Promoting Inclusive Engineering Identities in First-Year Engineering Courses

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Introduction

In order to cultivate a diverse and inclusive engineering student population, engineering programs must purposefully teach engineering students to identify as engineers, appreciate diversity, and work in inclusive environments. In this NSF-funded project, we collaborate with engineering faculty to design and implement interventions for first-year engineering students to strengthen their engineering identities and raise their awareness of how diversity benefits the engineering profession. This paper and poster describe the activities implemented during the first intervention year of the project and preliminary findings. The paper addresses the following questions:

1. What experimental intervention activities potentially support engineering students in developing engineering identities and appreciating diversity?

2. What patterns emerge in participants' engineering identities and appreciation of diversity after the experimental intervention activities have been implemented? Do these patterns differ by section or by sex?

To answer the first inquiry, we describe the experimental intervention activities and the classroom contexts in which they were implemented. Then a quantitative analysis of survey data is summarized to address the second inquiry. We conclude this paper with ideas about how to improve the efficacy and transportability of experimental intervention activities so they can be adapted for multiple classroom environments and professor teaching styles.

Description of Intervention Activities

In this section we describe our goals for the intervention activities and detail the interventions that were implemented. In adapting and developing the intervention activities, the study team had three main objectives for each intervention:

1. It should contribute to the process of engineering identity development by providing opportunities for students to form a definition of engineering, to engage in the social aspect of identity development, and/or to engage in sensemaking about their identities[4].
2. It should at the very least promote a sense of appreciation for diversity in engineering, and more preferably it should give students skills or insights that will help them work as an inclusive engineering student and ultimately engineer.
3. The activity should be something that could be transferred to another classroom with a limited amount of additional effort. Characteristics we looked for included the amount of prerequisite information needed by the students, the amount of time the activity would take, and the level of difficulty for the instructor. (For example, many engineering educators first embarking on this type of course material might not feel comfortable with their ability to successfully facilitate a conversation on social justice.)

Using literature review and observation of the subject courses in previous year, we identified a set of five potential activities that we detailed in [7]. We then worked closely with the course instructors of two different first-year courses, ENGR 101 Grand Challenges in Engineering and CIVE 102 Introduction to Civil and Environmental Engineering to implement several activities in each course.

ENGR 101 Grand Challenges in Engineering is a course intended for students who have been accepted into the College of Engineering but have not yet decided on a specific engineering discipline and is inspired by the National Academy of Engineering Grand Challenges for Engineering. The course emphasizes class discussion about societal challenges and how different engineering disciplines can contribute to addressing these challenges. The professor gives students opportunities to pick what challenges to tackle in class. The course also includes an Engineers Without Borders design challenge. This class meets for lectures three times a week.

CIVE 102 Introduction to Civil and Environmental Engineering is a first year course for students with declared interest in civil and/or environmental engineering. The course is the first of a two-course sequence meant to introduce students to different sub-disciplines within civil and environmental engineering. The fall semester emphasizes hydraulics, hydrology, and water quality, and is organized around a guided design of a stormwater retention pond on campus. This class meets for lecture twice a week and has a three-hour lab taught by graduate teaching assistants. The lab and course are closely integrated and lab activities such as surveying are an important part of the project.

The subsections below give a brief description of the different activities that were implemented in at least one of the two courses, and include some preliminary feedback from the course instructors. The activities are arranged roughly in the chronological order in which they were presented to the classes.

Student Trading Cards. The work of Barker, O'Neill, & Kazim[1] inspired this activity. The instructor has a set of cards with each student's name on a card and when the instructor poses questions to the class, s/he uses cards to select the student to answer. Using the cards allows instructors to more consistently call on all members of the class. We selected this activity because when the instructor looks for a response from *any* student it can help convey the message that each individual possesses knowledge and personal experiences that might be relevant to an engineering problem. This activity is meant to build engineering identity by helping students to see how they can contribute to discussions about engineering topics, and to help build an appreciation for the diverse responses different students might provide.

At the beginning of the semester, the research team gave instructors of both courses a set of index cards made from the course enrollment lists. We asked instructors to use the cards to call on students at appropriate times during the semester. Initially, both instructors had some hesitation and specifically expressed concern about putting shy students on the spot. The research team encouraged the instructors to use the cards in situations where the answer could be derived from student experiences and opinions, or where there were many possible answers. At the end of the semester the ENGR 101 instructor commented that he liked the cards because it helped him engage with more members of the class and manage those students who always wanted to talk. He also felt the cards were a good fit for the open, discussion style of his class. The CIVE 102 instructor did not use the cards and commented at the end of the semester that she didn't see how the cards would fit in her fact-based lectures.

Welcome Presentation by the Dean. In this activity, the Dean of the College of Engineering came to each class during the second week of the semester and gave a presentation to demonstrate the importance of egalitarian social norms in the college. This presentation was meant to help students understand the importance of communication skills to engineering practice and to think about the types of behaviors that were conducive to effective collaboration. The presentation given by the dean was closely modeled on the presentation studied by Bennett and Sekaquaptewa[2] at the University of Michigan, who graciously shared their presentation materials. We updated the presentation to include alumni from our institution and to fit the speaking style of our dean. The presentation starts by introducing the need for engineers to have more than technical competence and particularly the importance of working effectively in teams with people from a variety of cultures. The dean presented examples of diversity and accomplished alumni who successfully worked with and led teams. Finally, at the end of the presentation specific examples of biased actions were explicitly addressed. For example, the dean said that biased activities such as racist or sexist jokes were not tolerated in the College of Engineering. Directly following the presentation, the CIVE 102 instructor indicated that she liked the content and thought it was very relevant.

Panel of Professional Engineers. Around mid-semester we hosted a panel of engineers in both classes. The panels informed students about engineering practice and hopefully provided some role models to the students. In putting the panels together we attempted to represent at least some racial and gender diversity as well as diversity in engineering career paths within the practical constraints placed by 50-minute lecture periods. In ENGR 101 we had a panel of three engineers representing electrical engineering, mechanical engineering and materials engineering. In fact the materials engineer was actually a materials scientist who emphasized the need for engineers to work on teams with other disciplines. (Civil engineering was not represented as the course instructor is a civil engineer). In CIVE 102 we had a panel of four engineers representing sub-disciplines of civil engineering: transportation, structures, water resources and environmental engineering. Each panel had two women participants. The ENGR 101 panel had one African American woman, and the CIVE 102 panel had an Asian American male. We developed panel questions with the intent of encouraging responses about the different skills used by professional engineers and about the benefits of diversity to engineering. The general questions listed below were customized slightly for the context of each panel/class.

1. Please provide a five-minute introduction of yourself (name, collegiate degrees, company/position/basic responsibilities, examples of projects you have worked on, including the role of your discipline and the roles of other disciplines and the roles of non-engineers). Please bring pictures to show if possible.

2. Describe a time when you worked on a project that benefited from diverse backgrounds and areas of expertise and ideas from engineers and non-engineers.

3. Besides learning math, science, and engineering content from classes, what do undergraduates need to know and do to become good engineers?

4. Did you ever have any doubts about wanting to become an engineer?

5. If you could talk to yourself when you were a first-year student, what kind of advice would you give about becoming an engineer?

In both courses there were roughly ten minutes remaining at the end of the class session so students could pose their own questions. The ENGR 101 instructor asked his class for their opinions about the panel during the following session. The class gave him positive feedback, but indicated that they wanted to hear about work-life balance issues. The CIVE 102 instructor has conducted professional panels in her course for many years, but never before did the panels have this specific structure or the targeted questions. She was very pleased with the questions and the types of specific information the questions elicited from the panel. In the ENGR 101 class, students received a follow-up reflection assignment intended to promote the sense-making process in student engineering identity development. The assignment was composed of the following questions:

1. Based on what you learned from the panel, what do undergraduate students need to know and do to become good engineers? Which of these things are already areas of strength for you?

2. What kinds of qualities or skills do you want to strengthen while you are in school to help you become an engineer?

3. What did you learn about working on teams with other engineers and non-engineers? How can you use this information to make yourself a better team member for your design projects?

Lecture on the Nature of Engineering. In CIVE 102, a senior faculty member from the mechanical engineering department (who also serves as a city council member) gave a guest lecture. Given his role in city government, this professor had a unique perspective on the role of engineers in providing infrastructure for society and how engineers need to interact with policy makers. This lecture emphasized that engineering is design to benefit society, and raised the question of whose values come into play when determining what is of benefit to society. This lecture aimed to help students understand what distinguished engineers from other professions, to help students recognize their future responsibility to society, and to think about engineering as a subjective field that can benefit from diverse perspectives. The lecture was more philosophical than the research team and course instructor had originally anticipated, and to reinforce the importance of subjective values to engineering, students answered the following reflection questions:

1. Today in class the guest speaker talked about how engineering is design synthesis intended to create benefits for society. Different people and organizations might have

different ideas about what is beneficial. What are some important values to you that you would like to actualize to benefit society in your future career?

2. The speaker also talked about the importance of understanding and defining a problem before attempting to solve it. Viewing the same issue from different perspectives might suggest different problems or different approaches to solving the problem. Engineers often work in teams. What are the characteristics of engineering teams that would be well suited to defining problems and creating innovative designs to benefit society?

Interactive Theater Sketch. Finally, near the end of the semester in ENGR 101, an interactive theater sketch modeled on Finelli and Kendall-Brown[4] was prepared and presented by a local consulting company that specializes in interactive theater. The intent of the sketch was primarily to help students think about interpersonal skills they could apply to help teams function. The sketch also included a subtext of gender issues in STEM. The session began with three actors modeling a group of students working on a laboratory report together. In the sketch, tensions between the students built (due to a mistake made by one team member on a previous lab report) until eventually one student stormed away from the group. The facilitator then asked the audience what they would have done to change the outcome of interaction. The sketch was replayed and audience volunteers came up to join the actors as a fourth group member. Although the class was quite large, four willing volunteers came up to the front and helped the actors replay the sketch with a different outcome. The ENGR 101 instructor had the impression that several of the students took quite well to the experience. In the subsequent course meeting the instructor asked students, “If you had a chance to intervene in the group setting, what could you have done? Why?” and describe how they would have tried to change the outcome for the group.

These aforementioned interventions were implemented in fall of 2015. See Figures 1 and 2 for the course timeline, survey administration, and intervention timing.

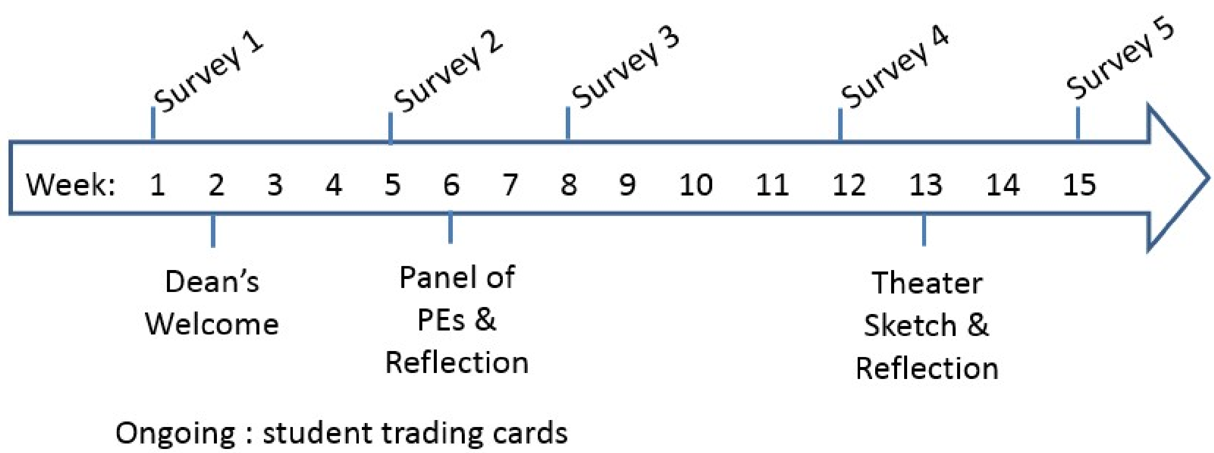

Figure 1. Timeline for Grand Challenges in Engineering (ENGR 101) surveys and interventions

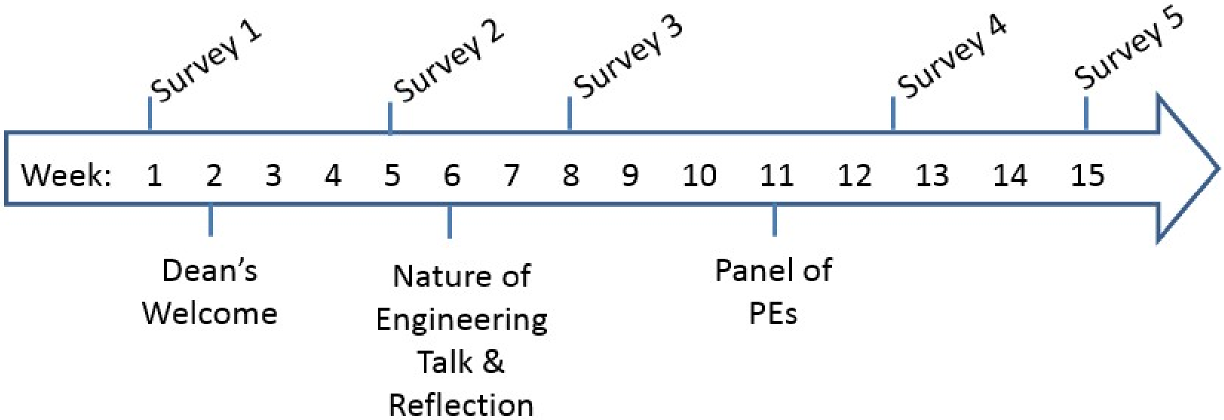

Figure 2. Timeline for Introduction to Civil and Environmental Engineering (CIVE 102) surveys and interventions

Survey Results

To answer research question 2, we tracked student appreciation of diversity and engineering identity across the semester for the comparison sections (CIVE 102 and ENGR 101 in 2014) and the intervention sections (CIVE 102 and ENGR 101 in 2015). To assess engineering identity, we adapted the Science Identity scale to reflect engineering [3, 5]. Students responded to a 7 point scale from strongly agree to strongly disagree to items such as "Being an engineer is an important reflection of who I am." To assess appreciation of diversity, we used a shortened version of the Appreciation of Cultural and Ethnic Diversity (r=.76) by Price, Williams, Simpson, Jastrzab, & Markovitz [8]. Students also responded to a 7 point scale from strongly agree to strongly disagree to items such as "Working with teams of people from diverse backgrounds is stimulating." The reliability of each scale was assessed at time 5 for both the comparison and intervention sections. The identity scales demonstrated acceptable reliability (r <. 70) at both time points assessed, while the diversity scales approached acceptable reliability in 2014 (r = .66 in 2014) but was acceptable in 2015 (r = .70).

On both the identity and diversity scales, the negatively phrased items were reverse scored and means were calculated for each scale. See Tables 1-2 for descriptive statistics by sex, section, and intervention status.

Table 2. *Descriptive Statistics for Engineering Diversity Separated by Section and Sex*

			2014			2015		
		Time Point	*N*	*M*	*SD*	*N*	*M*	*SD*
Civil Engineering	Female	1	21	6.11	0.78	25	5.53	0.73
		2	21	5.98	0.74	21	5.45	0.75
		3	20	6.07	0.54	23	5.30	0.77
		4	21	6.21	0.53	24	5.43	0.67
		5	21	6.16	0.45	25	5.36	0.75
	Male	1	24	5.60	0.99	36	5.21	0.67
		2	25	5.45	0.88	35	5.17	0.83
		3	23	5.22	1.07	34	5.34	0.80
		4	22	5.39	0.88	32	5.23	0.85
		5	22	5.38	0.79	32	4.84	0.65
General Engineering	Female	1	16	6.35	0.58	15	5.57	0.63
		2	12	5.42	1.11	15	5.52	0.66
		3	12	5.58	1.10	10	5.78	0.57
		4	12	5.69	1.09	9	5.53	0.56
		5	10	5.77	1.05	6	5.33	0.37
	Male	1	34	5.68	0.85	33	5.32	0.67
		2	24	5.22	0.66	29	5.19	0.66
		3	24	5.21	1.23	26	5.28	0.54
		4	22	5.56	1.02	20	5.32	0.76
		5	24	5.63	0.94	13	5.29	0.56

Note: Data from 2014 represent the comparison sections and 2015 represent the intervention.

Table 2. *Descriptive Statistics for Engineering Identity Separated by Section and Sex*

Note: Data from 2014 represent the comparison sections and 2015 represent the intervention.

			2014			**2015**		
		Time Point	*2014*	*M*	*SD*	*N*	*M*	*SD*
Civil Engineering	Female	1	21	4.62	0.67	25	4.63	1.11
		2	21	4.86	1.32	21	4.40	1.09
		3	20	5.10	1.19	23	4.74	1.13
		4	21	4.74	1.43	24	4.88	0.93
		5	21	4.69	1.03	25	4.51	1.18
	Male	1	24	4.42	0.95	36	4.94	1.12
		2	25	4.67	1.20	35	4.95	1.24
		3	23	4.67	1.24	34	4.82	1.42
		4	22	4.73	1.30	32	4.77	1.39
		5	22	4.41	0.55	32	4.79	1.37
General Engineering	Female	1	16	4.71	0.63	15	5.28	1.13
		2	12	4.71	1.05	15	5.35	1.05
		3	12	4.25	1.40	10	5.38	1.33
		4	12	4.63	1.73	9	5.56	1.21
		5	10	4.46	1.26	6	6.08	0.26
	Male	1	34	4.53	0.82	33	4.98	1.23
		2	24	4.36	1.49	29	4.99	1.37
		3	24	4.29	1.73	26	5.14	1.43
		4	23	4.34	1.81	20	4.96	1.37
		5	24	4.35	1.12	13	4.31	2.08

In Figures 3-6, the means of each time point are depicted and separated by section, comparison/intervention/ and sex. All intervention sections are represented by dashed lines, and the comparison sections are represented with solid lines. Figures 3-4 give preliminary findings for appreciation of diversity, while figures 5-6 give preliminary findings for engineering identity development.

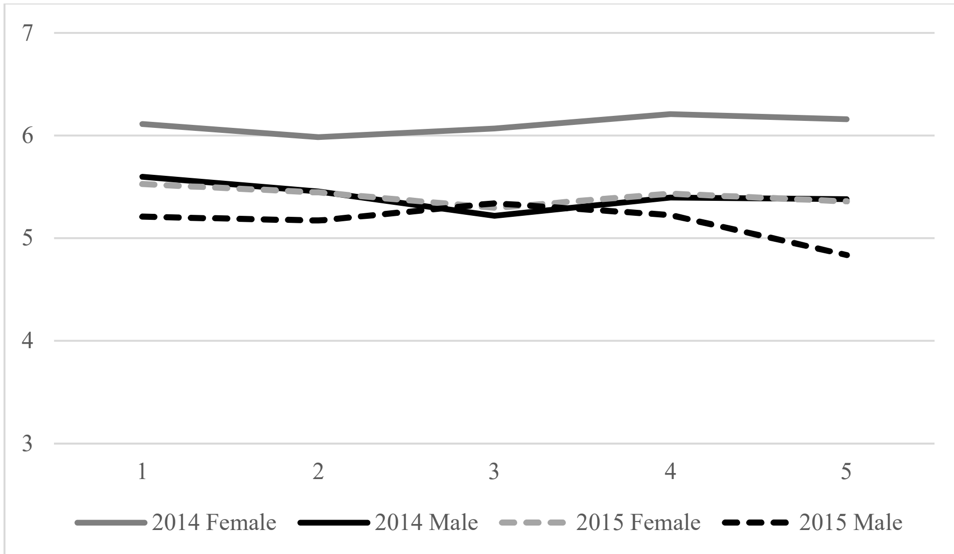

Figure 3. Depiction of appreciation of diversity means for civil engineering students. Data from 2014 represent the comparison sections and 2015 represent the intervention.

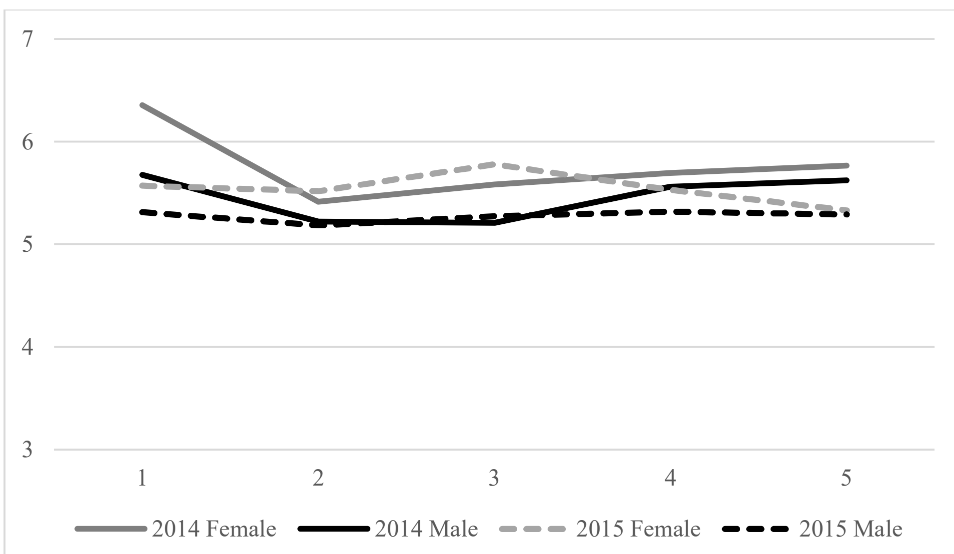

Figure 4. Depiction of appreciation of diversity means for general engineering students. Data from 2014 represent the comparison sections and 2015 represent the intervention.

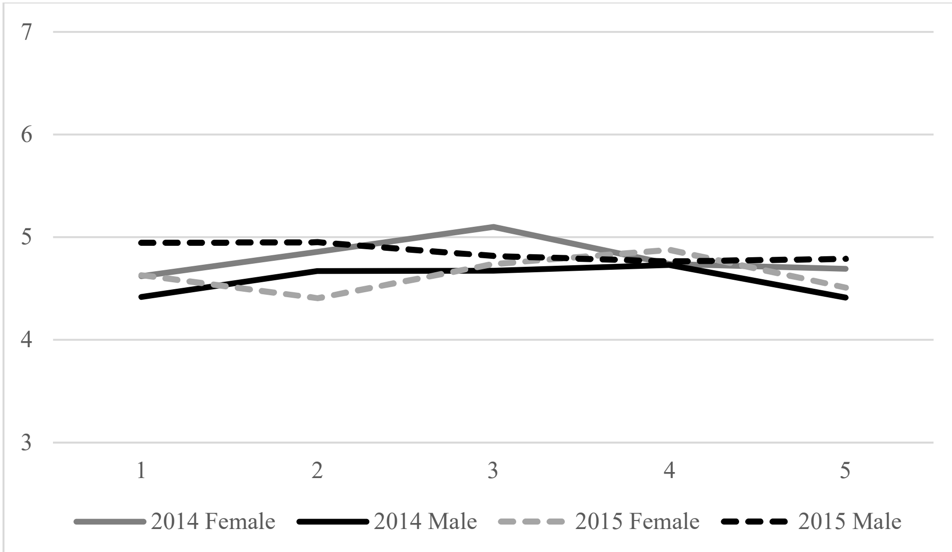

Figure 5. Depiction of engineering identity means for civil engineering students. Data from 2014 represent the comparison sections and 2015 represent the intervention.

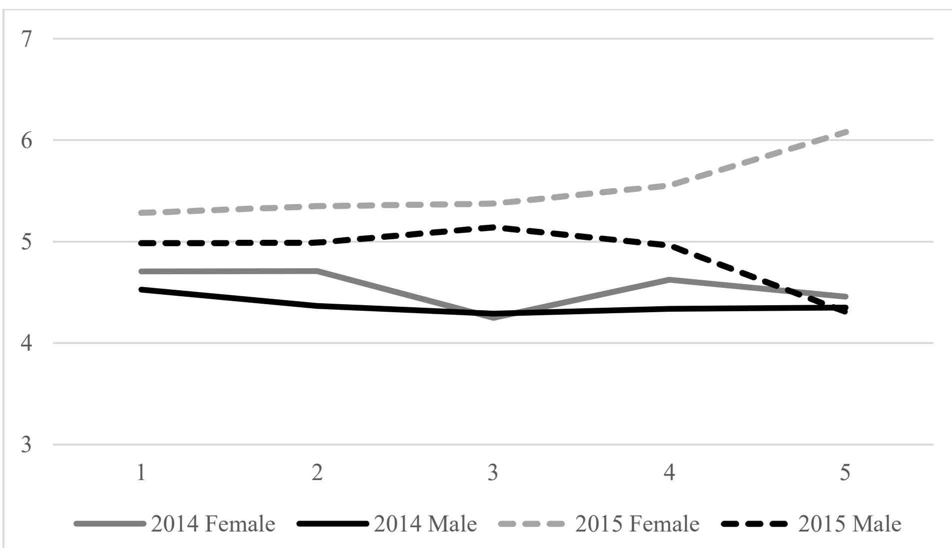

Figure 6. Depiction of mean of engineering identity for general engineering students. Data from 2014 represent the comparison sections and 2015 represent the intervention.

A few observations stand out. In Figures 3 and 4, while there were differences in initial appreciation for diversity by sex and intervention status, the appreciation for diversity was relatively consistent across sex and section. For identity development, students in both sections and in both years appeared to develop in relatively the same way despite differing starting points (see Figures 5 and 6). However, females in the intervention section of open option engineering (ENGR 101) appeared to make the greatest gains in engineering identity and showed an increase in identity in the last observation of the semester.

Lessons Learned and Future Research
This first attempt at modifying the two first-year courses to promote inclusive engineering identity development taught the research team a great deal about the particular interventions and about the effects of placing a concerted effort on inclusion.

In addition to the specific activities suggested by the research team, the interaction between the researchers and course instructors led to other course changes. For example, in an effort to help get the students involved in their education and major, the CIVE 102 instructor typically gives extra credit to encourage students to attend meetings of the student chapter of various professional organizations such as ASCE (the American Society of Civil Engineers). This year, for the first time, a student asked a question about organizations such as the National Society of Black Engineers (NSBE), and the course instructor broadened her list of organizations to include several other identity based engineering organizations such as Society of Hispanic Professional Engineers (SHPE) and Out in STEM (oSTEM). This research project also led to some changes in the annual presentation by the college career advisor. While the content of the presentation remained the same, the framing of the information was adjusted slightly to be more constructive of budding engineering identities and slightly less pressure packed, particularly for first-generation college students.

An important lesson the research team learned from this first year of implementation is the importance of flexibility to transferability. For example, the CIVE 102 instructor did not want to use the student trading cards. The cards themselves are not actually that important, instead the objective behind the cards is the important feature of the activity, and the cards are one example of a way to meet the objective. Demonstrating that all students have valuable perspectives to bring to the topic can be achieved outside the classroom by using the trading cards in the smaller lab sections, or by assigning a homework assignment asking students to use their existing knowledge and past experiences to analyze a civil or environmental engineering issue. As we work to implement inclusive engineering identity building activities in additional courses in Fall 2016, and ultimately to spread these activities to other schools, it is important for us to focus on identifying the objectives of the interventions and different examples of implementation.

We also saw that the somewhat subtle nature of some of the activities might not be enough to produce the desired effects. In choosing the intervention activities we sought to make the activities very relevant to engineering and wanted to avoid turning off majority students. However, we may have been too cautious in our approach and in the next year of the project we hope to be more assertive in implementing the interventions. For example, in order to enhance the dean's welcome, we plan to build on the examples of overt bias introduced by the dean and ask students to complete a homework assignment on unconscious or implicit bias where students can take an Implicit Association Test and reflect on their performance. In this way we can get students thinking more broadly about how bias can affect their careers as engineers. We also hope to find a more engaging way to talk to students about how their values impact engineering decision-making. The topics raised in the nature of engineering presentation were good, but the lecture format was not active enough.

Another important lesson the team learned in consideration for future research is to modify our survey items and data collection so that we get clarity about the impact of the intervention activities. Survey results from the open option engineering class of ENGR 102 suggest that by the end of the semester, women showed the highest gains in engineering identity. We speculate this occurred because the interactive theater sketch, the last intervention of the semester, focused on issues related to gender equity and teamwork. Future iterations of this research study will include questions that explicitly ask students about how they perceived the impact of an activity upon their engineering identities and appreciation for diversity. Not only will we revise questions in the survey, we will ask students to participate in focus groups so we can collect more robust data that sheds light on how students perceive and experience the intervention activities.

We also attempted to disaggregate the data by underrepresented minority status, but there were too few underrepresented minority students who completed the survey at several time points. In some instances, only 2 underrepresented minority students completed the survey. Once we have developed, piloted, and refined new diversity and identity interventions, we would like to expand the course interventions to other universities with larger populations of underrepresented minority students.

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