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

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ABSTRACT

We assessed the effectiveness of an integrated engineering public-speaking class relative to a traditionally taught public-speaking class. The integrated class was designed to meet the growing science, technology, engineering, and mathematics communication needs and the fundamental Accreditation Board for Engineering and Technology and the National Communication Association student outcomes related to public speaking. Working within the Communication in the Disciplines theoretical framework, this study employed a quasi-experiment with both a test (engineering specific communication class) and control (traditional communication class) group; finding a significant increase with respect to attitude toward communication for students before and after the engineering specific class compared with the traditional class. Along with attitude toward communication, efficacy toward communication and being enrolled in the engineering specific class related positively to a sense of engineering identity for students at the end of class. For students enrolled in the engineering specific class, their sense of engineering identity was mediated through an improved attitude toward communication.

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Communication underpins the evolution of every field of science (Penrose & Katz, 2010) 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. Accordingly, scientific discovery, and the innovative thinking associated with such discovery, is meaningless without the ability to communicate ideas in meaningful ways. Future scientists, innovators, and entrepreneurs, then, must equip themselves with the skills to communicate with their colleagues and peers as well as with decision-makers if they are to promote their work effectively.

In addition to the promotional benefits of communicating during and about science, the growing societal impacts of scientific research mean that STEM practitioners have a responsibility to communicate to the general public and enhance understanding of

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science (Greenwood & Riordan, 2001; Leshner, 2007). 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 with multiple audiences can lead to intelligent public conversations that allow for informed decisions in national and international debates involving science and technology (Leshner, 2003). 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 (Nisbet & Mooney, 2007). This lack of preparation encompasses both oral (Chan, 2011) and visual communication (Estrada & Davis, 2015).

Even with some public skepticism, confidence in science continues to be high in the U.S.; trust in STEM professionals and their organizations, though, has been wavering (Funk, 2017; National Science Board, 2018). To build trust among publics, organizations such as the American Association for the Advancement of Science (AAAS) and the National Academies of Sciences, Engineering, and Medicine (NAS) have recognized the need for STEM communities to engage with their publics (see AAAS' Center for Public Engagement with Science & Technology; see Sackler Colloquiums of Science of Science Communication). AAAS and NAS have begun focusing their efforts in training STEM professionals to not only educate, but to engage with media and dialogue with their publics about the societal and ethical impacts of STEM research (Nisbet & Markowitz, 2015). To accommodate these calls for STEM professionals to be trained in media and public engagement, several universities are plugging in programs to ensure undergraduate students majoring in STEM fields are receiving communication training that would ensure these future professionals being capable of engaging in respectful and effective communication with their publics (Nisbet & Markowitz, 2015).

The importance of learning oral communication skills specifically in the field of engineering has also been well documented as critical to engineering success within and outside of the classroom. For example, a survey of public works departments who hire engineers placed both "good listener" and "good communicator" in the top 10 needed skills for employment, ahead of both "technically proficient" and "organized" (see Veis, 2017). Additionally, Darling and Dannels (2003) found that 72 percent of practicing engineers indicated speaking skills (i.e., audience analysis, interpersonal communication, persuasion, teamwork) were important to their work. Even as early as 1982, scholars advocated for the introduction of specific courses in oral technical presentation skills to engineering curricula and documented that more than half an engineer's professional work comprised communication tasks (Spretnak, 1982). The emphasis on communication skills in engineering settings is critical, in part, because the results of communication failures can be significant. Moore (1992) provides a detailed analysis of the famous failure of the oral presentation made by engineers to NASA officials recommending that the Challenger space shuttle should not be launched prior to the first shuttle disaster. In a more typical example, Veis (2017) presents a case study of an engineer who failed in a promotion application due to poor oral communication skills.

We know from research that the work involved with engineering occurs within a fundamentally oral environment where communication skills are the "lifeblood of a practicing engineer" (Darling & Dannels, 2003, p. 15), and yet Miceli (2011) has argued that engineers' lack of communication skills has contributed to a widespread undervaluing of engineering as a discipline. ABET has attempted to address this disconnect, making "an ability to communicate effectively with a range of audiences" one of seven desired student outcomes in their criteria for accrediting engineering programs (ABET, 2018). It is clear many engineering professionals and educators alike have accepted the importance of communication to their field. In sum: given the need to communicate with both the media and general publics about not only the engineering itself, but also about the societal and ethical issues of engineering, science, and technologies; communication is here to stay as an integral component of a STEM professional's identity.

Theoretical framework: communication in the disciplines

An area of scholarship and practice that has focused on addressing the teaching and learning of communication (oral, visual, electronic, etc.) in STEM education is communication across the curriculum (CXC). CXC was initially developed in the 1970s and has seen success in a variety of fields (Cronin & Glenn, 1991; Steinfatt, 1986). Some CXC initiatives have been questioned, however, whether focusing too much on discipline-specific skills in other disciplines potentially dilutes the communication discipline (for discussion see Dannels & Gaffney, 2009). Given this, CXC has not been viewed by the National Communication Association (NCA) as a substitute for basic instruction provided by departments of communication (Fleury, 2005); it is, rather, meant to build on that instruction.

Building on CXC research, Dannels (2001) proposed an additional model for how to incorporate communication pedagogy in disciplinary specific manner, communication in the disciplines (CID). This model assumes that student learning which occurs in a general education classroom (i.e., traditional public-speaking classes) can be enhanced with content and instruction which is salient to a given discipline. The CID model is characterized by the four principles: "1) oral genres are sites for disciplinary learning, 2) oral argument is a situated practice, 3) communication competence is locally negotiated, and 4) learning to communicate is a context driven activity" (Dannels, 2001, p. 147). This model pushes students to consider particular audiences and how to speak in a way that is seen as competent, relative to their disciplinary norms and values. Vrchota (2011) suggested that a benefit of the CID model is that it encourages communication scholars to look beyond a one size fits all approach and opens pedagogical understanding to critical disciplinary knowledge that may otherwise be overlooked. For example, Dannels (2002) found communication competence in engineering as tied to the situated norms, values, and audiences specific to the field of engineering; translation of technical information for broad audiences being central.

Learning these disciplinary-communication competencies can help students define their identities within their communities of practice (Lave & Wenger, 1991; Wenger, 1998). In fact, whereas a STEM student's identity has primarily been perceived as their: (1) being able to understand technical concepts, (2) interests in their subjects, (3) recognition from their mentors, peers, and family of being good students, and (4) the technical competence in their field (Godwin, 2016; Hazari, Sonnert, Sadler, & Shanahan, 2010; Shanahan, 2009), increasingly communication competence has become central, as well. Specifically, the notion of being a competent communicator with peers within and outside their fields, to media sources, and to the general publics, is becoming more and more important to STEM identity. And while some students have been resistant to the inclusion of pedagogy regarding communication competencies and skills in their engineering classes (Dannels, Anson, Bullard, & Peretti, 2003), with communities such as the AAAS and the NAS identifying communication as an essential skill to being a successful STEM professional, it is worth investigating how students negotiate communication instruction and their professional identities within their respective STEM communities (Tonso, 2014).

This project returned to Dannels and Gaffney's (2009) call for a commitment to empirical rigor in CXC research. Using the CID theoretical model, we developed communication instruction with a cross-disciplinary team of experts from communication and engineering with the goal of improving STEM communication outcomes advocated for by both NCA and ABET, but in a context focusing on the specific needs of the engineering discipline. The integration of communication and engineering courses has previously proven successful in teaching essential writing skills to STEM students (Colton & Surasinghe, 2014; Manuel-Dupont, 1996), but oral communication has at times played a subordinate role to writing pedagogy (Ford & Riley, 2003). The purpose of this study, then, was to explore the role of oral communication pedagogy specifically designed to train engineering students to engage with professional and public audiences in the development of engineering identity. Specifically, we explored the following research question:

> RQ: What role, if any, might an integrated engineering oral communication class have in improving desired course outcomes relative to a traditionally taught oral communication class?

Course design: integrated engineering public speaking

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 public-speaking (IEPS) course for this project. Two sections of the integrated engineering and communication course 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 curricula at the study institution. For context: 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 (TPS) classes. The IEPS class was created to meet that same general education requirement, but was tailored 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 IEPS course was designed hand in hand with both communication and engineering faculty but taught exclusively by existing 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 TPS 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.

TPS 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. Our TPS classes follow what could be considered a typical public-speaking course template; the classes are standardized around a single textbook, 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). Our IEPS class followed that same model. The classes were standardized around a single handbook style text, met in person three hours a week, and were organized around a series of presentations that built off one another sequentially. Assignments in the integrated class 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 (Speaking and Listening Competencies for College Students, 2012) and ABET (Criteria for Accrediting Engineering Programs, 2016) desired student outcomes and are outlined briefly in Table 1. It is important to note that we designed IEPS assignments with the intention of helping students move from a deficit model of communication, where facts are assumed to speak for themselves, to a dialogue model of communication. This model invites differing perspectives, facilitates participation, encourages consensus building, and helps students learn from disagreement (Nisbet & Scheufele, 2009).

IEPS, student factors, and engineering identity

Frey and Fisher (2010) argued that academic motivation requires a meaningful task, "tailored to the developmental, academic, and social needs of students" (p. 30). Complimenting previous work in CXC, Ajzen's (1991) theory of planned behavior (TPB) helps us understand how pedagogy situated in the CID model may benefit students through meaningful tasks. TPB asserts three dimensions can help predict our understanding of future behavior: attitude toward the behavior, subjective norms, and perceived behavioral control. Doll and Ajzen (1992) defined each of these dimensions. *Attitude toward the behavior* was defined as the degree to which a person has a favorable or unfavorable appraisal of a given behavior. *Subjective norms* refer to the social pressure felt by an

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, and resiliency) groups presented a debate for and against a particular technology and then conducted a class discussion. Included a multimedia component.
6. Elevator speech	Less than 2-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.

individual to perform a behavior or not. Finally, *perceived behavioral control* refers to the perceived ease or difficulty of performing a behavior experience by an individual. This last dimension is assumed to reflect past experience as well as imagined obstacles. Given these definitions, TPB would suggest that situated pedagogy would have the potential to help students better understand the important role oral communication may have in the professional life. By helping students understand that oral communication is both an expectation of their discipline and something they are capable of mastering, their attitudes toward it may change.

Research suggests that students' beliefs about the topic of instruction, their experiences in classes, their perceived level of competence, and their general attitudes are all aspects of engineering identity (Godwin, 2016; Hazari et al., 2010). Greater engineering identity is linked to student retention in engineering programs as well as improved campus and workplace climate (Morelock, 2017). Therefore, to answer the research question about the role of the IEPS class in achieving desired student outcomes; this study focused on comparisons between the IEPS and TPS classes with regard to relationships between affect, motivation, attitude, efficacy toward communication, and the sense of engineering identity among students.

Affect

Affect towards course content and instructor (different from affective learning) have been found to influence students' compliance in classes, improve their motivation to learn, and aid their learning to a certain extent (Bolkan, 2015; Bolkan & Goodboy, 2015; McCroskey, 1994; Moreno & Mayer, 2007; Myers & Goodboy, 2015). Having a positive affective experience temporarily for a course content or an instructor cannot be assumed to transfer onto a more sustained attitude that will promote value and effort for continued learning of that topic; however, should the student be provided with a nurturing learning environment, then the potential for more sustained affective learning can become conducive (Myers & Goodboy, 2015; Thweatt & Wrench, 2015). While affect towards the course content and instructor has the potential to influence affective learning (Krathwohl, Bloom, & Masia, 1964), it is beyond the scope of this study to assess affective learning (Thweatt & Wrench, 2015). However, given how students have been known to express a distaste for learning communication skills in engineering courses (Dannels et al., 2003), this study explored the role that affect towards learning communication in a course and the affect toward an instructor teaching them about communicating their engineering topics (not typically trained as an engineer) in a course can shape a student's engineering identity.

Motivation

Being intrinsically motivated encourages learning (Deci & Ryan, 1985; Grolnick & Ryan, 1987; Nolen & Haladyna, 1990; Rigby, Deci, Patrick, & Ryan, 1992) and is closely related to shaping an individual's identity (Foote, 1951; Wigfield & Wagner, 2005). Motivation and identity have a reciprocal relationship, where identity has the potential to affect motivation and an intrinsic motivation has the ability shape identities (Brophy, 2009; Eccles, 2009; La Guardia, 2009). Thus, this study explored the relationship that intrinsic motivation during the oral communication course had on the sense of engineering identity among engineering students.

Attitude toward communication

Beliefs about the need to communicate engineering topics and addressing media and public questions or concerns will add up to either positive or negative attitudes toward communication among students (Ajzen, 2017; Doll & Ajzen, 1992; Fishbein & Ajzen, 1975). While there is some evidence that STEM communities have held negative or apathetic views on STEM communication, this attitude is slowly improving among STEM professionals (Besley, Dudo, Yuan, & Lawrence, 2018; Lo & Peters, 2015; Poliakoff & Webb, 2007). It is yet to be determined if students are also able to take on a positive attitude toward communication, and if that transfers into an increased sense of engineering identity following their experience in a communication course; which we explored in this study.

Efficacy toward engaging in communication

To expect students to start being effective communicators, we must assess their level of efficacy—the belief in their ability to successfully communicate with their peers, family, media, and publics (Ajzen, 2017; Besley et al., 2018; Doll & Ajzen, 1992; Fishbein & Ajzen, 1975; Poliakoff & Webb, 2007). A student's identity, especially in STEM, is closely tied with their perceived levels of competence and while this thus far has been studied in the context of technical skills (Godwin, 2016; Hazari et al., 2010); we explored, though, whether experiencing an increase in efficacy to communicate with peers, the media, and the public, can increase self-identified engineering identity.

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 12 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 TPS or IEPS 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). We initially limited the control group courses to only engineering students until the minimum number of engineering students needed for the purposes of the study were enrolled. Once seven engineering students were enrolled in each control group class, the courses were opened to the general population for enrollment. All of these manipulations were performed in a manner that the students were unaware of and the two groups therefore were created in a manner that approximated random assignment.

At the start of the spring 2018 semester, 70 college of engineering students were enrolled in the control group, and 57 college of engineering students were enrolled in the test group. These students were equally distributed across both control and test group classes. A total of 110 additional students from the general university population were also enrolled in the control group classes; no students from the general university population were enrolled in the test group classes.

Participants

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 presurvey and postsurvey. Given 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 the number of students who would be willing to participate in the presurvey and postsurvey; we were limited in ensuring all three conditions remained 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. A 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, and had a sample size approximately close to 34.

Among the 171 students in the study, the 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 nonengineer 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 nonengineers 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 IEPS 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 nonengineers, 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 ($F[1,81] = 0.941$, $p = 0.335$). 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 IEPS or TPS condition and there is no need to additionally control for gender, age, ethnicity, and class in following analyses.

Procedures and instrumentation

We asked all students to take part in pretest and post-test survey. This research received prior approval from the study institution's institutional review board. Willing participants took a pretest survey in the first regular week of class and a post-test survey in the last regular week of class. For each survey, the instructor directed students to an online informed consent document. After indicating consent, they took an online survey that involved a series of instruments to evaluate their attitudes regarding the course. We did adapt several instruments to change language relevant to the engineering discipline rather than general sciences. We did not provide rewards or inducement to encourage participation but surveys did take place during regular class time.[1]

Affect

We measured affect towards the course content and instructor using McCroskey's (1994) instruments. Participants completed 7-point, 4-item bipolar scales reflecting their affect toward (1) course content, (2) taking future classes in this content area, (3) instructor, and (4) taking future classes with the instructor. Some items were reverse coded, and were recoded before final analysis.

Motivation

We measured student motivation using Beatty, Behnke, and Froelich's (1980) motivation scale, as expanded by Richmond (1990; see also Houser, Cowan, & West, 2007). This measure explored 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. Some items were reverse coded, and were recoded before final analysis.

Attitude toward communication

We measured attitude toward communication using an adapted version of Poliakoff and Webb's (2007) instrument. 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. While the original scale included only 6 items, the researchers adapted it to accommodate two other contexts. Overall, attitudes were measured for face-to-face communication, social media, and presenting a talk. Some items were reverse coded, and were recoded before final analysis.

Efficacy toward engaging in communication

We measured efficacy toward communication using an adapted version of Poliakoff and Webb's (2007) instrument. This measure explored participant level of 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. Similar to the attitude scale above, efficacy was also adapted for 4 separate contexts of preparing materials, answering questions, training, and participation in several communication activities. Some items were reverse coded, and were recoded before final analysis.

Engineering identity

We measured engineering identity using an adapted version of Hanauer, Graham, and Hatful's (2017) 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."

Reliability

All scales were found reliable. With respect to affect, all four scales were found reliable: affect toward course content ($\alpha_{pre} = 0.83$; $\alpha_{post} = 0.89$); affect toward taking future classes in this content area ($\alpha_{pre} = 0.88$; $\alpha_{post} = 0.90$); affect toward instructor ($\alpha_{pre} = 0.96$; $\alpha_{post} = 0.93$); affect toward taking future classes with the instructor ($\alpha_{pre} = 0.94$; $\alpha_{post} = 0.91$). The scales for attitude towards communication ($\alpha_{pre} = 0.94$; $\alpha_{post} = 0.96$); motivation ($\alpha_{pre} = 0.93$; $\alpha_{post} = 0.95$); efficacy in communication ($\alpha_{pre} = 0.96$; $\alpha_{post} = 0.94$); and, engineering identity ($\alpha_{pre} = 0.93$; $\alpha_{post} = 0.94$) were also reliable.

Analyses

All analyses were performed using the programing language R. We ran paired sample *t*-tests, Welch two sample *t*-tests, and linear regressions. We also used a model-based design for our mediation analysis, which involved two models: first, the mediation model for the conditional distribution of our mediator given our treatment and our set of covariates and control variables, and second, the outcome model for the conditional distribution of our dependent variable given the mediator, treatment, covariates, and control variables (Tingley, Yamamoto, Hirose, Keele, & Imai, 2014).

Results

Paired sample *t*-tests were performed to assess if there were significant differences within preclass and postclass tests in each condition across all variables. There was no significant difference from preclass ($M = 5.45$, $SD = 1.06$) and postclass ($M = 5.24$, $SD = 0.90$) with respect to affect toward content for those in the IEPS class ($t[40] = 1.27$, $p = 0.21$). Similarly, there was no significant difference from preclass ($M = 5.08$, $SD = 0.94$) and postclass ($M = 5.12$, $SD = 0.93$) with respect to affect toward content for those in the TPS class ($t[42] = -0.29$, $p = 0.78$). Before classes started, there was no significant difference in affect toward content for those in the IEPS and TPS classes ($t[80] = 1.72$, $p = 0.09$). After classes too, there was no significant difference in affect toward content for those in the IEPS and TPS classes ($t[82] = 0.61$, $p = 0.52$).

There was no significant difference from preclass ($M = 3.88$, $SD = 1.41$) and postclass ($M = 4.01$, $SD = 1.49$) with respect to affect toward classes in this content for those in the IEPS class ($t[40] = -0.51$, $p = 0.62$). Similarly, there was no significant difference from preclass ($M = 3.41$, $SD = 1.05$) and postclass ($M = 3.15$, $SD = 1.29$) with respect to affect toward classes in this content for those in the TPS class ($t[42] = 1.30$, $p = 0.20$). Before classes started, there was no significant difference in affect toward classes in this content for those in the IEPS and TPS classes ($t[74] = 1.71$, $p = 0.09$). After class, affect toward classes in this content for those in IEPS class was higher than those in the TPS class ($t[79] = 2.83$, $p = 0.006$).

There was no significant difference from preclass ($M = 4.98$, $SD = 0.79$) and postclass ($M = 5.30$, $SD = 0.98$) with respect to affect toward instructor for those in the IEPS class ($t[40] = -1.97$, $SD = 0.06$). There was however a significant increase from preclass ($M = 4.77$, $SD = 0.89$) and postclass ($M = 5.63$, $SD = 1.02$) with respect to affect toward instructor in the TPS class ($t[42] = -5.14$, $p = 6.74e^{-06}$). Before classes started, there was no significant difference between students in the IEPS and TPS classes with respect to affect toward instructor ($t[82] = 1.18$, $p = 0.25$). Similarly, after classes, there was no significant difference between students in IEPS and TPS classes with respect to affect toward instructor ($t[82] = -1.53$, $p = 0.13$).

There was no significant difference from preclass ($M = 4.97$, $SD = 1.30$) to postclass ($M = 5.16$, $SD = 1.44$) with respect to affect toward taking classes with the instructor in the IEPS class ($t[40] = -0.77$, $p = 0.45$). There was no significant difference from preclass ($M = 4.72$, $SD = 1.72$) to postclass ($M = 5.30$, $SD = 1.72$) with respect to affect toward taking classes with the instructor in the TPS class ($t[40] = -1.97$, $p = 0.06$). Before classes started, there was no significant difference between students in the IEPS and TPS classes ($t[78] = 0.75$, $p = 0.46$). After classes too, there was no significant difference between students in the IEPS and TPS classes ($t[81] = -0.40$, $p = 0.69$).

There was a significant increase from preclass ($M = 5.31$, $SD = 0.97$) to postclass ($M = 5.84$, $SD = 1.01$) measures on positive attitudes towards communication for those in the IEPS class ($t[40] = -3.82$, $p < 0.001$). There was, however, no significant increase from preclass ($M = 5.18$, $SD = 0.84$) to postclass ($M = 5.26$, $SD = 0.88$) 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 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 attitudes towards communication was significantly higher for the IEPS class than the TPS class after taking the class ($t[79] = 2.80$, $p < 0.01$).

There was no significant increase in motivation from preclass ($M = 4.47$, $SD = 1.02$) to postclass ($M = 4.77$, $SD = 1.23$) measures on motivation for those in the IEPS class ($t[40] = -1.78$, $p = 0.08$), but there was a significant rise in motivation from preclass ($M = 3.84$, $SD = 0.75$) to postclass ($M = 4.17$, $SD = 0.92$) for those in the TPS class ($t[42] = -2.51$, $p = 0.02$). 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 ($t[74] = 3.25$, $p = 0.002$). The motivation after class was also significantly higher for those in the IEPS class than those in the TPS class ($t[74] = 2.52$, $p = 0.01$).

There was a significant increase from preclass ($M = 5.04$, $SD = 1.24$) to postclass ($M = 5.80$, $SD = 0.87$) in efficacy toward engaging in communication behaviors in the IEPS class ($t[40] = -3.97$, $p < 0.001$). There was also a significant increase from preclass ($M = 4.73$, $SD = 1.14$) to postclass ($M = 5.44$, $SD = 0.91$) in efficacy toward engaging in communication behaviors in the TPS class ($t[42] = -4.41$, $p < 0.0001$). There was no significant difference in efficacy toward engaging in communication behaviors in the IEPS and TPS class before classes started ($t[81] = 1.19$, $p = 0.24$) and after classes ended ($t[82] = 1.87$, $p = 0.06$).

There was significant increase from preclass ($M = 5.64$, $SD = 0.91$) to postclass ($M = 6.12$, $SD = 0.87$) in their engineering identity in the IEPS class ($t[40] = -3.01$, $p < 0.01$)

and from preclass ($M = 5.47$, $SD = 1.05$) to postclass ($M = 5.72$, $SD = 0.89$) 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 ($t[82] = 2.10$, $p = 0.04$).

To assess whether any of the variables significantly improved for the IEPS class compared with the TPS class, we used the Welch two sample *t*-test. We measured the difference between each student's pretest and post-test measures of each variable in the IEPS class and for the TPS class. We then compared the means of those differences between those in the IEPS class to those in the TPS class using the Welch two sample *t*-test. There was a significant difference noted with respect to attitude toward communication ($t[82] = -2.26$, $p = 0.03$, $d = 0.25$) with the difference for those enrolled in the IEPS classes ($M = 0.53$, $SD = 0.89$) being significantly higher than those enrolled in the TPS classes ($M = 0.07$, $SD = 0.96$). There were no significant changes noted between students before and after taking their IEPS and TPS classes with respect to affect toward course content ($t[82] = -0.60$, $p = 0.55$), affect toward taking future classes in this content area ($t[75] = -0.44$, $p = 0.66$), affect toward the instructor ($t[82] = 0.88$, $p = 0.38$), affect toward taking future classes with the instructor ($t[80] = -0.18$, $p = 0.14$), motivation ($t[77] = 0.17$, $p = 0.87$), efficacy ($t[79] = 0.65$, $p = 0.52$), or engineering identity ($t[71] = -1.21$, $p = 0.23$).

The first linear regression shown in Table 2 indicates that (upon controlling for demographic variables, affect, efficacy toward communication, and motivation), being enrolled in the IEPS class improved attitude toward communication. The second linear regression in Table 2 indicates that an increase in attitude toward communication, increase in efficacy toward communication, and being enrolled in the IEPS class had increased engineering identity for students after class. Figure 1 summarizes the findings of the regression analyses. Given how, after class, being enrolled in IEPS

Table 2. Linear regressions for effect on attitude toward communication and engineering identity.

	Attitude toward communication (postclass) *b* (*SE*)	Engineering identity (postclass) *b* (*SE*)
Intercept	3.502 (2.087)	0.096 (1.600)
Age	−0.053 (0.101)	0.054 (0.076)
Gender (female)	0.290 (0.234)	0.025 (0.178)
Race (white)	0.317 (0.334)	0.645 (0.253)*
Year (sophomore)	0.088 (0.224)	0.193 (0.168)
Affect toward course content	0.362 (0.197)	0.159 (0.152)
Affect toward future classes in this content	0.028 (0.083)	−0.066 (0.062)
Affect toward instructor	−0.082 (0.174)	0.121 (0.131)
Affect toward future classes with this instructor	−0.040 (0.095)	−0.116 (0.072)
Motivation	0.117 (0.137)	−0.033 (0.103)
Efficacy toward engaging in communication	0.094 (0.127)	0.280 (0.096)**
Type of class (IEPS)	0.466 (0.216)*	0.341 (0.168)*
Attitude toward communication		0.311 (0.089)***
	$R^2 = 0.292$; adjusted $R^2 = 0.182$ ($N = 72$)	$R^2 = 0.521$; adjusted $R^2 = 0.438$ ($N = 71$)

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

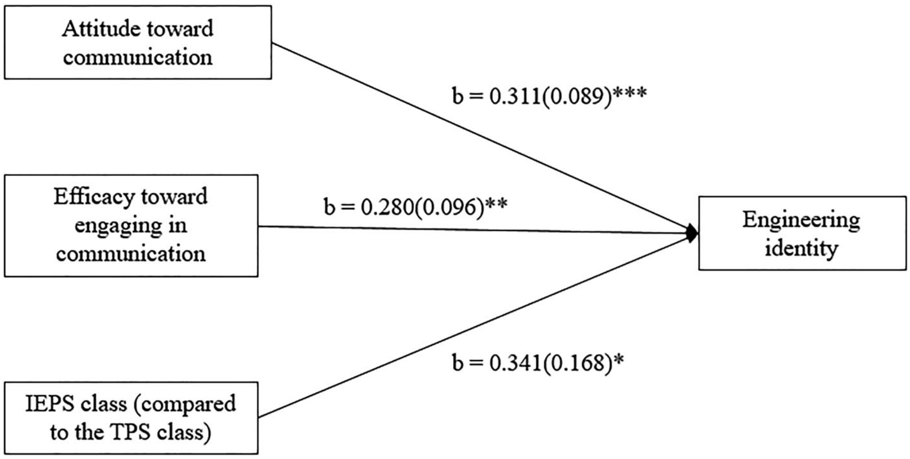

Figure 1. Linear regression to assess relationship of attitude toward communication, efficacy toward engaging in communication, and type of class on engineering identity. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

class increased attitude toward communication and also engineering identity, and how an increase in attitude toward communication also increased the sense of engineering identity, a mediation analysis (that uses Monte Carlo bootstrapping) was performed. Prior to running the mediation analysis, we confirmed that after controlling for all variables there was no significant interaction between type of class (treatment) and attitude toward communication (mediator) ($b = -0.291[0.168]$, $p = 0.088$). A specific randomness seed was also set for the mediation analysis. Results show that after controlling for demographic variables, affect, motivation, efficacy toward communication, the average direct effect (ADE) was not significant ($b = 0.341$, $p = 0.052$, 95% CI: –0.002 to 0.70), there was however a significant average causal mediation effect (ACME) ($b = 0.148$, $p = 0.044$, 95% CI: 0.001–0.38). Figure 2 summarizes the findings of the mediation analysis.

Linear regressions were also used to assess if the relationship each variable had on engineering identity significantly changed before and after the classes. As shown in Table 3, after controlling for demographic variables, an increase in attitude toward communication, efficacy toward engaging in communication, and being in the IEPS

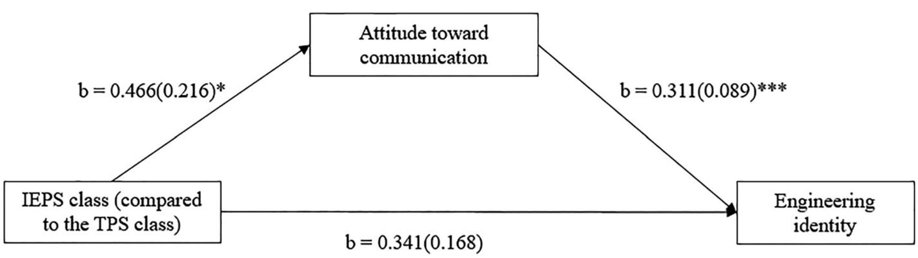

Figure 2. Attitude toward communication mediating the relationship between type of class and engineering identity. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

Table 3. Linear regressions to assess relationships of affect, attitude, efficacy, motivation, and type of class to engineering identity before and after classes.

	Engineering identity (preclasses) *b* (*SE*)	Engineering identity (postclass) *b* (*SE*)
Intercept	3.043 (2.010)	0.096 (1.600)
Age	−0.004 (0.101)	0.054 (0.076)
Gender (female)	0.793 (0.229)***	0.025 (0.178)
Race (white)	0.563 (0.317)	0.645 (0.253)*
Year (sophomore)	0.157 (0.211)	0.193 (0.168)
Affect toward course content	0.004 (0.159)	0.159 (0.152)
Affect toward future classes in this content	−0.031 (0.093)	−0.066 (0.062)
Affect toward instructor	0.160 (0.181)	0.121 (0.131)
Affect toward future classes with this instructor	−0.169 (0.072)*	−0.116 (0.072)
Attitude toward communication	0.022 (0.126)	0.311 (0.089)***
Motivation	0.211 (0.148)	−0.033 (0.103)
Efficacy toward engaging in communication	0.188 (0.095)	0.280 (0.096)**
Type of class (IEPS)	0.149 (0.215)	0.341 (0.168)*
	$R^2 = 0.372$; adjusted $R^2 = 0.265$	$R^2 = 0.521$; adjusted $R^2 = 0.438$

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$ ($N = 71$).

class (compared with the TPS class) increased a sense of engineering identity among students after classes. These were not significantly related prior to these classes.

Discussion

Our findings reveal a significant increase with respect to positive attitude toward communication for students before and after the IEPS class compared with the TPS class students. Along with attitude toward communication, efficacy toward communication, and being enrolled in the IEPS class related positively to a sense of engineering identity for students at the end of class. For students enrolled in the IEPS class, their sense of engineering identity was mediated through their improved attitude toward communication. While none of these relationships were significant before class, they improved significantly after class. In other words, at the end of the each class engineering students enrolled in the IEPS had a more positive attitude toward communication and a greater self-identified engineering identity than did engineering students enrolled in the TPS courses.

Attitude toward communication has been a well-founded variable with behavioral intentions and change (Ajzen, 2017; Doll & Ajzen, 1992; Fishbein & Ajzen, 1975), but this study suggests that through oral communication classes there is potential for it to provide an enhanced sense of identity among engineering students. While students improving their self-perceptions about their own ability to perform communication tasks is important to their present and future communication behaviors, it is positive attitude that will keep them open to public engagement and potentially motivate them to keep learning and growing as effective communicators. This is a significant contribution to the STEM fields and aligns with the goals of AAAS and NAS of producing future STEM professionals who are eager and able to engage with their peers, media, and publics (Nisbet & Markowitz, 2015; also see AAAS's Center for Public Engagement with Science & Technology; see Sackler Colloquiums of Science of Science Communication).

Matusovich, Streveler, and Miller (2010) suggests it is important for student retention to help students understand what it means to be an engineer and to encourage students to associate perceived engineering identity with their own personal identity. Having this sense of engineering identity among students reinforced aligns with the goals of all STEM organizations of maintaining student retention rates in STEM fields (Morelock, 2017; Tonso, 2014). According to the findings of this study we are able to show the contribution oral communication classes can have on the STEM retention agenda.

In utilizing the CID model, this study headed the words of Vrchota (2011) who encouraged scholars to look beyond a one size fits all model inherent to TPS classes. Our findings suggest that the IEPS courses did not devalue students' oral communication education in any identifiable way. Through the IEPS courses students were encouraged to consider the context specific nature of their communication. As Dannels (2001) suggested, CID seems to have only enhanced the student experience as shown by improved student outcomes.

Implications for teaching and learning

Results of this study suggest it might be salient to further investigate the advantages of having an integrated engineering communication curriculum over a traditional one within CXC or CID initiatives (Dannels & Gaffney, 2009; Fleury, 2005). This project has shown that some students may be better served by foundational public-speaking courses specifically tailored for their disciplinary and professional goals and interests. Engineering students in both the TPS and IEPS courses benefited in a variety of ways from their communication curriculum; the IEPS students, however, had benefits beyond those realized by the engineering students enrolled in the TPS classes. These benefits, it is important to again point out, were realized without the use of additional institutional resources. The class size, instructor, curriculum hours, and even physical class space were all consistent between the test and control groups. Though the gains may be viewed as moderate, they were gains made at very limited cost. By building a class which allowed students to learn fundamental communication skills in a context specific to their chosen field, students were changed in educationally beneficial ways. These findings should be of interest to any engineering program interested in better meeting ABET's desired student outcomes as well as any communication program interested in collaborating for meaningful CID.

It is possible classes similar to the course developed for this project could be similarly tested for disciplines beyond engineering and even STEM. Professional identity has implications in any context and courses that help build that identity while simultaneously engaging students in fundamental skills needs within and beyond their profession could have benefits across campus. This is particularly true when the relative cost, in time and resources, of the additional course is low, as it was in this case. It is also possible for faculty teaching TPS courses to consider incorporating discipline-specific assignments or activities. These lessons have potential value in even a more ad hoc application, and lessons taught to a future health care professional, for instance, may still help a future public relations practitioner have realizations about their own professional identity.

Limitations and future research

Although there are several encouraging findings in this study, there are also limitations that should be noted. The findings of this study are based on a pretest and post-test analysis of student perceptions. While these results are hopeful, it will take continued effort to nurture such relationships between variables to ensure a sustained sense of engineering identity tied to their perceptions and actions toward STEM communication. While students are often able to display these changes during classes, it is difficult for them to transfer their learnings and continue growing their engineering competencies, in particularly related to communication, when placed in a new context (Dannels, 2000).

This project encourages future, more robust testing of our results. For instance, while running the mediation analysis, we set a specific randomness seed to ensure exact reproduction of results. Due to Monte Carlo errors, not every run of the mediation analysis resulted in a significant mediation effect (Tingley, Yamamota, Hirose, Keele, & Imai, n.d.). Thus, we urge scholars for more replication studies to test this finding.

The study also assumed that just because STEM organizations and several STEM professionals are improving their attitudes toward communication (Besley et al., 2018), that the professors and peers close to the students are also endorsing this norm. This study did not assess the descriptive norms that would explain the students' perceptions of their engineering professors' and peers' behaviors towards communication and injunctive norms that would explain the students' perceptions of the attitudes their professors and peers have toward communication (Ajzen, 2017; Buerkle, Gearhart, & Oliveira, 2017; Doll & Ajzen, 1992; Fishbein & Ajzen, 1975). Hence, while this study borrowed heavily from research employing the theory of planned behavior (Ajzen, 1991), it did not explicitly test the theory. Future research could use this theory as a lens and examine the potential norms about STEM communication and the oral communication training associated with it have on their perceived sense of engineering identity. With the inclusion of norms and other factors, future researchers can begin developing a theory of engineering identity grounded in perceptions of communication.

Future research should also explore variations in assignments and class structure. This class was developed in collaboration with engineering faculty but taught exclusively by communication faculty. Other institutions may wish to experiment with assessment of a course that is team taught by communication and engineering faculty working collaboratively. It may also be useful to integrate communication faculty into design, laboratory, or other technical courses in a hybrid teaching model. It is possible students may make additional natural connections between the importance of communication and their engineering course work if it is blended with their engineering coursework.

Conclusion

This study compared communication outcomes and their relationship to engineering identity between students enrolled either in oral communication classes designed specifically for engineering or traditional oral communication classes. Findings suggest that while oral communication classes, regardless of type, can improve a sense of engineering identity for students, having a more engineering specific course design can benefit students' attitude toward communication and that, in turn, can improve their sense of engineering identity. These improvements can not only help students have greater confidence in their practice of communication but also potentially help retention in engineering programs and facilitate climate improvements on campus and within subsequent professional workplaces (Morelock, 2017).

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Note

1. This instrument did not include any attention checks, and researchers encourage future scholars to consider including them to improve the rigor of their findings.

References

ABET. (2018). Criteria for accrediting engineering programs, 2018–2019. Retrieved from http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*, 179–211. doi:10.1016/0749-5978(91)90020-T

Ajzen, I. (2017). Icek Ajzen: Theory of planned behavior. Retrieved from http://people.umass.edu/aizen/tpb.html

Beatty, M. J., Behnke, R. R., & Froelich, D. L. (1980). Effects of achievement incentive and presentation rate on listening comprehension. *Quarterly Journal of Speech*, *66*, 193–200. doi:10.1080/00335638009383515

Besley, J. C., Dudo, A., Yuan, S., & Lawrence, F. (2018). Understanding scientists' willingness to engage. *Science Communication*, *40*(5), 559–590.

Bolkan, S. (2015). Students' affective learning as affective experiences: Significance, reconceptualization, and future directions. *Communication Education*, *64*(4), 502–505.

Bolkan, S., & Goodboy, A. K. (2015). Exploratory theoretical tests of the instructor humor- student learning link. *Communication Education*, *64*, 45–64. doi:10.1080/03634523.2014.978793

Brophy, J. (2009). Connecting with the big picture. *Educational Psychologist*, *44*, 147–157.

Buerkle, C. W., Gearhart, C. C., & Oliveira, C. M. (2017). According to, student motivations … : A theory of planned behavior investigation of students' intention to orally cite sources. *Communication Reports*, *30*, 157–169. doi:10.1080/08934215.2017.1280737

Chan, V. (2011). Teaching oral communication in undergraduate science: Are we doing enough and doing it right? *Journal of Learning Design*, *4*(3). Retrieved from https://www.jld.edu.au/article/view/82

Colton, J. S., & Surasinghe, T. D. (2014). Using collaboration between English and biology to teach scientific writing and communication. *Journal of College Science Teaching*, *44*(2), 31–39.

Criteria for accrediting engineering programs, 2016–2017. (2016). Retrieved from https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/#GC3

Cronin, M., & Glenn, P. (1991). Communication across the curriculum in higher education: The state of the art. *Communication Education*, *40*, 356–367. doi:10.1080/03634529109378860

Dannels, D. P. (2000). Learning to be professional: Technical classroom discourse, practice, and professional identity construction. *Journal of Business and Technical Communication*, *14*(1), 5–37. doi:10.1177/105065190001400101

Dannels, D. P. (2001). Time to speak up: A theoretical framework of situated pedagogy and practice for communication across the curriculum. *Communication Education*, *50*, 144–158. doi:10.1080/03634520109379240

Dannels, D. (2002). Communication across the curriculum and in the disciplines: Speaking in engineering. *Communication Education*, *51*, 254–268. doi:10.1080/03634520216513

Dannels, D. P., & Gaffney, A. H. (2009). Communication across the curriculum and in the disciplines: A call for scholarly cross-curricular advocacy. *Communication Education*, *58*, 124–153. doi:10.1080/03634520802527288

Dannels, D. P., Anson, C. M., Bullard, L., & Peretti, S. (2003). Challenges in learning communication skills in chemical engineering. *Communication Education*, *52*, 50–56. doi:10.1080/03634520302454

Darling, A. L., & Dannels, D. P. (2003). Practicing engineers talk about the importance of talk: A report on the role of oral communication in the workplace. *Communication Education*, *52*, 1–16. doi:10.1080/03634520302457

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self determination in human behavior*. New York: Plenum.

Doll, J., & Ajzen, I. (1992). Accessibility and stability of predictors in the theory of planned behavior. *Journal of Personality and Social Psychology*, *63*, 754–765. doi:10.1037/0022-3514.63.5.754

Eccles, J. S. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Educational Psychologist*, *44*, 78–89.

Estrada, F. C. R., & Davis, L. S. (2015). Improving visual communication of science through incorporation of graphic design theories and practices into science communication. *Science Communication*, *37*, 140–148. doi:10.1177/1075547014562914

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior*. Philippines: Addison Wesley.

Fleury, A. (2005). Liberal education and communication against the disciplines. *Communication Education*, *54*, 72–79. doi:10.1080/03634520500077032

Foote, N. (1951). Identification as the basis for a theory of motivation. *American Sociological Review*, *16*, 14–21.

Ford, J. D., & Riley, L. A. (2003). Integrating communication and engineering education: A look at curricula, courses, and support systems. *Journal of Engineering Education*, *92*, 325–328. doi:10.1002/j.2168-9830.2003.tb00776.x

Frey, N., & Fisher, D. (2010). Motivation requires a meaningful task. *The English Journal*, *100*, 30–36. doi:10.2307/20787688

Funk, C. (2017). Mixed messages about public trust in science. Pew Research Center. Retrieved from http://www.pewinternet.org/2017/12/08/mixed-messages-about-public-trust-in-science/

Godwin, A. (2016). *The development of a measure of engineering identity*. Paper presented at the ASEE's 123rd Annual Conference and exposition, New Orleans: LA. Retrieved from https://www.asee.org/public/conferences/64/papers/14814/view

Greenwood, M. R. C., & Riordan, D. G. (2001). Civic scientist/civic duty. *Science Communication*, *23*, 28–40. doi:10.1177/1075547001023001003

Grolnick, W. S., & Ryan, R. M. (1987). Autonomy in children's learning: An experimental and individual difference investigation. *Journal of Personality and Social Psychology*, *52*, 890–898.

Hanauer, D. I., Graham, M. J., & Hatful, G. F. (2017). A measure of college student persistence in the sciences (PITS). *CBE—Life Sciences Education*, *15*), doi:10.1187/cbe.15-09-0185

Hazari, Z., Sonnert, G., Sadler, P., & Shanahan, M. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, *47*, 978–1003.

Houser, M. L., Cowan, R. L., & West, D. A. (2007). Investigating a new education Frontier: Instructor communication behavior in CD-ROM texts—do traditionally positive behaviors

translate into this new environment? *Communication Quarterly*, *55*, 19–38. doi:10.1080/01463370600998319
Krathwohl, D. R., Bloom, B. S., & Masia, B. B. (1964). *Taxonomy of educational objectives: The classification of educational goals. Handbook II: Affective domain*. New York, NY: Longman.
La Guardia, J. G. (2009). Developing who I am: A self- determination theory approach to the establishment of healthy identities. *Educational Psychologist*, *44*, 90–104.
Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
Leshner, A. I. (2003). Public engagement with science. *Science*, *299*(5609), 977. doi:10.1126/science.299.5609.977
Leshner, A. I. (2007). Outreach training needed. *Science*, *315*(5809), 161. doi:10.1126/science.1138712
Lo, Y.-Y., & Peters, H. P. (2015). Taiwanese life scientists less "medialized" than their Western colleagues. *Public Understanding of Science*, *24*, 6–22. doi:10.1177/0963662513513863
Manuel-Dupont, S. (1996). Writing-across-the curriculum in an engineering program. *Journal of Engineering Education*, *85*(1), 35–40. doi:10.1002/j.2168-9830.1996.tb00205.x
Matusovich, H. M., Streveler, R. A., & Miller, R. L. (2010). Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values. *Journal of Engineering Education*, *99*, 289–303. doi:10.1002/j.2168-9830.2010.tb01064.x
McCroskey, J. C. (1994). Assessment of affect toward communication and affect toward instruction in communication. In S. Morreale, & M. Brooks (Eds.), *1994 SCA summer conference proceedings and prepared remarks: Assessing college student competence in speech communication* (pp. 55–69). Annandale, VA: Speech Communication Association.
Miceli, M. (2011). Say what?: The importance of effective communication in engineering. *The Journal of The Minerals, Metals & Materials Society*, *63*, 25. doi:10.1007/s11837-011-0201-4
Moore, P. (1992). When politeness is fatal: Technical communication and the challenger accident. *Journal of Business and Technical Communication*, *6*, 269–292. doi:10.1177/1050651992006003001
Morelock, J. R. (2017). A systematic literature review of engineering identity: Definitions, factors, and interventions affecting development, and means of measurement. *European Journal of Engineering Education*, *42*, 1240–1262. doi:10.1080/03043797.2017.1287664
Moreno, R., & Mayer, R. (2007). Interactive multimodal learning environments. *Educational Psychology Review*, *19*, 309–326. doi:10.1007/s10648-007-9047-2
Myers, S. A., & Goodboy, A. K. (2015). Reconsidering the conceptualization and operationalization of affective learning. *Communication Education*, *64*(4), 493–497.
National Science Board. (2018). *Science and engineering indicators 2018*. Alexandria, VA: National Science Foundation. Retrieved from https://nsf.gov/statistics/2018/nsb20181/report/sections/science-and-technology-public-attitudes-and-understanding/highlights
Nisbet, M. C., & Markowitz, E. (2015). Public engagement research and major approaches. *Commissioned Annotated Bibliography in Support of the Leshner Leadership Institute American Association for the Advancement of Science*. Retrieved from http://www.aaas.org/sites/default/files/content_files/Biblio_PublicEngagement_FINAL11.25.15.pdf
Nisbet, M. C., & Mooney, C. (2007). Framing science. *Science*, *316*(5821), 56. doi:10.1126/science.1142030
Nisbet, M. C., & Scheufele, D. A. (2009). What's next for science communication? Promising directions and lingering distractions. *American Journal of Botany*, *96*(10), 1767–1778. doi:10.3732/ajb.0900041
Nolen, S. B., & Haladyna, T. M. (1990). Personal and environmental influences on students' beliefs about effective study strategies. *Contemporary Ediucational Psychology*, *15*, 116–130.
Penrose, A. M., & Katz, S. B. (2010). *Writing in the sciences: Exploring conventions of scientific discourse* (3rd ed.). New York, NY: Longman.
Poliakoff, E., & Webb, T. L. (2007). What factors predict scientists' intentions to participate in public engagement of science activities. *Science Communication*, *29*, 242–263. doi:10.1177/1075547007308009

Richmond, V. P. (1990). Communication in the classroom: Power and motivation. *Communication Education*, *39*, 181–195. doi:10.1080/03634529009378801
Rigby, C. S., Deci, E. L., Patrick, B. C., & Ryan, R. M. (1992). Beyond the intrinsic extrinsic dichotomy: Self-determination in motivation and learning. *Motivation and Emotion*, *16*, 165–185.
Shanahan, M.-C. (2009). Identity in science learning: Exploring the attention given to agency and structure in studies of identity. *Studies in Science Education*, *45*(1), 43–64.
Speaking and listening competencies for college students. (2012). Retrieved from https://www.natcom.org/sites/default/files/pages/Assessment_Resources_Speaking_and_Listening_Competencies_for_College_Students.pdf
Spretnak, C. M. (1982). A survey of the frequency and importance of technical communication in an engineering career. *Technical Writing Teacher*, *9*, 133–136.
Steinfatt, T. M. (1986). Communication across the curriculum. *Communication Quarterly*, *34*, 460–470. doi:10.1080/01463378609369663
Thweatt, K. S., & Wrench, J. S. (2015). Affective learning: Evolving from values and planned behaviors to internalization and persuasive behavioral change. *Communication Education*, *64*(4), 497–499.
Tingley, D., Yamamoto, T., Hirose, K., Keele, L., & Imai, K. (2014). Mediation: R package for causal mediation analysis. *Journal of Statistical Software*, *59*(5), 1–38. Retrieved from https://imai.fas.harvard.edu/research/files/mediationR2.pdf
Tingley, D., Yamamota, T., Hirose, K., Keele, L., & Imai, K. (n.d.). Mediation: R package for causal mediation analysis. *The Comprehensive R Archive Network*. Retrieved from https://cran.r-project.org/web/packages/mediation/vignettes/mediation.pdf
Tonso, K. L. (2014). Engineering identity. In A. Johri, & B. M. Olds (Eds.), *Cambridge handbook of engineering education research* (pp. 267–282). Cambridge: Cambridge University Press.
Veis, C. A. (2017). *Public speaking for engineers: Communicating effectively with clients, the public, and local government*. Reston, VA: ASCE Press.
Vrchota, D. (2011). Communication in the disciplines: Interpersonal communication in dietetics. *Communication Education*, *60*(2), 210–230.
Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press.
Wigfield, A., & Wagner, A. L. (2005). Competence, motivation and identity development during adolescence. In A. J. Elliot, & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 222–239). New York: Guilford.