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Creating Inclusive Environments in First-Year Engineering Classes to Support Student Retention and Learning

Dr. Christina H Paguyo, Colorado State University

Christina H. Paguyo, PhD, is a postdoctoral fellow in the College of Engineering at Colorado State University. Her research interests focus on mixed methods approaches for designing and examining educational environments grounded in research, theory, and equity. She has co-authored peer-reviewed articles published in the Peabody Journal of Education and the Encyclopedia of Diversity in Education.

Dr. Rebecca A Atadero, Colorado State University

Rebecca Atadero is an assistant professor in the Department of Civil and Environmental Engineering at Colorado State University, specializing in structural engineering. She conducts research on the inspection, management and renewal of existing structures, and on engineering education.

Dr. Karen E Rambo-Hernandez, West Virginia University

Karen E. Rambo-Hernandez is an assistant professor at West Virginia University in the College of Education and Human Services in the department of Learning Sciences and Human Development. In her research, she is interested the assessment of student learning, particularly the assessment of academic growth, and evaluating the impact of curricular change.

Jennifer Francis, West Virginia University

Jennifer Francis is a graduate student at West Virginia University in the College of Education and Human Services in the Education Research and Evaluation master's program. Her research interests include mathematics education, project/problem based learning, and evaluations of a variety of educational programs.

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Introduction

A new NSF-funded experimental study seeks to incorporate innovative curriculum activities that cultivate inclusive engineering identities and demonstrate how the engineering profession benefits from diversity. We intend to expand first-year engineering student perceptions about who can be an engineer and what engineers do. This effort aims to create a cultural shift in engineering departments so students think beyond stereotypical perceptions of who belongs to the engineering profession (White men) toward more expansive notions about how the engineering profession needs diversity to thrive. Arguably, inclusive engineering departments will contribute to the retention and success of students who are underrepresented in engineering in terms of gender and race, but also in terms of backgrounds, talents, and interests.

In this paper, we begin with an overview of scholarship regarding pedagogical practices that foster strong engineering identities and position diversity as essential for strong engineering practice. Next, we address the following research question: How do freshmen engineering students in traditional engineering courses identify with engineering and perceive diversity in engineering? To answer this question, we summarize findings from preliminary survey by tracking over time the engineering identities and perceptions about diversity in engineering of engineering freshmen during their first semester in two existing first-year courses. We conclude with theoretically-based and evidence-driven activities that will be incorporated in the same first-year engineering courses in subsequent years of this NSF grant.

Theoretical Framework

Our theoretical approach is grounded in sociocultural theories of learning, where learning is viewed as a shift in how students participate in community practices[8]. Becoming an engineer, for example, can be viewed as a shift in how students participate in engineering practices, where freshmen begin to appropriate engineering ways of talking, being, and interacting. Over time, freshmen who take up engineering behaviors become sophomores, juniors, seniors, and graduates who eventually identify as engineers. However, some professions have traditionally excluded populations from participating in community practices[11], including engineering norms that tend to marginalize women and people of color[24], thus preventing students from learning how to become engineers since few entry points exist for them to participate meaningfully in engineering practices or identify as engineers. Through the sociocultural framework, learning how to become an engineer depends upon the ability of institutions and educators to provide access for students to participate in engineering practices. Some examples of engineering practices include collaborating in teams to identify, critically analyze, and solve problems with innovation; using skills and knowledge in math, science, engineering, and communication to help society; and recognizing how lifelong learning and resourcefulness fortifies engineering. When students can access and participate in engineering practices, shifts will occur as they increasingly take up engineering behaviors and identify as engineers.

Foundational to our theoretical framework is the notion that **demographic** or **identity diversity** (e.g., gender, race, etc.) and **intellectual** or **cognitive diversity** (e.g., diverse ways of depicting situations or diverse ways of developing solutions to problems, etc.) strengthen engineering practice[20]. In our study, we design and implement experimental curricula to expose students to engineering practices that value demographic and intellectual diversity, that is, the development of inclusive engineering identities. By kindling inclusive engineering identities in students, we aim for participants to not only identify as engineers, but to also see how colleagues from all backgrounds can contribute productively to the engineering profession. With an understanding of the relationship that exists between learning and identity[8], we focus our literature review on cultivating professional identities.

Literature Review on Professional Identity

Students attend engineering school to *become* engineers. This process of becoming requires more than just gaining the technical knowledge and skills required by the profession. Stevens et al.[25] contend that students participate in the process of becoming an engineer by acquiring disciplinary knowledge, developing an engineering identity, and navigating through a degree program.

Eliot and Turns[7] define professional identity as “personal identification with the duties, responsibilities, and knowledge associated with a professional role” (p. 631). Part of developing a professional identity is then to develop a definition or understanding of the profession and its associated roles and responsibilities. Students come into engineering with preconceived ideas about engineers and the engineering profession; unfortunately, these ideas may not be accurate. The National Science Board[19] notes that one of the three key challenges facing engineering is inaccurate public perceptions about engineers. While the reality of engineering includes solving the great problems of society and improving human welfare, engineering is more often associated with math and science and “things” rather than people[19]. Engineers are also associated with poor social skills and jobs that are nearly entirely technical[15]. These associations can make it hard for some students to see themselves as engineers. For example, Du[5] notes that the professional identity of an engineer is associated with technology and mechanical ability, thus aligning engineering with the male gender. This alignment is reinforced by the long history of primarily male engineers. This restrictive definition of what an engineer is can make it harder for many students (especially women and students of color) who are interested in engineering to identify with engineering.

Identity development depends on two factors: (a) how a person identifies himself or herself, and (b) how others identify them in different contexts[25]. Traditional approaches for helping students from underrepresented groups persist and succeed in engineering, such as Women and Minorities in Engineering Programs, focus on the underrepresented students themselves. These efforts are aimed at helping students adapt to a culture that is different from them, and in some situations, they may help underrepresented students recognize themselves as engineers. But identity is two-sided, where peers/colleagues must identify students as engineers[25]. Programs focused on supporting the underrepresented students do nothing to encourage others to view underrepresented students as engineers. Unfortunately, these interventions may unintentionally affirm "the idea that these students are fundamentally (and irreconcilably) different from 'main-stream' youth, and different in ways that are inevitably linked to pathology" (p. 506)[12].

There are three main processes that must occur to develop a professional identity[7, 13]. The first is *doing* – participating in the activities of the profession, learning the necessary skills and knowledge, and developing an affinity for professional activities. Stevens et al.[25] refer to this as acquiring accountable disciplinary knowledge. The second process is *interacting* - developing a social network with others in the profession. Identities are formed as we position or identify ourselves in a group and are identified or positioned by others[25]. The third process is *sensemaking*. When identity is considered as a narrative, this sensemaking is a story we tell ourselves about who we are and how we fit. This part of professional identity development is a process of negotiation between the roles and expectations placed on a profession by society, and the individual who enters the negotiation with their own abilities and desires[7]. This process of negotiation can be made more difficult, depending upon desired profession and existing identity. Du[5] points out that women students need to negotiate their identity as a woman with their identity as an engineer and these two identities can conflict. This negotiation is not something that most male students need to navigate. In a similar vein, Eccles and Barber[6] discussed how students of color who persisted in STEM programs negotiated the university landscape by identifying strongly as scientists and engineers, but dismissing their racial and ethnic backgrounds. In contrast, Franco-Zamudio[10] showed that a high number of graduate students who integrated their academic and personal/social identities by joining organizations such as Women in Engineering Society or Society of Hispanic Professional Engineers, demonstrated success in graduate school. This speaks to the importance of delivering educational opportunities for students to identify in ways that honor their professional and personal backgrounds.

Engineering schools and departments play a very important but often implicit role in the development of an engineering identity by students. By giving deliberate attention to the engineering identity development of our students we can help participate in these three processes in ways that result in the more inclusive attitudes and practices that are needed in modern engineering. We plan to shape our students' perceptions of engineers and engineering by showing them that in order to **do** their work engineers must learn a variety of skills. This shows beginning engineers that technical knowledge alone is not enough to design high quality solutions. We want to teach our students how to **interact** with each other in ways that recognize the engineer in each student and value the advantages diversity can bring to engineered solutions. By facilitating inclusive engineering practices and inclusive engineering identities, we hope to aid the **sensemaking** of all students. In their sensemaking process, underrepresented students should not feel that their personal and desired professional identities are at odds. At the same time, as students from dominant populations experience their sensemaking processes, they should recognize that modern engineering involves the ability to lead teams and recognize how all kinds of diversity contribute to innovative problem-solving. When sensemaking activities position demographic and intellectual diversity as valuable components of robust engineering practice, then the possibility increases for students from both underrepresented and dominant populations to identify themselves and their peers as engineers.

Trede, Macklin, & Bridges[26] offer three criteria for developing classroom activities so students can participate in engineering practices, develop engineering identities, and integrate the value of all kinds of diversity in engineering. First, professors should teach the knowledge, skills, ways of being, and values of engineers to exemplify **similarities among engineers**. Second, professors should teach how engineers can collaborate with non-engineers by exposing students to the unique, and important, value that other professions bring when identifying and solving problems; this demonstrates **differences from non-engineers**. Third, professors should cultivate a sense of belonging—**identification with engineering**—so students identify themselves and their peers as engineers, regardless of their backgrounds. These factors constitute important elements toward developing inclusive engineering identities and appreciation for diversity, wherein professors are responsible for designing curricula so students not only learn technical skills and engineering content, but also learn the value of engineering to society and the value that all students bring to bear on the engineering profession.

This paper reports on the first year of a multi-year project to develop, implement, and study outcomes from the curriculum to promote development of inclusive engineering identities. To develop our experimental curricula of inclusive engineering practices, we draw on this literature review as well as survey data collected from the baseline year of this research project. The following section reports on baseline findings from students in two first-year engineering courses that did not include diversity or identity specific curriculum.

Baseline Survey

To assess the impact of the inclusive engineering identities curriculum, a quasi-experimental research design was adopted. Data collection took place at a large public university with a student body comprised of 17% underrepresented minorities, 51% women, and 7% international students. The College of Engineering at the university is comprised of 11% underrepresented minorities, 23% women, and 16% international students. When comparing the percentage of minorities and women between the institution and the College of Engineering, it is evident that minorities and women are underrepresented populations.

During the fall of 2014, students who had registered for two existing first-year courses were surveyed at multiple times during the semester. Since these students did not receive explicit exposure to issues of diversity and engineering identity, their survey data constitutes the comparison group. These data provide an initial snapshot of student perceptions regarding diversity and identity and will serve as a basis for comparison in future years when the curriculum is implemented. In this paper, we highlight differences in initial levels and in trajectories for underrepresented students and their counterparts on appreciation of diversity and identification with engineering. The final survey of the semester also included questions about the effect of existing course activities on student interest in engineering and self-efficacy regarding engineering. These findings helped to identify aspects of the existing curriculum that were candidates for modification and aspects that should stay unchanged.

Participants

Freshman students from two first-year engineering courses were recruited to take part in data collection during the Fall 2014 semester. The first course is titled Grand Challenges in Engineering and is an introductory course for students who have declared an interest in engineering but have not yet chosen a specific discipline. This course is taught with a very flexible style. During each offering the students and instructors choose the societal challenges they want the course to address, using the National Academy of Engineering Grand Challenges as a source for inspiration and brainstorming ideas (www.engineeringchallenges.org). Emphasis is placed on how engineers can contribute to defining as well as solving problems, and class sessions are often based in discussion. Students are introduced to the different disciplines within engineering through the context of the selected challenges.

The second course is Introduction to Civil and Environmental Engineering. This course is part of a two-semester sequence introducing students to the various sub-disciplines in civil engineering. During the fall semester the course focuses on hydrology, hydraulics, and environmental engineering, and students work in groups to design a storm water retention basin for the university campus. The class includes a lab where students learn about surveying and Microsoft Excel; lab activities contribute to the semester-long design project.

On average, 90 engineering students completed a survey five times throughout a semester to provide information about how strongly they identified as engineers (identity) and their appreciation of diversity in engineering (diversity), see Table 1. Approximately one-third of the participants on any one survey were female, and approximately one-tenth of the participants were underrepresented minorities (URM).

Procedures

The research team visited these two courses on the first day of class near the end of the lecture period. Students were presented with the research project and asked to complete a consent form if they were willing to participate. Consent forms were collected during the first week of the semester. Consenting students were then contacted via email and asked to complete an online survey five times during the semester. The surveys were sent during weeks two, five, eight, twelve and fifteen of the 15-week semester.

Measures

The students participated in five online surveys. The first and last surveys were the complete scales, and the three intermediate surveys contained shortened versions of each of the scales. For the shortened scales, we retained the items that had the highest squared multiple correlation on the first survey. All analyses reported here used the means of the shortened scales for all time points. All surveys were administered approximately three weeks apart. The first survey was administered during the second week of the semester (*time*=0). The final survey was administered in the last week before final exams (*time*=4).

Identity. To assess changes in student identity, we modified the *Science Identity* survey[4, 9] to reflect engineering instead of scientists. The shortened scale included four items ($\alpha_{\text{time } 5} = .92$), such as, “In general, being an engineer is an important part of my self-image.” All questions contained Likert items on a scale of 1 (strongly disagree) to 7 (strongly agree).

Diversity. To assess appreciation of diversity, we used the *Appreciation of Cultural and Ethnic Diversity* by Price, Williams, Simpson, Jastrzab, & Markovitz[22]. The shortened scale included three items ($\alpha_{\text{time 5}}$ = .89), such as, “Working with teams of people from diverse backgrounds is stimulating.” All questions contained Likert items on a scale of 1 (strongly disagree) to 7 (strongly agree).

Course Activities. Students were asked to rank each of the activities included in the course as to how the activities increased their confidence and interest in engineering. Students responded to a list that was specific to the civil engineering course or grand challenges course. Students rated class activities using a Likert scale ranging from 1 (definitely decreased my confidence) to 7 (definitely increased my confidence) and from 1 (definitely decreased my interest) to 7 (definitely increased my interest).

Variables

Sex was a self-report measure that was collected at time 0 and time 4. We coded the student as either male (*female*=0) or female (*female*=1). Underrepresented minority status (*URM*=1) was determined by identifying as at least one of the following: (a) Hispanic or Latino ethnic group, (b) American Indian or Alaskan Native race, (c) Black or African American race, or (d) Native Hawaiian or Other Pacific Islander race. Students who did not identify as one of the above were coded non-URM (*URM*=0).

Plan of Analysis for Identity and Diversity Data

First, we present the data for identity and diversity. The repeated measures for identity and diversity were analyzed using HLM v. 7[23]. Repeated measures (level-1) were nested within students (level-2). By clustering the data within students, we modeled individual trajectories (level-1), and we were able to identify which person-level variables (i.e., sex, URM) predicted where students started out and how students changed across time. After determining how much variability there was to explain between students (proportion of variability at level-2), we selected which type of trajectory best fit the level-1 data: no growth, linear growth (e.g., steady growth), quadratic growth (e.g., instantaneous initial growth followed by decline), or cubic growth (e.g., initial growth followed by both a decline and increase). The model with the lowest Bayesian Information Criterion (BIC) was selected to be the best fitting model[14]. Next, we determined the best fitting level-2 model. For both identity and diversity, we added sex and underrepresented minority (URM) as predictors of the intercept and slope parameters. Because there were so few URM students ($n \leq 10$ at each observation), we did not test for an interaction between gender and URM. For the final identity and diversity models, we retained and reported all gender and URM predictors that were statistically significant.

Results for Identity and Diversity Data

The descriptive statistics for identity and diversity at each time point are provided in Table 1. At each time point, females reported slightly stronger identification as engineers than males and a consistently higher appreciation for diversity, see Table 2. URM consistently reported a lower overall sense of identity and a similar appreciation of diversity than non-underrepresented minorities, see Table 3.

Growth Model for Identity. First, we fit a model of identity with no predictors. This null model indicated that approximately 44% of the variability in identity was between students, which also indicated that approximately 56% of the variability existed within individual student trajectories. Next, we fit growth models to determine which type of growth model best fit the data. The quadratic growth model provided the best fit to the data (BIC=1093.95[1]). Of note, the linear and quadratic growth terms for the identity model were not statistically significant; however, the random effects were. This indicated that while the overall growth was negligible there was a statistically significant variability to be explained in both how student identities initially changed and how that accelerated or slowed across time. Thus, we added sex and URM as predictors of these trajectories. In all models, sex and URM status did not statistically significantly predict where students started (intercept, β_{00}), their instantaneous growth (linear growth, β_{10}), or acceleration or deceleration (quadratic growth, β_{20}). The results for the final growth model for identity are provided in Table 4.

Growth Model for Diversity. First, we fit a model for diversity that included no predictors. The null models indicated that approximately 37% of the variability in diversity was between students, which also indicated that 63% of the variability in diversity lay within individual student trajectories. Next, we fit competing growth models to the data to determine which type of trajectory best fit the data. Like the identity model, the quadratic growth model provided the best fit to the data (BIC=1022.78). Finally, we added sex and URM in separate models as predictors of the intercept, linear growth, and quadratic growth. Only sex was a statistically significant predictor of the intercept and was retained in the final model (see Table 4). Thus, females began with a higher appreciation for diversity than their male classmates. Appreciation for diversity among both females and males initially declined but by the end of the semester had risen back to levels almost commensurate with the start of the semester (see Figure 1).

Table 1
Descriptive statistics by time for identity and diversity

	Time 1		Time 2		Time 3		Time 4		Time 5	
	n	M(*SD*)	*n*	M(*SD*)	*n*	M(*SD*)	*n*	M(*SD*)	*n*	M(*SD*)
Identity	95	4.55 (*0.79*)	94	4.69 (*1.25*)	89	4.63 (*1.39*)	92	4.73 (*1.56*)	84	4.53 (*0.98*)
Diversity	95	5.87 (*0.87*)	94	5.53 (*0.84*)	89	5.472 (*1.05*)	91	5.73 (*0.90*)	84	5.69 (*0.88*)

[1] Technically, the BIC for the cubic model was 0.31 smaller (BIC_{cubic}=1093.64). However, we chose the more parsimonious quadratic model because the change in the BIC was extremely small, and none of the fixed effects for the growth terms were statistically significant in either model.

Table 2

Descriptive statistics by time for identity and diversity by sex

	Time 1		Time 2		Time 3		Time 4		Time 5	
	n	M (*SD*)	*n*	M (*SD*)	*n*	M (*SD*)	*n*	M (*SD*)	*n*	M (*SD*)
Identity										
male	58	4.48 (*0.87*)	56	4.57 (*1.29*)	51	4.49 (*1.49*)	55	4.71 (*1.64*)	51	4.47 (*0.94*)
female	37	4.66 (*0.65*)	37	4.85 (*1.18*)	36	4.82 (*1.27*)	37	4.76 (*1.47*)	33	4.61 (*1.06*)
Diversity										
male	58	5.64 (*0.91*)	56	5.40 (*0.79*)	51	5.20 (*1.11*)	54	5.57 (*0.94*)	51	5.52 (*0.91*)
female	37	6.22 (*0.70*)	37	5.73 (*0.89*)	36	5.81 (*0.85*)	37	5.96 (*0.81*)	33	5.96 (*0.75*)

Table 3

Descriptive statistics by time for identity and diversity by URM status

	Time 1		Time 2		Time 3		Time 4		Time 5	
	n	M (*SD*)	*n*	M (*SD*)	*n*	M (*SD*)	*n*	M (*SD*)	*n*	M (*SD*)
Identity										
non-URM	82	4.60 (*0.77*)	70	4.67 (*1.28*)	66	4.71 (*1.43*)	66	4.76 (*1.52*)	66	4.53 (*0.99*)
URM	9	4.26 (*0.70*)	8	4.19 (*1.50*)	10	4.10 (*1.59*)	10	4.23 *(2.03*)	10	4.43 (*1.25*)
Diversity										
non-URM	82	5.91 (*0.86*)	70	5.54 (*0.87*)	66	5.51 (*0.96*)	65	5.71 (*0.85*)	66	5.73 (*0.83*)
URM	9	5.93 (*0.66*)	8	5.50 (*0.78*)	10	5.53 (*0.86*)	10	5.87 (*1.24*)	10	5.70 (*0.92*)

Table 4

Fixed and random effect estimates for the multilevel models for identity and diversity

	Identity	Diversity
	Coefficient (SE)	Coefficient (SE)
Intercept, β_{00}	4.61 (*0.08*)***	5.70 (*0.10*)***
Female, β_{01}	---	0.41 (*0.14*)**
Linear, β_{10}	0.14 (*0.10*)	-0.27 (*0.08*)**
Quadratic, β_{20}	-0.04 (*0.02*)	0.06 (*0.02*) **
Random Effects	Variance components	
Level one error, σ_2	0.27	0.48
Intercept, τ_{00}	0.37***	0.66***
Linear Growth, τ_{11}	0.66***	0.35***
Quadratic Growth, τ_{22}	0.03***	0.02***

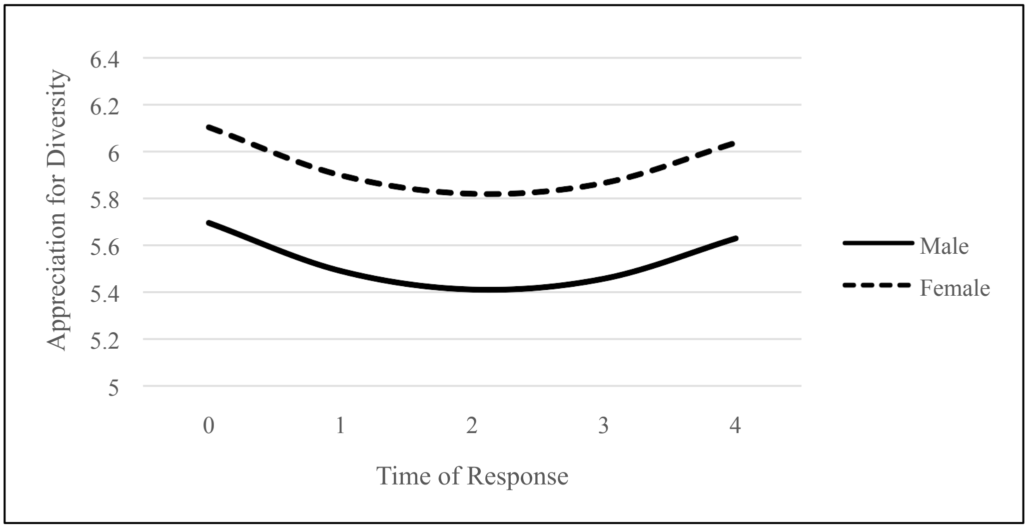

Figure 1. The model implied trajectories in appreciation for diversity for males and females.

In summary, student identity overall remained stable throughout the semester, but there was a lot of variability in engineering identity between students; however, sex and URM status did not explain this variability. Further, at the beginning of the semester, females indicated a higher appreciation for diversity than males. While the difference in appreciation for diversity between males and females remained constant throughout the semester, both males and females experienced a drop in appreciation for diversity in the middle of the semester. However, on average, all students had returned to their original levels of appreciation for diversity by the end of the semester.

Results for Student Ranking of Class Activities

In addition to the diversity and engineering identity survey questions, students rated class activities to better understand what pedagogical practices fostered self-efficacy and engineering identity (see Tables 5-8).

Students in the grand challenges course indicated that the visit with Steve Swanson (NASA astronaut) was the most helpful course activity in developing student self-efficacy and interest. Students also suggested that discussions about engineering and interacting with professors was helpful in developing self-efficacy while discussion of engineering challenges helped to foster interest. Students in the civil engineering course indicated that learning practical skills helped to build student self-efficacy. Learning more about the engineering profession helped to foster interest in civil engineering.

These findings suggest that students preferred activities that allowed them to learn about real engineering in action and practice, whether that included hearing from professional engineers or learning tools to enhance engineering practices.

Table 5.
Descriptive statistics of activities that fostered self-efficacy among engineering open option freshmen.

	Mean	*SD*	Rank
Visit by Steve Swanson (NASA astronaut)	5.89	1.09	1
Discuss the engineering design process	5.74	1.13	2
Interactions with Professors	5.61	1.20	3

Table 6.
Descriptive statistics of activities that fostered interest in engineering among engineering open option freshmen.

ENGR Interest – Survey Items	Mean	*SD*	Rank
Visit by Steve Swanson (NASA astronaut)	5.89	1.09	1
Discuss NAE grand challenges in general	5.66	1.19	2
Space Exploration Grand Challenge	5.61	1.10	3

Table 7.
Descriptive statistics of activities that fostered self-efficacy among civil engineering and environmental engineering freshmen.

CIVE Self-Efficacy – Survey Items	Mean	*SD*	Rank
Learn about Microsoft Excel	5.67	1.16	1
Learn about surveying	5.63	1.32	2
Presentations from Professional Engineers	5.61	1.20	3

Table 8.
Descriptive statistics of activities that fostered interest in engineering among civil engineering and environmental engineering freshmen.

CIVE Interest – Survey Items	Mean	*SD*	Rank
Tunnel Construction Video	5.72	1.19	1
Lecture about what civil engineers do	5.59	1.11	2
Presentations from Professional Engineers	5.59	1.11	2

Proposed Experimental Activities

In this section, we propose six experimental activities to facilitate the growth of inclusive engineering identities: student trading cards, egalitarian social norms, panel of professional engineers, reflective writing assignments, examples of diversity benefiting engineering practice, and interactive theater sketch. We identified these activities based upon criteria for developing professional identities[25, 26], review of literature, and student feedback from the surveys. In selecting these activities we have sought to identify practices that are discrete activities that can be implemented without requiring significant re-working of the existing curriculum, are applicable to the full range of engineering disciplines, and demand relatively low time commitment from the engineering faculty instructors. We believe these characteristics are important to help increase transferability of the intervention to other classes, universities, and disciplines outside of engineering. Also, these easily portable activities can support the sustainability of the intervention once implemented. We recognize that transferring activities across different sites requires a negotiation between effort, replicability, and impacts. For example, activities requiring less effort may be easier to replicate, yet produce marginal impacts; on the other hand, activities requiring more effort may be more difficult to replicate, yet produce potentially stronger impacts. By implementing experimental activities that require a combination of moderately easy effort and more intensive effort, we aim to create larger impacts on the development of inclusive engineering identities among freshmen participants. The following activities are listed in order of perceived expenditure of effort, from least to most.

Student trading cards. Barker, O'Neill, & Kazim[2] suggest printing trading cards of students that include their pictures and names. At the beginning of each period, the professor will shuffle the card deck. Whenever s/he poses a question to the class, the professor will pull a card from the shuffled stack and call on the student who appears on the card. This particular practice not only engages students, but creates an expectation that all students bring important perspectives that the professor values. We will include this activity as an example of creating access to **doing** engineering[25] and an implicit form of **sensemaking** where students make meaning of how their perspectives and ideas fit with the engineering class.

Egalitarian social norms. Bennett and Sekaquaptewa[3] examined whether attitudes of male students toward diversity in engineering shifted after hearing egalitarian social norms from senior White male faculty members. The message of egalitarian social norms integrated three components: (a) how long the faculty member worked in the college; (b) the high rank of the faculty member in the college; and (c) norms about how engineers and engineering students normally behave or should behave. Some examples of these norms included the following: "Students here understand the value of learning alongside students who are different from themselves" or "Once a student made a racist comment during lecture and the rest of the class groaned; it was hard for that student to find a study partner after that" or "I've seen students here say let's take turns at being the group note-taker' rather than constantly assigning one person to take notes" (p. 348)[3]. Results from this study suggest that delivering a message about egalitarian social norms at the beginning of the semester has strong potential to cultivate an inclusive learning environment and an appreciation for diversity in colleges of engineering. We will incorporate this activity as an example of **doing**[25] engineering and understanding **similarities among engineers**[26].

Panel of professional engineers. As discussed in the findings section, students appreciated opportunities to understand what real engineering practice looks like. Subsequently, we will draw on our alumni network to arrange a panel of professional engineers from multiple disciplines or sub-disciplines representing both identity diversity and intellectual diversity to talk about themselves: what skills they bring to engineering, their personality traits, and their backgrounds. Additionally, we will ask the panel to discuss their experiences of working on teams with engineers and non-engineers and focus on how diversity contributed to stronger engineering practice. Next, we will ask the panel to talk about the skills described in the "Engineer of 2020" reports[17, 18] and how the panel has witnessed these skills in action. Finally, students will have the opportunity to ask questions. We will integrate this panel as an example of **interacting** with engineers[25], **similarities among engineers**[26], **differences from non-engineers**[26], and **identification with engineering**[26].

Reflective writing assignments. Reflective writing has been shown to help students learn course content, for example, by helping them identify their own confusion so they can resolve it[1]. But writing has the potential to help students learn and succeed in other ways. For example, having students specifically write about their personal values and why those values were important to them for about 15 minutes two times near the beginning of the semester was shown to reduce the gender gap in physics performance on exam scores and eliminate the gap on a physics concept inventory[16]. This psychological intervention was easy to conduct and produced measurable gains in student performance by helping to buffer students against stereotype threat. Reflective writing also aligns well with the sensemaking activities students need as part of identity development. Eliot and Turns[7] describe how professional portfolios help students make meaning of their identities as engineers, and specifically pointed to students' need for opportunities to engage with the internal frame of reference: "making sense of themselves as engineers while also building a personal vision of the engineering profession" (p. 649).

We plan up to three short reflective writing assignments. The first one will occur after the panel of professional engineers, and students will be asked to write a paper identifying the skills, personality traits, values and prior experiences they can contribute to engineering. In effect, this assignment asks students to recognize the ways they might already identify with engineering. The second assignment will ask students to reflect on the engineering skills they want to strengthen and how they might benefit from working with peers who have those skills. This writing assignment will ask students to recognize the engineering skills in their classmates and will hopefully help students recognize their perceived weaknesses as opportunities for growth rather than barriers to persisting in engineering. The final assignment will occur when students start working in teams. We will prompt them to talk about how they can be a strong contributor to their team and how they can help ensure that their team benefits from the diversity in ideas inherent in the team members. We will use this activity as an example of **sensemaking**[25].

Examples of diversity benefiting engineering practice. We want to promote the understanding in students that diversity is deeply relevant to engineering. Freshman engineers are likely to hold the common societal perceptions about engineering as a field dominated by math, science and technology. Efforts to promote an appreciation of diversity may be rejected unless we can ensure that students see how diverse perspectives directly lead to engineering solutions. We anticipate an intervention of this type being more directly tied to a particular engineering discipline and have identified three possible ways to introduce the relevance of diversity to engineering that vary in their level of difficulty. The first method is to find examples in the history of engineering where the presence of a diverse team or at least the introduction of diverse perspectives led to engineering breakthroughs, and talk through these examples as case studies of successful engineering. The second method is to pose a simulated problem and ask students to role-play various stakeholders. A hot topic on campus might serve as an engaging issue for students to consider, and we hope that by having students specifically consider the views of different stakeholders they may recognize the value of engineers who can relate to those stakeholders. The third method draws on the common first-year design experience. A carefully constructed design assignment could help students see the role of different perspectives, opinions, and experiences on the ultimate design solution. All of these methods could be considered examples of **doing** engineering**,** or at least observing how other engineers **do** engineering[25].

Interactive theater sketch. Finelli and Kendall-Brown[27] documented the effects of an interactive theater sketch on engineering students' ideas about the importance of teamwork and diversity in engineering. The sketch involves an experienced facilitator and a theater troupe of actors and actresses. The sketch begins with a facilitator who poses questions to students about their experiences with working on teams and difficulties they encounter. After this brief discussion, the theater troupe enacts a challenging team scenario of engineering students attempting to work together. During this activity, the actors and actresses manifest common difficulties on engineering teams, including gender dynamics, miscommunications, misunderstandings, and other frustrations that emerge from teamwork. Afterwards, the facilitator leads a discussion with the students, including a Q&A session between students and the actors and actresses in character. The interactive theater sketch ends with an invitation for the audience to brainstorm strategies to improve interactions within teams. The actors/actresses then re-enact their scenario, but incorporate the suggested strategies to improve their synergy. Findings suggest that the interactive theater sketch can help students work on teams more productively and demonstrate increasing value for diversity. Out of all the proposed activities, we recognize this will require the most effort. To help with ease of transferability and costs, we will explore the possibility of collaborating with theater students who can receive course credit or extra credit for participating in the sketch. We will also consider hiring an experienced facilitator to lead a productive discussion about the interactive sketch. This activity is an example of **interacting with engineers**[25].

Conclusion

Diversity in engineering education is often framed as a problem with numbers. This is evident when legislators and educators lament that the number of women and people of color enrolled in engineering does not reflect the number of women and people of color in the overall United States population, or the numbers of students continue to plummet because they fall out of the leaky K-16 pipeline[21]. Framing the problem of diversity as a matter of numbers is problematic because it rarely interrogates how classroom and institutional climate contribute to the student experience in engineering[24]. By incorporating a framework that strengthens classroom practices for all first-year engineering students, we shift the problem of retention and learning from students and place responsibility upon institutions and educators who do have the agency to kindle inclusive engineering identities. Through our analyses and experimental curricula, our goal is to help all students not only identify as engineers, but to also appreciate, value, and ultimately seek out diversity in engineering. A deeper understanding of how to develop inclusive engineering practices can help institutions and educators implement interventions that are responsive to the needs, resilience, and potential of students in ways that support retention and learning in engineering.

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