. Due to low scale reliability (see Table 2), course affect could not be assessed in this study and thus H1 could not be tested. There was a significant increase from pre-class ($M=5.31$, $SD=0.97$) to post-class ($M=5.84$, $SD=1.01$)

measures on attitudes towards communication for those in the IEPS class ($t(40) = -3.82$, $p = 0.0005$). There was, however, no significant increase from pre-class ($M = 5.18$, $SD = 0.84$) to post-class ($M = 5.26$, $SD = 0.88$) measures on positive attitudes towards communication for those in the TPS class ($t(42) = -0.50$, $p = 0.62$). Before classes started there was no difference in positive attitudes towards communication between students in the IEPS and TPS classes ($t(79) = 0.64$, $p = 0.52$), however there was a significant difference in the post-test where the positive attitudes towards communication was significantly higher for the IEPS class than the TPS class after taking the class ($t(79) = 2.80$, $p = 0.006$). Thus, positive attitudes towards communication improved significantly for those students in the IEPS class compared to the TPS class. Thus, H2 was supported.

There was no significant increase in motivation from pre-class ($M = 4.54$, $SD = 1.02$) to post-class ($M = 4.35$, $SD = 1.06$) measures on motivation for those in the IEPS class ($t(40) = -1.39$, $p = 0.17$), but there was a significant rise in motivation from pre-class ($M = 4.01$, $SD = 0.74$) to post-class ($M = 4.30$, $SD = 0.77$) for those in the TPS class ($t(42) = -2.46$, $p = 0.02$). There was a significant difference in motivation before classes where those in the IEPS class were significantly more motivated than those in the TPS class ($t(73) = 2.69$, $p = 0.009$). The motivation after class was also significantly higher for those in the IEPS class than those in the TPS class ($t(73) = 2.20$, $p = 0.03$). In other words, while those in the IEPS classes had higher motivations before and after class, students in the TPS class saw the most improvement in motivation before and after class. Thus, H3 was partially supported in that overall after class motivations of those in the IEPS class were higher than those in the TPS classes, but they were higher from even before taking the class.

There was a significant increase from pre-class ($M = 5.28$, $SD = 1.10$) to post-class ($M = 5.84$, $SD = 0.86$) in intentions to engage in communication behaviors in the IEPS class ($t(40) = -3.31$, p=0.002). There was also a significant increase from pre-class (M=4.97, SD=1.04) to post-class (M=5.69, SD=0.91) in intentions to engage in communication behaviors in the TPS class (t(42) = -5.87, $p=6.1e^{-07}$). There was no significant difference in intentions to engage in communication behaviors in the IEPS and TPS class before classes started (t(81)=1.34, p=0.19) and after classes ended (t(82)=0.78, p=0.44). Thus, intentions to engage in communication behaviors improved significantly from taking the class for students in the IEPS and TPS classes. Thus, H4 was partially supported in that they improved significantly for both IEPS and TPS classes.

There was significant increase from pre-class (M=5.64, SD=0.91) to post-class (M=6.12, SD=0.87) in their engineering identity in the IEPS class (t(40) = -3.01, p=0.005) and from pre-class (M=5.47, SD=1.05) to post-class (M=5.72, SD=0.89) in their engineering identity in the TPS class (t(42)= -2.30, p=0.027). While there was no significant difference in engineering identity before class started for those in the IEPS and TPS classes (t(81)=0.79, p=0.43), there was a significant difference in engineering identity after class with those in the IEPS class having a higher engineering identity than those in the TPS class (t(82)=2.10, p=0.04). Thus, while students in the IEPS and TPS classes both had no difference before taking the class, for those in the IEPS class their engineering identity significantly improved more than for those in the TPS class. Thus, H5 was supported.

Table 7 summarizes the results the study. Overall, intentions to engage in communication and engineering identity improved for students in the IEPS and TPS classes. Positive attitude towards communication only improved for those in the IEPS classes. Motivation was high for IEPS students even before classes started, and while they improved for only those in the TPS classes, those in the IEPS classes continued to have higher motivation after class than those in the TPS classes. An examination of the post-test results comparing IEPS and TPS classes reveals that positive attitudes towards communication, motivation, and engineering identity improved significantly more for those in the IEPS classes compared to those in the TPS classes. It should be noted that while there was no difference between students' attitudes towards communication or engineering identity before classes, they significantly improved after class and even more so for those in the IEPS classes.

Discussion:

Findings of this study indicate that having engineers engage in a public speaking class can have positive effects on their intentions to engage in communication, motivation, and engineering identities. These outcomes, along with attitudes towards communication, seem to improve significantly for those in the IEPS classes than TPS classes. These findings affirm previous research in that having an integrated oral communication course that is specific for the engineering fields can improve several communication outcomes and engineering identity for students [12].

These findings also contribute to the conversation of the effectiveness of CXC curriculums [10], [11], because our results open a discussion about further investigating the advantages of having an integrated engineering communication curriculum over a traditional one. As discussed, most of our communication outcome variables and identity improved for those in TPS and IEPS classes and although there was a significantly higher improvement in those measures along the IEPS classes, this study urges for more research to replicate these higher levels and urges investigators to explore the underlying mechanisms that are enabling the increase in these measures in the IEPS courses over the TPS courses. One potential direction this research alludes to is to use the identity-based motivation theory [19], [20]. Our study already indicates that while pre-test measures of identity were not significantly different for those in the IEPS and TPS classes but they improved for the post-test significantly for both, but the pre-test measures of motivation were already higher for those in the IEPS classes and continued to be higher in the post-test compared to the TPS classes. Future research can investigate how motivation for IEPS classes and TPS classes vary based on their engineering identity and how it shapes their experiences going through these courses and ultimately affects their identity. Moreover, the finding that motivation towards a communication course improved for the TPS class and that they were high for IEPS students throughout the course contradicts previous research about engineering students being reluctant towards public speaking courses [15]. Thus, we request researchers to investigate the conditions under which motivation varies and how instructors could design courses to enhance motivation from the beginning and keep it high throughout such IEPS courses. Finally, given how attitudes can have a significant impact on intentions and eventually behaviors [25], [26], future research should investigate their relationship in the context of CXC curriculums.

Another contribution from this study is the design of the integrated engineering public speaking curriculum that is training engineers to communicate not following a deficit but a dialogue approach, which is the most effective and needed type of communication [27]. The activities described in Table 1 were carefully crafted to ensure engineers practice perspective-taking and communicate in ways that encourage dialogue over simple information transfer to their publics. This type of training is what is most needed as recognized by the American Association for the Advancement of Science (AAAS) and the National Academies of Sciences, Engineering, and Medicine (i.e., NAS). Both organizations have stressed for training engineers who can engage with their publics rather than speak-down to them (see AAAS' Center for Public Engagement with Science & Technology; see Sackler Colloquiums of Science of Science Communication) to build the ever-declining trust in science and engineering among publics [27]. While confidence in science (i.e., deference to scientific authority) has been high for decades, trust in science (i.e., the attitude that scientists are competent, caring, benevolent individuals who share values with them) has been declining [28], [29], [30]. Thus, this study paves way to developing IEPS course designs and testing their effects on improving trust among publics through their communication.

Conclusion: This study compared communication outcomes and engineering identity between students enrolled in IEPS classes to those in the TPS classes. Findings indicate that communication outcomes such as intentions to engage in communication and engineering identity improved for those in the IEPS and TPS classes. Attitudes towards communication improved for those in the IEPS classes and not for those in the TPS classes. Motivation, while it improved for those in the TPS classes, were higher for those in the IEPS classes from before and after the classes. Overall, attitudes towards communication, motivation, and engineering identities were significantly higher for those in the IEPS classes than the TPS classes. Findings reveal that while having a public speaking course in general can be beneficial to engineering students, there might be more communication and professional identity gains from implementing IEPS courses. The study raises promising directions for future investigation into mechanisms that make IEPS courses more effective than TPS courses for communication outcomes and identity of engineering students.

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Table 1: Engineering and Communication Integrated Course Assignments

Assignment	Assignment Description
1. Introductory speech	Two-minute introductory speech, including “why you chose to become an engineer”.
2. Historic artifact speech	Replaced ceremonial speech. Four-minute speech informing the audience about a “structure, project, or concept” from engineering history.
3. Science fiction speech	Replaced informative speech. Six-minute speech detailing the “near and/or long-term future of an engineering system or practice.”
4. Persuasive speech	Seven-minute speech to “change, instill, or reinforce your audience’s stance on an engineering practice or project.”
5. Group project	Choosing from broad topic areas (water, sanitation, transportation, energy, & resiliency) groups presented a debate for and against a particular technology and then conducted a class discussion. Included a multi-media component.
6. Elevator speech	Less than two-minute speech articulating how the student was particularly well suited for a specific position with a specific employer.
7. Social media assignment	Several times over the course of the semester students wrote both an informative and persuasive tweet (message less than 280 characters) related to an engineering focused article supplied by the instructor.

Table 2: Measures & Reliability of Course Affect

Variable: Course Affect (7-point scale)	M (pre)	SD (pre)	M (post)	SD (post)
Course affect: Content				
I feel the content for this class is bad…good	5.93	1.04	6.24	0.98
I feel the content for this class is valuable…worthless#	5.85	1.42	4.99	1.29
I feel the content for this class is unfair…fair	5.96	1.11	6.27	0.91
I feel the content for this class is positive…negative#	4.10	1.07	4.23	0.97
Content subscale reliability; α_{pre} = 0.83; α_{post} = 0.89	5.46	0.95	5.43	0.91
Course affect: Future courses				
My likelihood of taking future courses in this content areas is unlikely…likely	2.77	1.43	2.87	1.69
My likelihood of taking future courses in this content areas is possible…impossible#	4.24	1.32	4.10	1.49
My likelihood of taking future courses in this content areas is improbable…probable	3.26	1.53	3.20	1.63
My likelihood of taking future courses in this content areas is would…would not#	3.77	1.67	4.12	1.77
Future courses subscale reliability; α_{pre} = 0.88 & α_{post} = 0.90	3.51	1.28	3.57	1.45
Overall, course content affect: α_{pre} = 0.28 & α_{post} = 0.51				
Course affect: Instructor				
Overall, the instructor I have in this class is bad…good	6.42	0.84	6.46	0.94
Overall, the instructor I have in this class is valuable…worthless#	3.30	0.92	5.31	1.08
Overall, the instructor I have in this class is unfair…fair	6.32	0.95	6.37	1.11
Overall, the instructor I have in this class is positive…negative#	3.45	0.88	5.42	1.06
Instructor subscale reliability; α_{pre} = 0.96 & α_{post} = 0.93	4.87	0.84	5.89	0.96
Course affect: Future courses with same instructor				
Were I to have the opportunity, my likelihood of taking future courses with this specific teacher would be unlikely….likely	5.45	1.72	5.67	1.76
Were I to have the opportunity, my likelihood of taking future courses with this specific teacher would be possible….impossible#	5.43	1.56	5.26	1.83
Were I to have the opportunity, my likelihood of taking future courses with this specific teacher would be improbable….probable	5.18	1.69	5.18	1.94
Were I to have the opportunity, my likelihood of taking future courses with this specific teacher would be would….would not#	5.62	1.54	5.92	1.46
Future courses with same instructor subscale reliability; α_{pre} = 0.94 = & α_{post} = 0.91	5.42	1.50	5.51	1.56
Overall, course instructor affect: α_{pre} = 0.51 & α_{post} = 0.75				

#recorded variable; N=84

Table 3: Measures & Reliability of Attitude toward Communication

Variable: Attitude towards Communication (7-point scale)	M (pre)	SD (pre)	M (post)	SD (post)
Attitude: Presenting a talk				
Presenting a talk to those in the engineering discipline would be bad…good	5.80	1.16	5.98	1.20
Presenting a talk to those in the engineering discipline would be unenjoyable…enjoyable	5.24	1.39	5.50	1.38
Presenting a talk to those in the engineering discipline would be pointless…worthwhile	5.61	1.19	5.82	1.16
Presenting a talk to those in the engineering discipline would be unpleasant….pleasant	4.99	1.49	5.51	1.33
Presenting a talk to those in the engineering discipline would be foolish…wise	5.71	1.15	5.88	1.09
Presenting a talk to those in the engineering discipline would be harmful…beneficial	5.89	1.01	6.04	0.98
Attitude: Presenting a talk subscale reliability; $\alpha_{pre} = 0.91$; $\alpha_{post} = 0.92$	5.54	1.04	5.79	1.00
Attitude: Posting on social media				
Posting on social media to communicate with friends, family, and general public about engineering issues would be bad…good	5.02	1.34	5.24	1.44
Posting on social media to communicate with friends, family, and general public about engineering issues would be unenjoyable…enjoyable	4.46	1.40	4.80	1.59
Posting on social media to communicate with friends, family, and general public about engineering issues would be pointless…worthwhile	4.49	1.60	4.99	1.57
Posting on social media to communicate with friends, family, and general public about engineering issues would be unpleasant….pleasant	4.52	1.29	4.88	1.46
Posting on social media to communicate with friends, family, and general public about engineering issues would be foolish…wise	4.76	1.30	5.05	1.46
Posting on social media to communicate with friends, family, and general public about engineering issues would be harmful…beneficial	4.96	1.17	5.32	1.24
Attitude: Posting on social media subscale reliability; $\alpha_{pre} = 0.93$; $\alpha_{post} = 0.96$	4.70	1.18	5.05	1.35
Attitude: Face-to-face conversations				
Having face-to-face conversations with family or friends regarding engineering issues would be bad…good	5.79	1.16	5.95	1.12
Having face-to-face conversations with family or friends regarding engineering issues would be unenjoyable…enjoyable	5.37	1.25	5.79	1.22

Table 3: Measures & Reliability of Attitude toward Communication (cont.d)

Variable: Attitude towards Communication (7-point scale)	M (pre)	SD (pre)	M (post)	SD (post)
Having face-to-face conversations with family or friends regarding engineering issues would be pointless…worthwhile	5.37	1.40	5.70	1.30
Having face-to-face conversations with family or friends regarding engineering issues would be unpleasant…pleasant	5.39	1.17	5.61	1.28
Having face-to-face conversations with family or friends regarding engineering issues would be foolish…wise	5.52	1.17	5.82	1.11
Having face-to-face conversations with family or friends regarding engineering issues would be harmful…beneficial	5.61	1.12	5.88	1.07
Attitude: Face-to-face conversations subscale reliability; $\alpha_{pre} = 0.96$; $\alpha_{post} = 0.95$	5.49	1.10	5.79	1.07
Overall, attitude scale reliability; $\alpha_{pre} = 0.74$; $\alpha_{post} = 0.82$	5.25	0.90	5.54	0.99

N=84

Table 4: Measures & Reliability of Motivation

Variable: Motivation (7-point scale)	M (pre)	SD (pre)	M (post)	SD (post)
As a student in this class I feel: motivated….unmotivated#	3.68	1.18	4.96	1.56
As a student in this class I feel: interested….uninterested#	3.58	1.24	5.56	1.26
As a student in this class I feel: involved….uninvolved#	4.68	1.14	4.63	1.94
As a student in this class I feel: not stimulated….stimulated	5.19	1.44	5.35	1.46
As a student in this class I feel:don't want to study…want to study	4.77	1.47	4.31	1.69
As a student in this class I feel: inspired….uninspired#	4.23	1.22	5.35	1.44
As a student in this class I feel: unchallenged….challenged	4.94	1.27	4.89	1.55
As a student in this class I feel: uninvigorated….invigorated	4.89	1.21	4.93	1.39
As a student in this class I feel: unenthused….enthused	5.02	1.29	5.05	1.42
As a student in this class I feel: excited….not excited#	3.82	1.44	5.02	1.46
As a student in this class I feel: aroused….not aroused#	3.70	1.63	3.95	1.81
As a student in this class I feel: not fascinated….fascinated	4.99	1.28	5.00	1.55
As a student in this class I feel: dreading it…looking forward to it	4.61	1.52	4.86	1.52
As a student in this class I feel: important….unimportant#	3.56	1.12	3.62	1.09
As a student in this class I feel: useful….useless#	3.76	1.16	3.86	1.13
As a student in this class I feel: helpful….harmful#	2.87	1.08	2.94	1.02
Overall, motivation scale reliability; $\alpha_{pre} = 0.93$ & $\alpha_{post} = 0.95$	4.27	0.92	4.64	1.10

#recorded variable; N=84

Table 5: Measures & Reliability of Intended Behavior

Variable: Intended Behavior (7-point scale)	M (pre)	SD (pre)	M (post)	SD (post)
Intended behavior: Preparing materials				
I feel confident that I could prepare the necessary materials to participate in the following engineering communication activity: professional talks (disagree…agree)	5.37	1.42	6.13	0.88
I feel confident that I could prepare the necessary materials to participate in the following engineering communication activity: media interviews (disagree…agree)	4.93	1.56	5.86	1.08
I feel confident that I could prepare the necessary materials to participate in the following engineering communication activity: social media posts (disagree…agree)	5.42	1.24	5.93	1.08
I feel confident that I could prepare the necessary materials to participate in the following engineering communication activity: face-to-face conversations (disagree…agree)	5.79	1.26	6.26	0.84
Intended behavior: Prepare materials subscale reliability; $\alpha_{pre} = 0.90$; $\alpha_{post} = 0.90$	5.38	1.21	6.05	0.86
Intended behavior: Answering questions				
I feel confident that I could answer questions posed to me by my audience during: professional talks (disagree…agree)	5.08	1.51	6.06	0.96
I feel confident that I could answer questions posed to me by my audience during: media interviews (disagree…agree)	4.98	1.56	5.91	1.01
I feel confident that I could answer questions posed to me by my audience during: social media posts (disagree…agree)	5.37	1.37	6.05	0.98
I feel confident that I could answer questions posed to me by my audience during: face-to-face conversations (disagree…agree)	5.51	1.29	6.11	0.97
Intended behavior: Answering questions subscale reliability; $\alpha_{pre} = 0.95$; $\alpha_{post} = 0.96$	5.24	1.34	6.03	0.92
Intended behavior: Training				
I do NOT have enough training to participate in engineering communication activities such as: professional talks (disagree…agree)[#]	4.02	1.78	5.37	1.73
I do NOT have enough training to participate in engineering communication activities such as: media interviews (disagree…agree)[#]	4.11	1.65	5.35	1.69
I do NOT have enough training to participate in engineering communication activities such as: social media posts (disagree…agree)[#]	4.52	1.62	5.46	1.51
I do NOT have enough training to participate in engineering communication activities such as: face-to-face conversations (disagree…agree)[#]	4.69	1.61	5.57	1.60
Intended behavior: Training subscale reliability; $\alpha_{pre} = 0.94$; $\alpha_{post} = 0.97$	4.34	1.53	5.44	1.56

Table 5: Measures & Reliability of Intended Behavior (cont.d)

Variable: Intended Behavior (7-point scale)	M (pre)	SD (pre)	M (post)	SD (post)
Intended behavior: Participating in communication activities				
For me to participate in the following communication activities and address engineering issues would be: professional talks (difficult…easy)	4.25	1.64	5.38	1.23
For me to participate in the following communication activities and address engineering issues would be: media interviews (difficult…easy)	4.19	1.62	5.37	1.16
For me to participate in the following communication activities and address engineering issues would be: social media posts (difficult…easy)	4.88	1.45	5.64	1/19
For me to participate in the following communication activities and address engineering issues would be: face-to-face conversations (difficult…easy)	4.98	1.48	5.75	1.24
Intended behavior: Participating in communication activities subscale reliability; $\alpha_{pre} = 0.91$; $\alpha_{post} = 0.93$	4.57	1.38	5.54	1.09
Overall, intended behavior scale reliability; $\alpha_{pre} = 0.90$; $\alpha_{post} = 0.77$	4.88	1.20	5.76	0.88

[#]recorded variable; N=84

Table 6: Measures & Reliability of Engineering Identity

Variable: Engineering Identity (7-point scale)	M (pre)	SD (pre)	M (post)	SD (post)
I have a strong sense of belonging to the community of engineers (strongly disagree to strongly agree)	5.19	1.40	5.79	1.27
I derive great personal satisfaction from working on a team that is doing important research (strongly disagree to strongly agree)	5.68	1.15	6.08	0.95
I have come to think of myself as an "engineer" (strongly disagree to strongly agree)	5.43	1.43	5.99	1.35
I feel like I belong in the field of engineering (strongly disagree to strongly agree)	5.58	1.46	5.99	1.41
The daily work of an engineer is appealing to me (strongly disagree to strongly agree)	5.51	1.46	5.83	1.33
"A person who thinks discussing new theories and ideas between engineers is important" (not like me at all…very much like me)	5.45	1.21	5.80	1.04
"A person who thinks it is valuable to conduct research that builds the world's engineering knowledge" (not like me at all….very much like me)	5.61	1.05	5.89	1.03
"A person who thinks that engineering research can solve many of today's world challenges" (not like me at all…very much like me)	5.87	1.04	6.12	1.00

Table 6: Measures & Reliability of Engineering Identity (cont.d)

Variable: Engineering Identity (7-point scale)	M (pre)	SD (pre)	M (post)	SD (post)
"A person who feels discovering something new in engineering is thrilling" (not like me at all…very much like me)	5.91	1.16	6.10	0.94
It is important to take part in engineering communication activities with the non-engineering public because taxpayers' money funds engineering research and projects (strongly disagree…strongly agree)	5.41	1.28	5.76	1.07
I have a duty as an engineer to take part in engineering communication activities targeting the non-engineering public (strongly disagree…strongly agree)	5.44	1.21	5.73	1.12
Overall, engineering identity scale reliability; $\alpha_{pre} = 0.93$; $\alpha_{post} = 0.94$	5.55	0.98	5.92	0.90

N=84

Table 7: T-test Summary Results

	Attitude towards communication	Motivation	Intentions to engage in communication	Engineering identity
IEPS (pre-test to post-test)	(t(40)= -3.82, p=0.0005)***	(t(40)= -1.39, p=0.17)	(t(40) = -3.31, p=0.002)**	(t(40) = -3.01, p=0.005)**
TPS (pre-test to post-test)	(t(42)= -0.50, p=0.62)	(t(42)= -2.46, p=0.02)*	(t(42) = -5.87, $p=6.1e^{-07}$)***	(t(42)= -2.30, p=0.027)*
Pre-test (Before class IEPS and TPS)	(t(79)=0.64, p=0.52)	(t(73)=2.69, p=0.009)*	(t(81)=1.34, p=0.19)	(t(81)=0.79, p=0.43)
Post-test (After class IEPS and TPS)	(t(79)=2.80, p=0.006)*	(t(73)=2.20, p=0.03)*	(t(82)=0.78, p=0.44)	(t(82)=2.10, p=0.04)*

***p<0.001, **p<0.005, *p<0.05