Building Inclusive Engineering Identities: Implications for Changing Engineering Culture

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ABSTRACT

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Ongoing efforts to broaden the participation of women and people of color in engineering degree programs and careers have had limited success. This paper describes a different approach to broadening participation that seeks to work with all students and develop inclusive engineering identities. Researchers worked with the instructors of two first-year engineering courses to integrate curriculum activities designed to promote the formation of engineering identities and build an appreciation for how diversity and inclusion strengthen engineering practice. Multilevel modeling results indicated positive effects of the intervention on appreciation for diversity but no effects on engineering identity, and qualitative results indicated students learned the most about diversity not through one of the intervention activities, but through team projects in the courses. We also describe lessons learned in how to teach engineering students about diversity in ways that are relevant to engineering.

Keywords: diversity, inclusion, equity, engineering education, culture change, broadening participation

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Introduction

The lack of diversity in engineering degree programs and in the profession, is a long-standing concern (Lichtenstein et. al. 2014). After many years of small or nonexistent gains in the proportion of engineering graduates from historically underrepresented groups including women and students of color in the United States (U.S. National Science Foundation 2015), there is a growing urgency in efforts to broaden participation in engineering and other STEM disciplines. Traditionally, efforts to encourage and support students from underrepresented populations in engineering have focused on specific subgroups and occurred in co-curricular settings, for example women and minorities in engineering programs. Despite these efforts, the percentages of underrepresented students graduating with engineering degrees have only slowly increased. While targeted programs may foster a supportive environment, they do not directly influence the culture of the college of engineering as a whole, and students may still face difficult or disparate environments in classroom settings where they interact with majority students (examples specific to the experience of women students include Felder et. al. 1995; Colbeck et.al. 2000; Meadows and Sekaquaptewa 2014; Seron et. al. 2016).

Increasing the participation and success of all students in engineering degree programs is critical to the future vitality of engineering in several different ways. For example, although there is disagreement about the adequacy of the current supply of STEM workers (PCAST 2012; Xue and Larson 2015), the demographics of the U.S. and European populations are shifting, and men of northern European and Asian descent, who have traditionally occupied most jobs in engineering, are becoming a smaller portion of younger segments of the population. Simply maintaining the current engineering workforce will become more difficult if faster growing segments of the population are not invited to participate and persist in engineering.

Broadening participation is also important due to the types of problems facing engineers. Page (2007) demonstrates how in certain situations a team of problem solvers with cognitively diverse approaches to a problem will outperform a team of the cognitively best problem solvers. One of the situations where diversity trumps sheer ability is in addressing very difficult problems; the complexity of modern engineering problems meets this criterion. While cognitive diversity and identity diversity are not the same, identity diversity often corresponds to differences in experience that can be related to cognitive differences. Finally, it is important to consider the role of engineers in society. The preamble of the U.S. National Society of Professional Engineers states, "Engineering has a direct and vital impact on the quality of life for all people" (NSPE 2007). Since engineering designs affect all portions of the population, a more diverse and representative engineering workforce will better live up to the ideals and ethical obligations of engineering.

To supplement diversity programs and make continued gains in broadening participation, we recognize the importance of changing engineering culture and regard engineering classrooms as one place to start. In this paper, we describe an ongoing effort to build an inclusive climate in a college of engineering and to develop inclusive engineering identities among our engineering students. We define inclusive engineers as engineers who:

- Possess engineering knowledge and the ability to apply it in problem-solving practice
- Recognize the variety of skills and abilities needed in engineering
- Identify and disrupt stereotypes about who can be an engineer

- Approach teamwork with an inclusive attitude that values and facilitates diversity of thoughts and identities
- Embrace the social responsibility of engineering to serve ALL populations
- Acknowledge the potential impact of implicit and explicit biases as they work in teams and with stakeholders
- Appreciate the need to participate in life-long learning practices related to engineering diversity, inclusion, and equity

This paper focuses on curriculum change in first-year engineering courses as a way to develop inclusive engineering identities. Our theoretical framework is based in professional identity development, and our goal is for our students to build inclusive engineering identities so they become inclusive engineers. We first explain the use of professional identity development and the concepts of diversity, inclusion and equity in our theoretical framework. A literature review of previous efforts to teach STEM students about diversity, which served as an important foundation for our activities, is then provided. The paper then describes our research design to assess the impact of the experimental curriculum implemented in the first-year courses to date and our research findings as to the effectiveness of these activities. We conclude with our lessons learned and plans for future curriculum change based on our preliminary findings.

This article is a revised version of manuscripts published in American Society for Engineering Education National Conference proceedings (Paguyo et al. 2015 and Atadero et al. 2016). Significant new theoretical and empirical contributions to this manuscript include the following: an expanded definition of how we conceptualize Inclusive Engineering Identities, inferential statistical analyses of original baseline and intervention data, and the inclusion of qualitative results to provide greater depth in findings about how students experienced the intervention activities.

Theoretical Framework

Professional identity development is a framework that has been used by other researchers interested in the development of students' engineering identities. For example, Eliot and Turns (2011) define professional identity as "personal identification with the duties, responsibilities, and knowledge associated with a professional role" (631), and they found that creating professional portfolios can help engineering students with the sense-making process involved in establishing a professional identity. Stevens et. al. (2008) proposed that students become engineers by going through changes along three different dimensions: disciplinary knowledge, identification, and navigation, and that these dimensions can be used to understand how the experiences of individual students differ. And Chachra et. al. (2008) and Du (2006) investigated the interaction of gender and engineering identity development, finding that men and women students might be identifying with different aspects of the engineering profession (Chachra et.al. 2008) or that the historic association of engineering with masculine traits can make it harder for women students to identify as engineers (Du 2006).

Development of a professional identity may be described in terms of three overlapping processes (Eliot and Turns 2011; Stevens et. al. 2008; Trede, Macklin and Bridges 2012): 1) forming a definition or understanding of the profession, which can often be achieved by doing engineering tasks and learning necessary knowledge; 2) identifying oneself and being identified by others as an engineer - i.e. the development of a social identity; and 3) reconciling the new professional identity with other existing identities through sensemaking. These three processes occur in engineering programs, but the engineering curriculum or faculty do not always intentionally facilitate educational opportunities for students to engage in these processes in and out of the classroom.

A more intentional approach to building engineering identities provides a way to educate engineering students so they learn how to become inclusive engineers, and this framework provides clear guidance to our study. First, the framework of engineering identity development provides cues about teaching diversity and inclusion in ways that are directly relevant to students' future engineering careers. We want to tie the curriculum directly to engineering so that students are not tempted to see the content as "other" and thus less important. Second, our intention is to help all students form an inclusive definition of engineering by broadening their perception about who can be an engineer. This broader perception should help students from underrepresented groups in engineering more easily see themselves as engineers and to understand that their other social identities (e.g. gender, race, ethnicity) can help them be a better engineer and do not need to be pushed into the background. Third, we recognize that identities are social and the identities we hold need to be affirmed by others. Because we seek to broaden the definition of engineering for all students we also hope to open opportunities for majority group engineering students to recognize their underrepresented peers as engineers. And finally, we have made the choice to use identity development as our theoretical framework because we want students' attitudinal changes to be long lasting. Our goal is not merely to change the climate of first-year courses. We want students impacted by our curriculum to carry their inclusive approaches to engineering with them through their degree program and into professional practice. We expect that building an appreciation for diversity into students' engineering identities will generate this desired long-term effect.

Central to the framework of inclusive identities are our understandings of diversity, inclusion, and equity. The term diversity has become prosaic in educational scholarship and practice, reflecting a wide spectrum of meanings and intentions (Gutiérrez, Paguyo, and Mendoza 2012). Too often, however, diversity is used to label people of color. In our framework, we draw on a multidimensional perspective of diversity that values *identity diversity*, such as gender, race, sexual orientation, ability, age, geography, language, socioeconomic status (to name a few) as well as *cognitive diversity*, such as approaches to depicting phenomena and solving problems (Page 2007).

For diversity to thrive, it is incumbent upon institutions and educators to purposefully organize learning ecologies around inclusion. As such, we refer to definitions from Association of American Colleges and Universities (AACU) to frame our study. More specifically, the AACU (2016) defines *inclusion* as the

> active, intentional, and ongoing engagement with diversity—in the curriculum, in the co-curriculum, and in communities (intellectual, social, cultural, geographical) with which individuals might connect—in ways that increase awareness, content knowledge, cognitive sophistication, and empathic understanding of the complex ways individuals interact within systems and institutions (para. 6).

Finally, we intertwine the framework of identity, diversity, and inclusion with the construct of *equity*. Scholars have conceptualized equity as perspectives and behaviors that recognize how the strengths, vibrancy, and brilliance of students are co-constructed from their experiences, homes, communities, and cultural practices (Mendoza, Gutiérrez, and Kirshner in press; Shirin, Hooper and Escude 2016). When discussions of diversity and inclusion emerge, scholars and educators tend to appropriate deficit-oriented perspectives that position students, particularly underrepresented students, as problems that need fixing or populations that are "academically and culturally deficient" (Sólorzano, Villalpando, and Oseguera 2005, 286). On the other hand, equity-oriented perspectives position students as experts with deep knowledge and great potential for learning, leading, and changing the world. In this way, particularly for engineering education research and practice, we can see ALL students as engineers in the making.

Review of Relevant Literature

There is a significant body of literature describing ways for faculty to create more inclusive classrooms. Some suggested inclusive pedagogical practices can be considered just plain good teaching, such as involving students in active learning (Ruggs & Hebl, 2012), organizing opportunities for students to work collaboratively (Busch-Vishniac & Jarosz, 2004), encouraging content mastery rather than performance comparisons, and advertising student support services to all students (Brown et al., 2009). However, there are also several strategies that have been particularly noted for their benefits to women and underrepresented populations in engineering classrooms.

First, many students, and particularly women and students from underrepresented groups, want to see the societal benefit of engineering and the connection between engineering and society should be make explicit, not obscured behind technical content (Busch-Vishniac & Jarosz, 2004). Past engineering accomplishments by women and people of color should be highlighted in such a way that it is clear a woman or person of color completed the work, for example, by using the woman's first name or showing pictures of the individual (Busch-Vishniac & Jarosz, 2004). Role models can also be introduced by selecting faculty that represent diversity for particular courses. Furthermore, topics can be reframed in ways that are more attractive to women (Ruggs & Hebl, 2012). Second, faculty can carefully organize and provide scaffolding for group work activities. For example, Jigsaw classroom activities can be specifically designed to require input of all students (Ruggs & Hebl, 2012). Other ways to enhance group work include providing specific instructions on working in groups (Natishan et. al., 2000), carefully considering group formation so that underrepresented students are not isolated on teams (Brown et.al., 2009), and designing group assessments to value individual contributions (Haynes & Heilman, 2013). Third, instructors can consider what background knowledge or skills are helpful for students to complete an assignment. Some knowledge may not be necessary to be successful in a particular major, but assignments requiring some background expertise can give students the wrong impression or put them at a disadvantage (Busch-Vishniac & Jarosz, 2004). A project that requires hands-on work, for example, could disadvantage many women and other students who did not grow up with a "tinkering" background (Du, 2006). Although these strategies are intended to help faculty welcome, value and affirm students in their classroom, they do very little to teach students in the class about how diversity and inclusion are relevant, valuable, and even essential to engineering.

To address the notion of inclusive engineering identities, we conducted a literature review to examine ways for students to learn how diversity strengthens engineering and to develop engineering identities. We used keywords of "diversity" and "STEM" and "engineering identity" to search articles in the *European Journal of Engineering Education, Journal of Engineering Education, Review of Educational Research, Educational Researcher,* and *Journal of Women and Minorities in Science and Engineering*. We used this search to capture a lay of the land as it relates to diversity and engineering identity, which are foundational to the professional identities framework we use as our theoretical ballast.

We recognize that the limited scope of the keyword search omitted articles such as the Schäfer (2006) study, which incorporated a diversity lecture in a required engineering course for students to learn about the challenges women may encounter in the engineering profession and strategies to help women navigate the workplace productively. In fact, within STEM education scholarship, the primary way for students to learn about diversity is through co-curricular or extra-curricular interventions that support students from historically underrepresented populations, such as the Society for Women Engineers and professional organizations that offer platforms for students to coalesce their racial and career identities (Tonso 2014). To clarify, while we believe in the transformative potential of interventions that support underrepresented populations, we aim to create a cultural shift that speaks to all students, particularly majority students. We took this approach because population-specific interventions, while helpful, also put the onus of change upon underrepresented students instead of all students. With this context in mind, our literature review serves to highlight specific research-supported interventions that we were able to adopt and adapt for this study.

Student Trading Cards is an activity inspired by Barker, O'Neill, and Kazim (2014). Instructors for each course receive a set of cards with a student's name on each card. During class discussion professors can use the cards to call on students. The intent of the trading cards is to signify that all students can make contributions and unique perspectives are valued. According to Barker and colleagues, equitable opportunities for each student to talk encouraged more extroverted students to listen more thoughtfully and supported introverted students to grow beyond their comfort zones. In fact, survey data from 2002 through 2014 suggests that students' interest in the course subject increased steadily over time, a boost that coincides with the practice of using *Student Trading Cards.*

The work of Bennett and Sekaquaptewa (2014) leverages social egalitarian norms to set the tone for how engineers ought to behave if they follow role models in a *Welcome Presentation from the Dean's Office*. In their study, a distinguished, White, male member of the college of engineering welcomed students to higher education and explained that engineers need effective communication skills to work with diverse disciplines and to address the needs of diverse global stakeholders. The end of the presentation explicitly addressed the ways that overtly biased actions can harm communication. When comparing the sample of 129 students who heard the welcome speech to students in the control condition, the students who heard from the speaker "had stronger intentions to speak out against racist behaviors" and "more positive attitudes toward diversity in engineering" (Bennett and Sekaquaptewa 2014 p. 343).

An *Interactive Theater Sketch* is described in an article by Finelli and Kendall-Brown (2009). A local theater troupe performed a scene that many engineering students experience in college. Given that team projects occur frequently in engineering curricula, the troupe of actors performed a sketch where a group struggled with working productively, and as part of this struggle, some gender bias emerged. The troupe then facilitated a productive dialogue where students critically reflected on and practiced how to mediate group conflicts. The University of Michigan documented that students who participated in the interactive theater sketch demonstrated statistically significant increases ($p < .001$) in their abilities to address common conflicts that emerge in team projects, particularly communicating, developing a plan of action, and creating team cohesion (Finelli and Kendall-Brown 2009).

The activities we found to teach about diversity and inclusion did not directly address professional identity development, which is the basis of our approach, thus we also looked for activities that would intertwine diversity knowledge and professional identity. Developing a professional identity requires students to understand what engineers do and to interact with engineers. Internships represent a powerful way for students to have this experience, but they generally occur later in the educational experience. In Malaysia, for example, Mohd-Yusof, Phang, Sadikin, Helmi, and Kamaruddin (2014) describe how internships are not available until after a student has completed his/her third year of study. To overcome this time barrier and encourage students to begin interacting with professional engineers, they developed an "Engineering Overview Assignment" that required their students to interview two engineers. Quotes from student journals indicated that the interviews were an effective way to help students see themselves in engineering roles. However, the class only enrolled 36 students, a considerably smaller sample than engineering enrollments at a larger university where having each student interview two engineers might overwhelm local engineers. Additionally, requiring only two interviews limits exposures to the broad spectrum of engineers who demonstrate diversity in their career paths, job tasks, and identities. To expose students to the heterogeneity of engineering professions, panels of diverse guest speakers can be offered to give students the chance to interact with diverse engineering professionals and help expand their concept of who can be an engineer (Ruggs & Hebl 2012).

To address the need for students to engage in sensemaking, a required part of their professional identity development, our search lead us to reflective writing Reflective writing can be a powerful learning tool in a variety of contexts, for example helping biology students identify conceptual misunderstandings (Balgopal & Montplaisir, 2011), helping medical students practice empathy (DasGupta & Charon, 2004) and improving first-year engineering students' quiz scores (Burrows, McNeill, Hubele, & Bellamy 2001). Since we aim to promote inclusive engineering identities, we were drawn to the work of Miyake et.al. (2010), in which students in an undergraduate physics course were asked to write statements affirming their values. When students write what their personal values are and why they find these values important for 15 minutes on two separate occasions near the beginning of the semester, gender gaps in performance on exams and physics concept inventories decrease (Miyake et al. 2010). This psychological intervention was easy to conduct and produced measurable gains in student performance by helping to buffer students against stereotype threat. We tailored the engineering interviews and reflective writings by inviting panels of engineers to speak and asking students to write reflections about the similarities they share with the panelists.

As mentioned at the beginning of this brief review of literature, few studies exist that examine long-term effects of STEM classroom interventions aimed to boost identity development and appreciation of diversity. In fact, the majority of opportunities for students to learn about diversity are located in non-STEM areas, particularly teacher preparation programs, social work, counseling, humanities, or extracurricular activities (Paguyo, 2014). Furthermore, as our framework suggests, we argue that engineering educators ought to teach students not only about diversity, but also about issues of inclusion and equity.

Research Design

In the current study, we sought to foster inclusive engineering identities in first-year students by developing and implementing a set of curriculum activities intended to build identification with a broader definition of the engineering profession and an appreciation for the contributions of diversity to engineering practice. In other words, we aimed for the experimental curricula to intentionally develop inclusive engineering identities among participants. The activities were implemented in two first year introductory courses, a civil and environmental engineering course and an open option engineering course. We collected baseline data in fall

2014 from students in both courses before we implemented any new activities. We developed two sets of intervention activities, each tailored to their respective courses. We then collected data from students who participated in the revised curriculum in fall 2015. We compared survey data and open student responses from students in 2014 and 2015 to identify what effect the revised activities had on student appreciation for diversity and engineering identity.

In our study, we seek to answer the following research questions:

1. Over the course of the semester, what effect did either set of interventions have on student appreciation for diversity?
2. Over the course of the semester, what effect did either set of interventions have on student engineering identity?
3. What aspects of the course or their first-semester experience do students identify as important to building their appreciation for diversity in engineering?
4. What aspects of the course or their first-semester experience do students identify as important to building their engineering identity?

We make use of quantitative analysis of student survey responses to answer research questions one and two, while research questions three and four are addressed through qualitative analysis of open-ended student responses.

Participants

In the comparison sections in fall 2014, the civil and environmental engineering course (CIVE) had 58 of 71 enrolled students consent to participate, and open option engineering (ENGR) had 61 of 72 students enrolled consent to participate. In the intervention year, the sections had larger enrollments, and 70 of 119 students enrolled in the civil and environmental engineering course and 66 of 146 students in ENGR consented to participate. Table 1 contains a breakdown of students by sex and underrepresented minority status. Because we were not able to experimentally assign students to the comparison or the intervention, we conducted chi-square difference tests to be certain there were no differences in the composition of the courses. Of the students enrolled, chi-square analyses indicated that there were no differences between the proportion of male students (CIVE: χ^2 [df = 1] = 0.08, r = .02, p = .78; ENGR: χ^2 [df = 1] = 0.08, r = .02, p = .78) and underrepresented students by intervention status for the two courses. (CIVE: χ^2 [df = 1] = 0.02, r = .01, p = .89; ENGR: χ^2 [df = 1] = 0.01, r = .01, p = .92).

Procedure

Context.

This study was conducted in two first year engineering courses. The first course (CIVE) is the anterior course in a two semester introductory series offered by the department of civil and environmental engineering. The series of courses is intended to introduce students to basic engineering tools (e.g. surveying, spreadsheet software) and to the different sub-disciplines within civil and environmental engineering. The course is organized around a guided design of a storm water retention pond for campus and emphasizes the fields of hydrology, hydraulics, and environmental engineering. The second course (ENGR) is for first-year students who have been accepted into the college of engineering but have not yet committed to majoring in a particular engineering discipline. The course is inspired by the U.S. National Academy of Engineering Grand Challenges for Engineering (http://www.engineeringchallenges.org/). The curriculum of this course is more flexible than in most engineering courses as the class gets to help choose which challenges are discussed each semester. For each challenge, the potential contributions of different engineering disciplines are discussed and the fact that nearly all challenges require contributions from multiple disciplines inside and outside engineering is emphasized. The course also uses the Engineers Without Borders Challenge (http://www.ewbchallenge.org/) to provide a group project to the students.

Experimental course interventions.

The experimental curriculum additions were developed considering a review of available literature as well as the existing structure of the two courses. For the sake of future transferability, we chose to emphasize activities that required relatively little initial knowledge on the part of students and instructors. We also looked to develop activities that could be carried out in a single class session and that would not require a course instructor to make substantial revisions to existing course content. Given the tight curriculum in many engineering programs and the common need to satisfy several different learning objectives in a single course, we chose to study the effect of small steps that professors can take to change an existing course to promote the development of inclusive engineering identities, rather than seeking to create an ideal course for introducing engineers to diversity, inclusion and equity.

Based upon the literature review we conducted, the following intervention activities were implemented:

1) student trading cards (Barker, O'Neill, and Kazim 2014);

2) welcome presentation by the dean (Bennett and Sekaquaptewa 2014);

3) panel of professional engineers, an adaptation of the Engineering Overview Assignment (Mohd-Yusof, Phang, Sadikin, Helmi, and Kamaruddin 2014). Our panel was purposely diverse with respect to race, gender, and age with questions focused on the importance of working in teams;

4) reflective writing assignments to foster sensemaking;

5) guest lecture on the nature of engineering intended to highlight the societal role of engineers; and

6) interactive theater sketch (Finelli and Kendall-Brown 2009).

For a more detailed description of the activities, including panel questions and reflection prompts please see Atadero, Paguyo, Rambo-Hernandez and Henderson (2016). The intervention activities were spread through the semester and were timed to fall between the five surveys given to students. Due to the different nature of the two courses in terms of content and instructor style, different activities were conducted in the two classes. Figure 1 shows the timing of the surveys and intervention activities in the open option engineering course, and Figure 2 shows the timing of the surveys and intervention activities in the civil and environmental engineering course (Atadero et.al. 2016).

Measures

Students participated in five online surveys during the comparison and intervention years. Because each of the scales contained multiple items and we did not want to fatigue the students, we chose to give all the items to the students only on the first and last survey. For the second, third, and fourth surveys we administered shortened versions of each of the scales, which had fewer items than the original scales. To select which items on each scale would be on the shortened versions, we retained the items that had the highest squared multiple correlation on the first survey completed during year one (Paguyo, Atadero, Rambo-Hernandez, and Francis 2015). The shortened scales were used for the analyses in this paper.

To assess changes in student identity, the *Science Identity* survey (Chemers et al. 2010; Estrada, Woodcock, Hernandez, and Shultz 2011) was modified to reflect engineers instead of scientists. The engineering identity measure contained four items in the shortened scale, such as, "In general, being an engineer is an important part of my self-image." Students responded on a scale from 1 (strongly disagree) to 7 (strongly agree). In year one, using the shortened scales, we obtained and alpha coefficient of .92 for the scale at time point 5, and in year two, we obtained an alpha coefficient of .92 at time point 5.

To assess changes in appreciation of diversity, we used the *Appreciation of Cultural and Ethnic Diversity* scale (Price, Williams, Simpson, Jastrzab, and Markovitz 2011). The appreciation of diversity measure contained three items in the shortened scale, such as, "Working with teams of people from diverse backgrounds is stimulating." Students responded on a scale from 1 (strongly disagree) to 7 (strongly agree). In year one, using the shortened scales, we obtained and alpha coefficient of .89 for the scale at time point 5, and in year two, we obtained an alpha coefficient of .90 at time point 5.

To address research questions three and four, in the qualitative portion of the survey, students responded to the following open-ended questions at the end of the semester: Which course activities increased your appreciation for diversity in engineering? Which course activities helped you identify as an engineer?

Data Analysis

Research questions 1 and 2

After examining the descriptive statistics, we analyzed the data in HLM v. 7 (Raudenbush and Bryk 2002) to account for the nested nature of the data, i.e., repeated measures (level-1) within students (level-2). Since independent samples t-tests indicated the two comparison classes did not differ on initial appreciation for diversity or engineering identity (appreciation for diversity: t (93) = .31, p = .76; engineering identity: t (93) = -0.04, p = .97), the two comparison sections were collapsed. However, because the two intervention classes had slightly different interventions (e.g., open option engineering had the theatre troupe while the civil and environmental engineering course did not, and the panels of professional engineers were not identical), we treated the interventions as two separate interventions. Additionally, to account for potential differences between sections and intervention status from the very beginning of the semester, we modeled only time points two through five after controlling for time one scores. Appreciation for diversity and engineering identity were modeled in two separate multilevel models. See appendix 1 for more detail.

To answer research questions one and two, we first established the shape of the trajectories of appreciation of diversity and engineering identity by comparing three ways to model the data: (a) a null model that assumed no change over the semester, (b) a model that assumed steady change over the course of the semester, and (c) a quadratic model that assumed some slowing or speeding up of change over the course of the semester. Next, we proceeded to identify whether the intervention had an effect on appreciation for diversity or engineering identity while accounting for sex and where students started. Specifically, we entered the explanatory factors in three blocks: (a) main effects of the construct at time 1, sex, and intervention, (b) interactions of sex and interventions, and (c) interactions of intervention and initial score. For each block of variables, we compared the more complex model to the more parsimonious model using a chi-square difference test. To estimate the effect sizes, we used the Raudenbush and Lui (2001) standardized effect size formula for statistically significant parameter estimates.

Research questions 3 and 4

To analyze responses to these survey items, the research team leveraged qualitative methods. First, the qualitative researcher coded responses through deductive means to analyze whether any themes from existing scholarship were located in the data (Erickson 2004). Second, responses were coded through inductive means to identify new themes that emerged from the data itself that were not yet documented in scholarship (Sipe and Ghiso 2004). Third, coded responses were reviewed again to ensure consistency in the application of deductive and inductive coding structures. This iterative approach provided enough organization and elasticity for the qualitative researcher to determine how the survey data fit with findings from extant literature.

Results

Descriptive Statistics

Appreciation for Diversity.

The descriptive statistics for diversity at each time point and year are provided in Table 2. During year one and two, females reported an initially higher appreciation for diversity than males that persisted across the semester. However, there was some variability in appreciation of diversity between sections and sex across time, particularly at times two and three. Appreciation for diversity seemed to drop and was generally followed by an increase at the end of the semester.

Engineering Identity.

The descriptive statistics for identity at each time point and year are provided in Table 3. For the comparison sections, females reported slightly stronger identification as engineers than males. There was some variability in engineering identity most notably between females across time. In the intervention sections, females enrolled in open option engineering reported the highest identification as engineers with a slight increase over time. Females enrolled in civil and environmental engineering were slightly lower in their reported identity when compared to males at all time points except the fourth. Males and females both demonstrated variability in their engineering identity across time.

Multilevel Modeling Results

Research question 1

To answer research question 1, we first determined the shape of the trajectory of appreciation for diversity across the semester (Table 4). Results indicated appreciation for diversity was relatively flat across the semester (β_{10}. = .04, p = .60, β_{20}. = .00, p = .85). However, there was potential variability to be explained in these trajectories (τ_{11} = .13, p = .09, τ_{22} = .01, p = .06). Therefore, we included linear and quadratic terms for time to model this potential variability in the repeated measures of appreciation for diversity.

After controlling for initial appreciation for diversity, both of the intervention sections demonstrated statistically significantly higher appreciation for diversity than the comparison classes at time 2 (see Table 4, β_{04} = 0.32, p =.007; β_{05} = 0.33, p = .008). The effect size for both interventions were similar (δ = 0.43 for civil and environmental engineering, δ = 0.44 for open option engineering). The students in the civil and environmental engineering intervention class demonstrated a drop in their appreciation for diversity over time (β_{13} = -.11, p = .04, δ = -0.31) when compared to students in the comparison classes.

The change over time is more easily understood with the model implied trajectories for each class in Figure 3. After controlling for their initial appreciation for diversity, open option students in the intervention year had high appreciation for diversity at time point 2 and stayed relatively higher in reference to the comparison classes. Also after controlling for their appreciation for diversity, civil engineering students in the intervention year started higher than the comparison classes but fell to the same level of diversity appreciation as the comparison students by the end of the semester (Figure 3).

Research question 2

To address research question 2, we first determined how engineering identity changed over time. By examining the three types of models previously described, the best fitting model for engineering identity only included a linear term in engineering identity. On average, engineering identity was flat across the semester, but there was a lot of variability in this trajectory of engineering identity, meaning some students increased and others decreased but when averaged across students there was no change in engineering identity.

We entered the blocks of predictors as described above to explain the variability in engineering identity in the intercept and in the linear slope. Neither sex, intervention status nor any interactions were helpful in predicting engineering identity. Only initial engineering identity (time 1) was predictive of engineering identity at the intercept (time 2, Table 4). In other words, while there was statistically significant variability in the linear slope, none of the model predictors explained that variability.

Qualitative Findings

Research question 3

When asked what course activities increased their appreciation for diversity in engineering, 85% of research participants in the open option engineering course and 80% of research participants in the civil and environmental engineering course identified activities such as group projects, panels of professional engineers, student organizations, and the interactive theater sketch as interventions that supported their learning about diversity. Figure 4 shows how often different activities were mentioned by the ENGR and CIVE students. Of these activities, students most frequently identified group projects and opportunities for teamwork as the platform from which they learned about issues of diversity. However, 15% of students in the open option engineering course and 20% of students in the civil and environmental engineering course did not recall participating in any activities that increased their appreciation for diversity. In fact, one participant from the civil and environmental engineering course claimed to learn about diversity through the process of taking the survey.

Research question 4

When asked what course activities helped students identify as engineers, 83% of research participants in the open option engineering course and 71% of research participants in the civil and environmental engineering course named activities that were related to carrying out engineering skills, acquiring engineering knowledge, and receiving evidence of success. Figure 5 shows the variety of student responses to this question. More specifically, activities that supported engineering identities included hands-on components, where students actively engaged in practicing engineering skills, such as projects to solve Grand Challenges in the open option engineering course and to build a retention pond in the civil and environmental engineering class, both of which are group projects requiring teamwork. Additionally, students identified as engineers when they acquired knowledge and skills in STEM and received good grades, feedback that helped them identify more strongly as engineers.

Other course activities that supported engineering identity included panels of professional engineers, support from co-curricular interventions (such as residence halls and student organizations), and teamwork. Although the majority of students in both classes were able to name activities that helped them identify as engineers, 7% of students in the open option engineering course and 11% of students in the civil and environmental engineering course could not articulate any activities that contributed to developing their engineering identities.

Discussion

The purpose of this study was to determine the effects of an experimental curriculum on developing inclusive engineering identities. Rather than focusing on students who are historically marginalized, we sought to change engineering culture in the classroom by including all students in the process. Three findings stand out: (a) while both intervention classes demonstrated higher appreciation for diversity than the comparison classes following the dean's talk, only the open option intervention classes maintained a higher appreciation for diversity than the comparison classes, (b) engineering identity was not different between the comparison and intervention sections and remained stable over the semester, and (c) the greatest potential to impact student appreciation for diversity and engineering identity stems from activities that are both overt in their intention and clearly connected to engineering practices.

After controlling for initial appreciation for diversity, students in the intervention courses demonstrated a higher appreciation for diversity than the comparison classes. The difference in appreciation for diversity between the comparison and intervention classes was observed at time point 2— immediately following the welcome presentation by the dean (the first intervention) which mimics the effectiveness found by Bennett and Sekaquaptewa (2014). Additionally, students in the open option class maintained their greater appreciation for diversity while the civil and environmental class dropped until they matched the appreciation for diversity of the comparison classes. The primary difference between the two sets of interventions was the theatre sketch: students in the open option class participated in the theatre sketch, but students in the civil course did not. In many ways, the welcome presentation and the theatre sketch were the two most explicit of the interventions in directly articulating how diversity and inclusion strengthen engineering. Most of the other experimental activities tried to *show* students diversity, but did not necessarily explain why it was needed specifically in engineering. While there are many differences between the courses, we suspect the maintenance of the appreciation for diversity in the open option intervention course was due to the fact these students participated in a second, overt intervention —the theatre sketch— whereas the civil engineering intervention students did not. A Harvard Business Review article summarizing diversity efforts in corporate settings suggested that while mandatory diversity training for all is an ineffective strategy that can, in fact, backfire, engaging leaders as change makers to address diversity concerns represented a more successful strategy for increasing diversity (Dobbin & Kalev 2016). Transferring this notion from corporate to educational settings, showing students why engineering needs diversity (for example, through activities like the theatre sketches) and engaging students with the department and college to make climate improving changes may be a more effective approach to shifting student attitudes.

After controlling for initial engineering identity, the interventions did not explain variability in engineering identity trajectories, which remained flat when averaged across all students. However, our results indicated there was quite a bit of variability in student engineering identity across time, but the variables from our study do not explain why that variability occurred. This likely occurred because, as our theoretical framework suggests, students cultivate engineering identities when educators design and implement interventions where students *do* engineering tasks, *develop* identities where they are positioned by their peers and themselves as engineers, and *engage* in sensemaking activities where they can understand what engineering means to them (Stevens et al 2008). Our survey measures were designed to capture the end result of these activities on students' appreciation for diversity and engineering identity, not the process. Thus, more nuanced measures may be needed to understand how the activities served to encourage appreciation of diversity and foster engineering identity.

Additionally, the qualitative results indicated that many students noted that working in teams helped them to appreciate diversity, but surprisingly about 20% of students did not recognize any of the activities as promoting diversity or engineering identity. In their written responses, students frequently pointed to group projects as course activities that not only helped them appreciate and learn about issues of diversity, but to also learn about becoming engineers through hands-on work. The clear connection between teamwork and engineering makes group projects a clear gateway to show students the value of diversity in engineering and how to behave in inclusive ways. Group projects already exist throughout most engineering curriculums, yet many sources have recognized robust and positive interactions within teams do not occur organically simply because students must participate in group projects (Yang and Yan 2008) Thus methods to enhance student's basic teamwork skills along with their broader recognition of the value of diversity to engineering is a promising trajectory for future investigation. Although we did not build teamwork into our experimental curricula, we now recognize its transformative potential and plan to design and infuse activities to enhance teamwork as part of the professional inclusive identities curricula.

Limitations

When conducting research in actual classrooms, the research team is nearly always constrained by practical limitations imposed by the university setting. One strength was that the same instructor taught both of the courses in the comparison and intervention years (instructor A for the civil and environmental engineering course, instructor B for the open option engineering course), but the intervention and comparison courses were not taught in the same semester, thus prohibiting students from being randomly assigned to the intervention or comparison courses. An additional limitation was the instructor was not the same for all four classes, thus potentially introducing an instructor effect into the results that was comorbid with the course type (open option and civil engineering).

While we had also hoped to look for differences in appreciation for diversity and engineering identity for underrepresented students of color, there were simply not enough underrepresented students to assess any differences. Typically, only five or six students in each section identified with underrepresented races or ethnicities. Also, the participation rate was lower in the year that the intervention occurred than in the comparison year. Another limitation was missing data across students, namely not all students completed all five surveys.

Practical Implications

The research team did learn several important things from experiencing and observing the first year of implementation. First, it is critical to have the instructor of the engineering course fully on board with the importance of the subject matter. Although we believe that issues of diversity, inclusion and equity are important to engineering, they are not topics that many first-year engineering students will expect to see. Going against student expectations, especially with a topic that can cause discomfort, can have implications for the course instructor, including impacts on teaching evaluations. In fact, many college campuses have become spaces "where almost everyone is afraid to speak", particularly professors who may fear losing their jobs if they are too political and if they receive suboptimal student evaluations (Samuels 2017 para. 4). Discussing issues of diversity, inclusion, and equity, then, becomes a risky venture for some professors if they are still seeking tenure. However, if the instructor is on board and supported by the institution to address issues of diversity, inclusion, and equity, when opportunities for talking about these topics arise outside of the specific interventions, the instructor can leverage those opportunities as ways to supplement the class.

Second, we suspect that we may have been too tentative in developing and implementing the original set of intervention activities. We were cautious because we wanted the activities to be palatable to the course instructors, so that they allowed us to carry out experimental activities and conduct research in their class. And we were cautious because we wanted to engage the students in a way that would not cause too much discomfort. If we were too direct, we feared we might provoke some backlash from students. The relatively flat appreciation for diversity survey results for the open option class who participated in two overt interventions, the disappearance of the initial greater appreciation for diversity in the civil engineering class who participated in only one intervention, and the qualitative results strongly suggest the indirect approach was too weak. This is an especially profound point to consider when interventions in one first-year classroom remain immersed within a larger context—a college of engineering—where students are interacting with professors, policies, and students *outside* this class. We do not know the degree to which other professors, policies, and students are enacting messages and behaviors that very directly challenge and disrupt inclusive engineering ideals.

Third, we more fully recognized that the goals of the intervention activities are of prime importance and that different means to reach the same goal might help with adoption in different courses and contexts. For example, the civil and environmental engineering course instructor did not want to use the student trading cards because they did not fit the instructor's teaching style. The research team accepted this as a cost of keeping the instructor content and willing to continue working with the research team, but we should have explored different activities (perhaps outside of class) that would have given students the opportunity to recognize and reflect on the unique contributions they might bring to the class.

Fourth, we realized that the effectiveness of some activities can be closely related to the person facilitating the activity. For example, the theater troupe who came into the open option engineering course was led by an experienced and energetic facilitator. It would have been very difficult to find or prepare an engineering faculty member to have the same level of facilitation expertise. Although it is important to position the activities as relevant to engineering, we do not think all the content needs to be delivered or facilitated by an engineering faculty member. In the case of the theater troupe, they acted out a scenario from a first-year science lab that was very relevant to most of the students, and the instructor of the course gave a strong welcome to the presentation and followed up on the activity during the following class session.

Conclusions

This paper describes early efforts to start shifting the culture in a college of engineering to an inclusive culture where all students are recognized for the skills, talents, experiences and ways of thinking that they bring to engineering. We have approached this problem through the framework of identity development and have sought to help first-year students identify with an inclusive vision of the engineering profession through a series of classroom interventions. More specifically, we aimed to develop inclusive engineering identities among our participants. Our findings show that cultural change will not be an easy process for institutions.

In order for students to even participate in engineering identity development processes, institutions must move students to the center of engineering education. In other words, simply providing access for students is not enough. Engineering educators must recognize that technical

STEM skills and knowledge constitute only one aspect of engineering identity. An open orientation and appreciation toward diversity, inclusion, and equity serve as equally important characteristics of engineering identity that engineering educators must purposefully develop if we truly want to graduate inclusive engineers and broaden participation in engineering.

This study has demonstrated that integrating four to five somewhat subtle diversity activities into a one-semester course is not adequate to produce large changes in student's appreciation of diversity or engineering identity development. Continuing efforts along the path to developing inclusive engineers must include 1) activities that are more explicit and direct in their intent – but which retain a direct relevance to engineering and provide opportunities for engagement with the topic; 2) a longer term sustained interaction with diversity, inclusion, equity concepts and more direct focus on engineering identity development; and 3) additional measurements of student affect that more directly investigate the link students make between engineering and diversity.

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Table 1.
Demographic Data for the Comparison and Intervention Sections.

			Female		Underrepresented Minority	
		Total*	*N*	Percent	*N*	Percent
Comparison	CIVE	58	22	44	5	11
	ENGR	61	16	30	5	10
Intervention	CIVE	70	29	41	8	11
	ENGR	66	18	27	6	9

*The total reflects the total number of students in each section who consented to participate. Due to some students not completing all portions of the survey the percent reflects students who responded not necessarily the percent of all students who consented to participate in the surveys.

tion for Diversity Separated by Intervention Status, Course Type, and 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)*
e	24	5.60 (0.99)	27	5.41 (0.86)	25	5.25 (1.03)	24	5.42 (0.86)	24	5.38 (0.78)
ale	21	6.11 (0.78)	22	5.95 (0.74)	21	5.97 (0.69)	22	6.14 (0.61)	22	6.11 (0.51)
e	34	5.68 (0.85)	25	5.27 (0.68)	25	5.17 (1.22)	24	5.58 (1.03)	29	5.66 (1.03)
ale	16	6.35 (0.58)	12	5.42 (1.11)	12	5.58 (1.10)	12	5.69 (1.09)	10	5.77 (1.05)
e	37	5.88 (0.96)	35	5.69 (1.11)	34	5.92 (0.85)	32	5.59 (1.19)	32	5.39 (1.07)
ale	25	6.41 (0.68)	21	6.19 (0.80)	23	6.09 (0.81)	24	6.29 (0.65)	25	6.23 (0.74)
e	35	6.05 (0.80)	31	5.95 (0.95)	29	6.03 (0.70)	22	5.83 (0.99)	16	5.88 (1.32)
ale	15	6.51 (0.49)	15	6.47 (0.55)	10	6.57 (0.50)	9	6.30 (0.45)	6	6.39 (0.49)

ring Identity Separated by Intervention Status, Course Type, and 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)*
e	24	4.70 (1.20)	27	4.75 (1.19)	25	4.73 (1.21)	24	4.77 (1.25)	24	4.75 (0.91)
ale	21	4.95 (0.91)	22	4.85 (1.29)	21	5.10 (1.16)	22	4.78 (1.41)	22	4.88 (1.43)
e	34	4.75 (1.21)	25	4.40 (1.47)	25	4.36 (1.73)	25	4.55 (1.88)	28	4.58 (1.69)
ale	16	4.98 (0.90)	12	4.71 (1.05)	12	4.25 (1.40)	12	4.63 (1.73)	10	4.73 (1.77)
e	37	4.93 (1.10)	35	4.95 (1.24)	34	4.82 (1.42)	32	4.77 (1.39)	32	4.79 (1.37)
ale	25	4.63 (1.11)	21	4.40 (1.09)	23	4.74 (1.13)	24	4.88 (0.93)	25	4.51 (1.18)
e	35	4.97 (1.20)	31	5.08 (1.37)	29	5.20 (1.39)	22	5.06 (1.36)	16	4.52 (1.97)
ale	15	5.28 (1.13)	15	5.35 (1.05)	10	5.38 (1.33)	9	5.56 (1.21)	6	6.08 (0.26)

Table 4.

Model Implied Estimates for Appreciation of Appreciation for Diversity and Engineering Identity across Time

	Appreciation for Diversity		Engineering Identity
	Time only Model Coefficient (*SE*)	Final Model Coefficient (*SE*)	Final Model Coefficient (SE)
For Intercept, π_0			
Intercept, β_{00}	5.76 (0.06)***	5.82 (0.06)***	4.72 (.06)***
Initial appreciation for diversity, β_{01}		0.61 (0.08)***	
Initial engineering identity, β_{02}			0.84 (.05)***
Sex, β_{03}		0.14 (0.11)	
CIVE intervention, β_{04}		0.32 (0.12)**	
ENGR Intervention, β_{05}		0.33 (0.12)**	
For Linear slope, π_1			
Intercept, β_{10}	0.04 (0.07)	0.04 (0.08)	-0.004 (.03)
Initial appreciation for diversity, β_{11}		-0.08 (0.04)*	
Sex, β_{12}		0.08 (0.05)	
CIVE intervention, β_{13}		-0.11 (0.05)*	
ENGR Intervention, β_{14}		-0.02 (0.06)	
For Quadratic slope, π_2			
Intercept, β_{20}	-0.01 (0.03)	0.00 (0.02)	
Random Effects		Variance	
Intercept, τ_{00}	0.57***	0.18***	0.49***
Linear slope, τ_{11}	0.13	0.12	0.09***
Quadratic slope, τ_{22}	0.01	0.01	
level-1, σ^2	0.30	0.32	0.32

*$p < .05$, **$p < .01$, ***$p < .001$

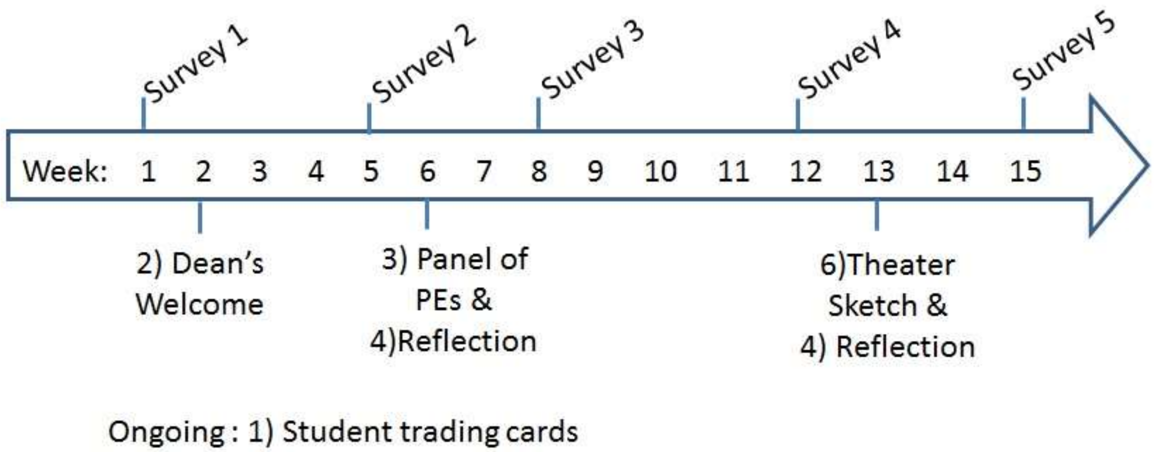


Figure 1. Timing of Surveys and Experimental Activities in Open Option Engineering Course

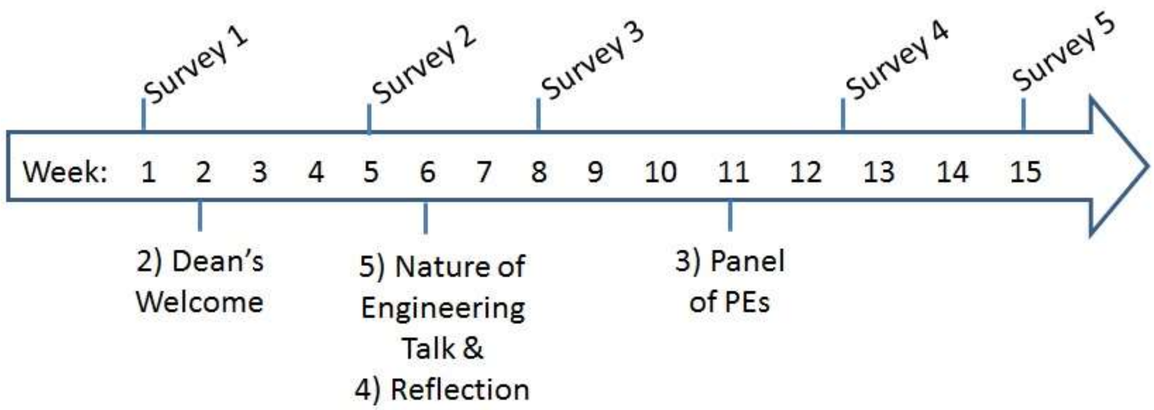


Figure 2. Timing of Surveys and Experimental Activities in Civil and Environmental Engineering Course

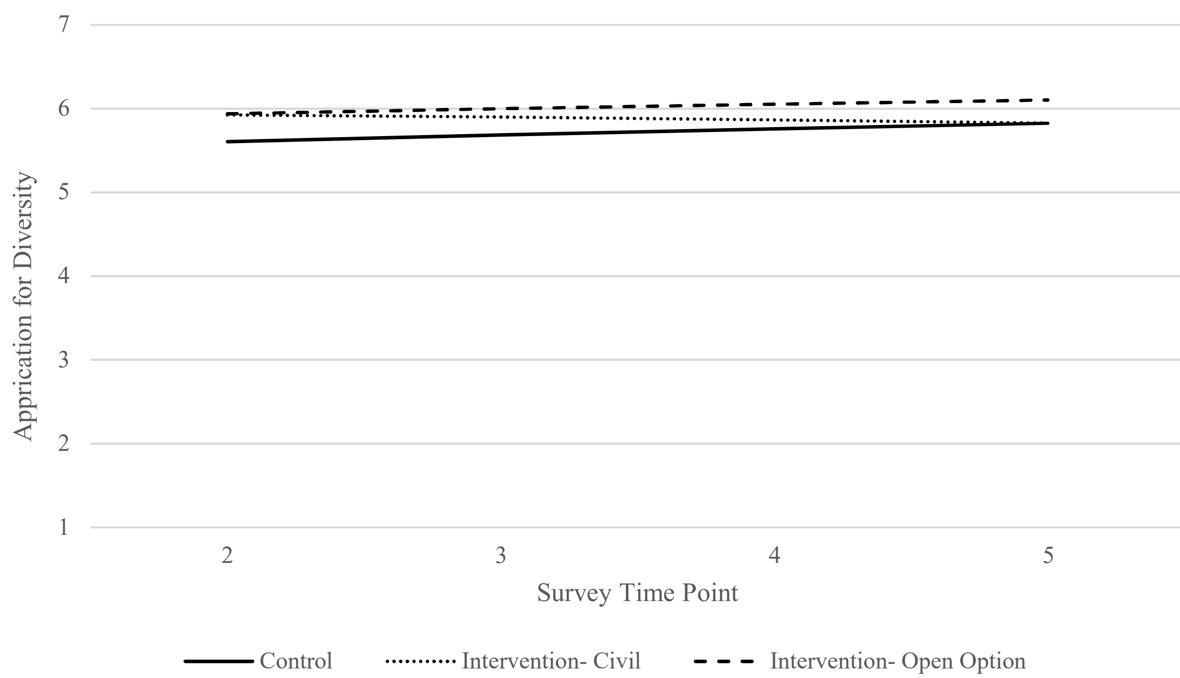


Figure 3. Model implied trajectories for appreciation of diversity for students in the comparison sections, in the intervention section of civil and environmental engineering, and the intervention section of the open option engineering course.

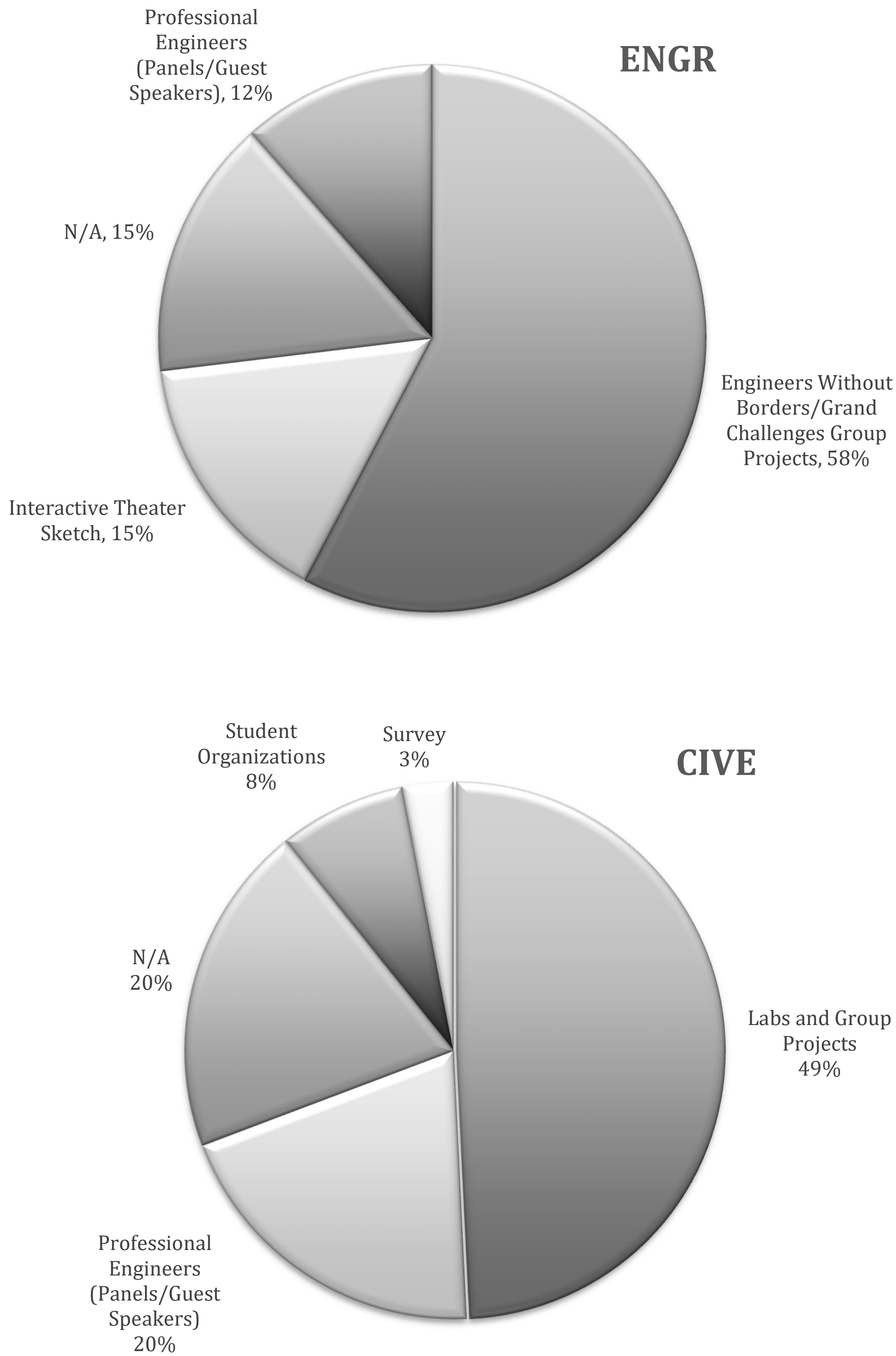
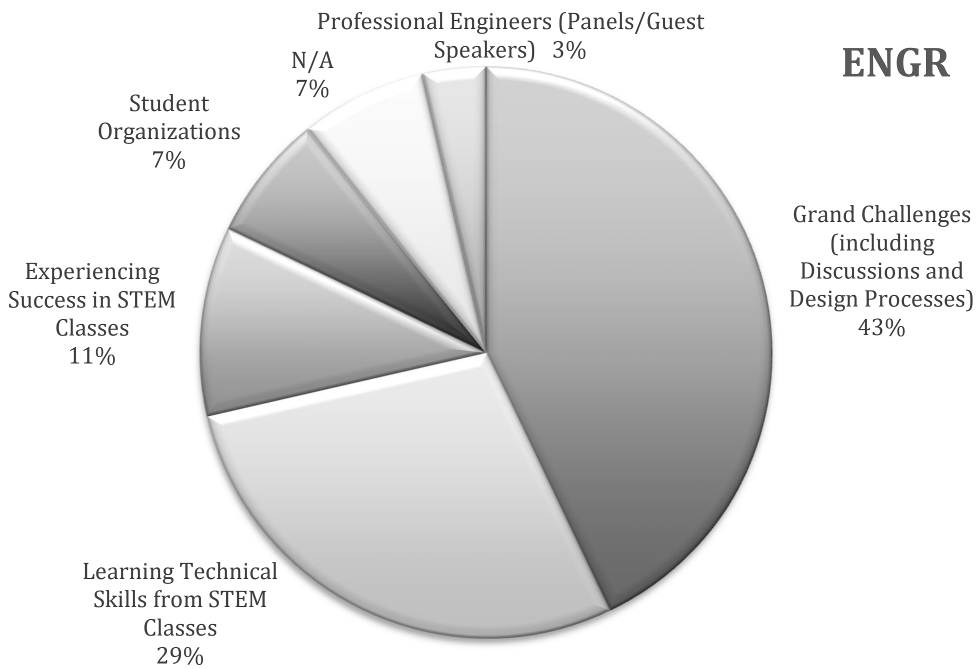


Figure 4. Student responses to "Which course activities increased your appreciation for diversity in engineering?"



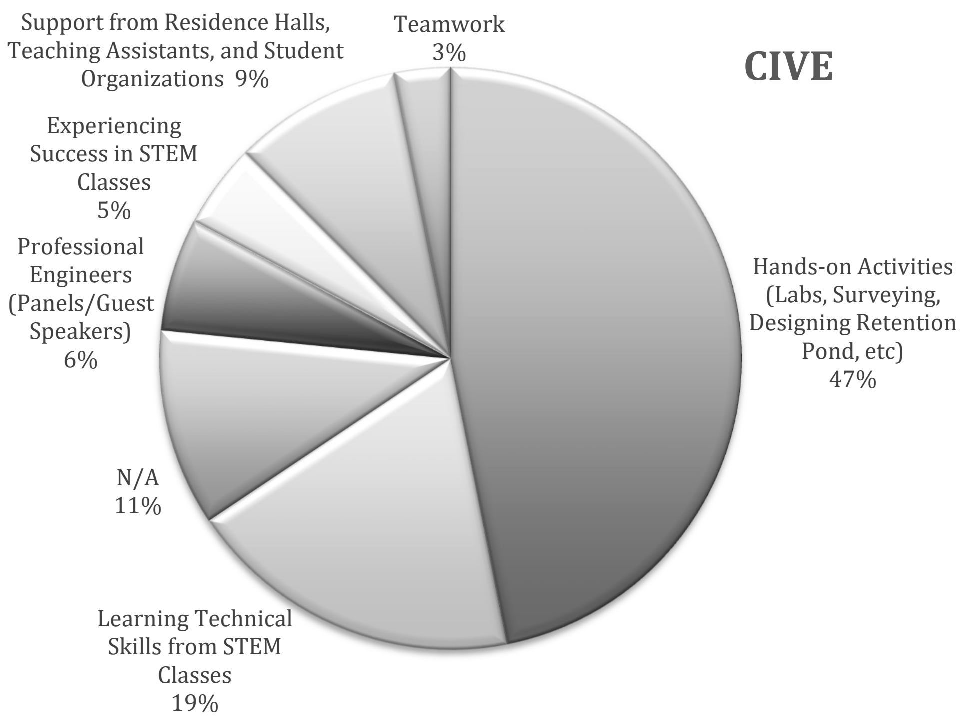


Figure 5. Student responses to “Which course activities helped you identify as an engineer?”

Appendix A.

Coding Variables

We used effect coding for the sex and intervention status variables. Appreciation for diversity at time one and engineering identity at time one were grand mean centered when entered in their respective models. We also created two sets of interaction codes to account for potential sex by intervention status interactions and initial starting scores by intervention status interactions.

We chose to control for potential differences due to sex by using effect coding (sex_{male} = -0.5, sex_{female} = 0.5). We also used two effect codes to identify comparison and intervention classes ($TRT1_{comparison}$ = -.33333, $TRT1_{intervention1}$ =.66667, $TRT1_{intervention2}$ = -.33333; $TRT1_{comparison}$ = -.33333, $TRT1_{intervention1}$= -.33333, $TRT1_{intervention2}$ = -.66667).

We also included appreciation for diversity and engineering identity at time one in their respective models (grand mean centered) as potential predictors of the intercept and slopes. Finally, to test for interaction effects, we also created two sets of interaction codes: Sex by treatment 1, sex by treatment 2, time 1 scores by treatment 1, and time 1 scores by treatment 2. Time was centered on time point two: linear code: $time_2 = 0$, $time_3 = 1$, $time_4 = 2$, and $time_5 = 3$; quadratic code: $time_2 = 0$, $time_3 = 1$, $time_4 = 4$, and $time_5 = 9$.