Examining the Effects of Equity, Inclusion, and Diversity Activities in First-Year Engineering Classes

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This completed research paper describes the research-based activities [1], [2] that were integrated into a first-year engineering course at a large mid-Atlantic university and assesses their impact on student appreciation for diversity in engineering and their likelihood for enacting inclusive behaviors on teams.

To effectively serve diverse populations and successfully work in diverse teams, engineers need to recognize the importance of diversity in engineering teams and should consider a wide variety of diverse populations in design. Even with efforts to create change, white women and People of Color continue to be under-represented in engineering, even as under-representation for some populations has decreased in other STEM fields [3]. Diversity in engineering teams is important beyond the intrinsic value of equity, as diverse teams are better problem solvers [4]. Individuals must have specific knowledge about the benefits of team diversity and how to leverage diverse contributions, however, as in the absence of this knowledge tasks may be inequitably allocated to team members based on biased assumptions about their ability to contribute [5], [6]. Helping students recognize the importance and value of diversity in engineering teams, therefore, may help to create teams that leverage the benefits of their diversity, design more effectively for diverse populations, and create more inclusive learning environments.

Under-representation of women or People of Color in engineering programs is not explained by preparation or test scores [7], [8]. Additionally, once these students from under-represented groups enter undergraduate engineering programs, they have lower retention rates than their majority peers with similar grades and test scores [7]–[9]. Instead, problems with climate, teaching style, and misperceptions of students' abilities by peers, faculty, and advisers, all influence the retention of students from under-represented groups [7]–[9]. While programs that support under-represented students can be helpful, larger-scale systemic changes are needed at the instructional and engineering culture level to address the "chilly climate" that some students face [9], [10].

Recent work in the problem-solving fields has identified that diverse teams are better problem solvers and innovators than homogenous teams, even if individual ability is lower on the diverse teams [4], [11]. Focusing on the importance of diversity in problem solving may help create climate change in undergraduate engineering classrooms, and possibly engineering as a whole, even if individuals do not value diversity from an equity standpoint. When bringing the value of diverse teams to the forefront it is important to avoid tokenizing individuals from under-represented groups.

The innovativeness of diverse teams may be particularly important for universal design – considering the wide variety of diverse populations that will use or be influenced by the products of engineering. Innovation can either be incremental, which clearly builds upon what already exists, or radical, which involve more drastic changes [11]. Diverse teams are particularly high performing for radical innovation [11], which may be particularly beneficial in addressing novel problems, and re-designing items that only work for a limited subset of the population. For example, optimizing the function of stairs, or the related ramp, may work in some situations, but the more radical innovation of an elevator solved the problem of moving vertically using universal design, in a way that focusing on stairs and stair-like objects could not. While some benefits in radical innovation may come from the specific identities of the members of a team, the benefits of diversity in innovation and problem solving are not limited to membership identity - each team has its own synergy that facilitates innovation and problem solving [11].

The need for a cultural shift in engineering to create more inclusive environments can be supported by the benefits of diverse teams in problem solving and innovation. A research team of engineering faculty and education researchers designed multiple classroom-based activities to highlight the need for diversity, equity, and inclusion in engineering. Reported here are initial results that assess the impact of these activities on student appreciation for diversity in engineering and their likelihood for enacting inclusive behaviors on teams.

Theoretical Framework

Professional identity development theory explains how students transition into identifying with the roles, responsibilities, and knowledge associated with their professional role [12]. This theory has been used in engineering fields to specifically look at how students develop engineering identities. There are three dimensions of identity development identified as important for engineering students: disciplinary knowledge, identification, and navigation [13]. These dimensions are also useful for studying how different students develop their individual professional engineering identities. Some researchers [14], [15] have specifically studied the interaction of gender and engineering identity development, and found that men and women may affiliate with different parts of the engineering profession. Using professional identity development as a lens to study how students interact with diversity-oriented curriculum, the impact of the interventions on helping *all* students value diversity within engineering can be explored.

Methods

Study context

In fall 2017, students in a total of eight sections of a common first-year engineering course took four surveys throughout the semester and were taught by three distinct instructors. Each instructor had an equal number of intervention (four sections, n =116) and comparison sections (four sections, n = 137).

The students in the intervention sections participated in multiple activities, which are described subsequently. Table 1 shows when each of the activities occurred throughout the fall term.

Table 1. Activities and Timeline

Activity	Week of Semester
Dean's Talk and Reflection Questions	2
Teamwork Video and Reflection Questions	2
Implicit Bias Module and Essay	3
Panel of Practicing Engineers Discussion and Reflection Questions	6
Iceberg Activity	9
Theatre Sketch and Reflection Questions	9

The dean of the college of engineering spoke to students in the course about egalitarian norms and the importance of functioning as an engineer in a global workforce.

Student learning outcomes for the course include ABET outcomes, including "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives". The teamwork activity was designed to align with the aforementioned ABET outcome. Students were required to watch a video about the importance of psychological safety in teams and complete reflection questions related to the video. The reflection prompts included: (1) Describe a setting where you would be willing to admit mistakes when working with a team, (2) What can you do to help establish a team dynamic where mistakes are welcomed and recognized as part of the design process?, and (3) How important is psychological safely in engineering teams and why?.

In an effort to further foster inclusive behaviors, students were exposed to the idea of implicit bias and were required to write a two-page reflection essay. The implicit bias module included a video aimed at educating students about implicit bias, an Implicit Association Test (IAT) of the student's choice, a video about the impacts of implicit bias, and an essay prompt. In the essay, students were asked to articulate the difference between implicit and explicit bias, discuss the results from their IAT test, and describe how what they learned about implicit bias will impact how they approach working in engineering teams.

In the sixth week of the semester students attended a panel of practicing engineers discussion. The panels were deliberately composed of engineers from diverse personal, educational, and professional backgrounds. The moderator posed questions focusing on the importance of teamwork, working with engineers and non-engineers, skills engineers need beyond math and science, what qualities make them an engineer, what knowledge they wish they learned in school that would be helpful as a practicing engineer, and whether or not they ever doubted their choice to pursue an engineering major. Students were also encouraged to ask questions to the panelists. After attending the panel, students completed a homework assignment which included 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? And (3) What did you learn about working in teams with other engineers and non-engineers? How can you use this information to make yourself a better team member for your design projects?

Students also completed an iceberg activity focusing on exposing how society makes assumptions about people, either consciously or subconsciously, and how those assumptions are frequently inaccurate. This activity incorporated the campus read "Hidden Figures". Students were given a worksheet to complete outside of class. The worksheet asked them to think about a character from the book and to provide identities and/or adjectives that would be associated with that person: (1) if someone just met them, and (2) after they have read the book and are familiar with the characters. The students were also asked to write what identities and/or adjectives people might assign to them at a first meeting, and then what people would say about them after getting to know them. Class-time was dedicated to discuss the student activities and if what students learned from this activity will impact how they work with engineering students who are different from them.

The final activity was an interactive theatre sketch [16]. This activity started with an ice-breaker that required the students to interact with each other and intentionally removed them from their comfort zones. The students then watched trained actors perform a sketch in which three students (two men and one woman) are working on a team project. The team has a variety of issues that lead to its dysfunction, most notably the behavior of one of the men towards the woman. After the theatre sketch was completed, students were asked what they observed about the performance. Throughout the sketch, an empty fourth chair was on stage. The sketch was then performed again and students were given the opportunity to stop the sketch at any time and intervene as the fourth member of the team. After each intervention trained facilitators led the audience in providing affirmations to the student who intervened and led a discussion about how the intervention worked. As part of the course, students were required to complete a reflection essay on all of the out-of-class experiences, including the theatre sketch.

Students (n intervention=116, n comparison= 137) took the Valuing Diversity and Enacting Inclusion in Engineering Scale [17], which assesses four related constructs. Specifically, the survey asked to students to indicate their agreement with why engineers should value diversity in engineering: (a) fulfill a greater purpose (n=4, r = .88) and (b) serve customers better (n = 4, r = .91), and whether the students would (c) promote a healthy team culture (n = 4, r = .87), and (d) challenge discriminatory behavior (n = 5, r = .93). Students took the survey four times during the semester, approximately after the first week of class, fifth week, tenth week, and thirteenth week.

The Larger Context

Of note, this study is focused on one piece of a much larger NSF funded project. Although not discussed in this paper, we are implementing additional activities in second semester first year, sophomore, junior, and senior level courses at this university and implementing both tailored first year curriculum and upper level activities at other campuses. All of the activities tie to one of three purposes: (a) why engineers should care about diversity, (b) how to work with people who are different from you, and (c) who to consider when designing products or services. Sometimes those activities take place in the context of team projects, such as a senior mechanical engineering design course asked teams of students to redesign a power tool to work for veterans with specific disabilities. Others help students build skills to work with team members different from them. For example, for one activity we give each student a picture at various levels of magnification and ask them to get in order from closest to farther away without showing their picture. We get students talking about sharing their full perspective (and hearing other's) and the importance of connecting with teammates. For more information, see http://partnership4equity.com.

Further, we are collecting data from the participating students in various other ways. For example, there is a common set of reflection questions students answer after each activity, and students also respond to open ended questions (e.g., about characteristics of good engineers) on survey 1 and survey 4. Also, on survey 4 students answer several other questions about working in diverse teams and what activities helped them learn about working well in teams. Separate manuscripts in various stages examine the results of open ended survey questions, the student responses to the activities and the related reflection questions, effectiveness of activities developed for other classes, and the implementation at multiple campuses.

Data analysis

Data were analyzed using multiple regression using a model building process. In the first model (Model A), the means of the student construct scores were predicted from a set of two effect codes to control for potential differences due to instructor. In the second model (Model B), time was added as a predictor of student construct means. In the final model (Model C), two variables were added: one to indicate whether the student was in an intervention or comparison section and the second was the interaction of time and intervention status, the variable of interest.

Of primary interest was the change in proportion of variance explained, R^2, from Model B to Model C, which included the intervention variable and its interaction with time. Further, the parameter estimate for interaction of time and the intervention indicated whether students in both intervention and comparison classes changed in the same way across the semester. A non-statistically significant parameter estimate of the interaction with time and intervention indicated there was no difference in how students changed over the semester with respect to the dependent variable of interest— while a statistically significant result indicated here *was* a difference in how students in the intervention and comparison changed over the semester with respect to the dependent variable of interest.

Results

Descriptive statistics indicated the scores across all four constructs were high and relatively stable (Table 2). Of note, the variability on this seven-point scale was relatively small and ranged from 0.58 to 1.32. With the exception of challenge discriminatory behavior, the intervention and comparison sections demonstrated similar initial means. Students in the intervention section started with slightly higher scores than the comparison sections in their likelihood to challenge discriminatory behavior. By the end of the semester, intervention classes appeared to have slightly higher mean scores across all constructs.

Table 2. Descriptive statistics of the Four Constructs of Interest by Time and Intervention Status

	Time	Comparison			Intervention		
		N	Mean	*SD*	*N*	Mean	*SD*
Fulfill a Greater Purpose	1	137	5.91	1.24	115	5.89	1.22
	2	123	5.72	1.26	96	5.91	1.32
	3	118	5.68	1.22	104	5.79	1.22
	4	123	5.89	1.11	102	6.02	1.11
Serve Customers Better	1	137	6.16	0.85	115	6.12	0.88
	2	123	6.03	0.98	96	5.99	1.27
	3	118	5.99	0.94	104	6.03	1.07
	4	123	6.12	0.94	102	6.25	0.89
Promote a Healthy Team Culture	1	137	6.35	0.62	115	6.33	0.70
	2	123	6.36	0.72	96	6.42	0.73
	3	118	6.26	0.92	104	6.37	0.67
	4	123	6.23	0.83	101	6.51	0.58
Challenge Discriminatory Behavior	1	136	5.45	1.54	115	5.69	1.20
	2	121	5.71	1.34	96	5.85	1.12
	3	116	5.61	1.40	104	5.80	1.14
	4	122	5.78	1.31	101	5.82	1.03

Next, the three regression models previously described for each of the four construct means were applied (Table 3). Only Promote a Healthy Team culture showed a statistically significant increase in the change in R^2 when the intervention and interaction variables were added.

Table 3. Model comparison results for the three fitted models for each of the four constructs of interest

	Model	*R*	R^2	ΔR^2	ΔF	*df1*	*df2*	*p for* ΔF
Fulfill a Greater Purpose	A	0.003	0.001	0.003	1.303	2	915	0.272
	B	0.003	0.000	0.000	0.028	1	914	0.867
	C	0.005	-0.001	0.002	0.855	2	912	0.426
Serve Customers Better	A	.043	0.002	0.002	0.860	2	915	0.423
	B	.044	0.002	0.000	0.080	1	914	0.777
	C	.056	0.003	0.001	0.531	2	912	0.588
Promote a Healthy Team Culture	A	.096	0.009	0.009	4.221	2	914	0.015
	B	.096	0.009	0.000	0.009	1	913	0.927
	C	.140	0.020	0.010	4.861	2	911	0.008
Challenge Discriminatory Behavior	A	.036	0.001	0.001	0.603	2	908	0.547
	B	.070	0.005	0.004	3.254	1	907	0.072
	C	.095	0.009	0.004	1.871	2	905	0.155

Note: Model A controlled for teacher effects. Model B included time as a predictor. Model C added intervention and its interaction with time.

The parameter estimates illustrate the same pattern but with more detail (Table 4). There were only statistically significant effects of the intervention on time (Model C, β_5) in the model for the likelihood to promote a healthy team culture. In the likelihood to promote a healthy team culture models, the non-statistically significant parameter estimate of the intervention (Model C, β_4) indicated there were not differences between the intervention and comparison sections *at the beginning* of the semester in their likelihood to promote a healthy team culture, which is good because this non-statistically significant effect illustrates two groups were not different at the beginning of the semester. However, the statistically significant interaction effect (Model C, β_5) indicates that as time passed, students in the intervention sections increased in their likelihood to promote a healthy team culture while the students in the comparison class decreased in their likelihood to promote a healthy team culture. The effects are illustrated in Figure 1. Using the variability in the means for the intervention students at the beginning of the semester as a metric (*SD* =.70), by the end of the intervention students were approximately 0.35 standard deviations different from the comparison students by the end of the semester.

Table 4. Parameter estimates for the three models for each of the four constructs of interest

	Fulfill a Greater Purpose				Serve Customers Better				Promote a Healthy Team Culture				Challenge Discriminatory Behavior			
	b	*SE*	*β*	*p*	*b*	*SE*	*β*	*p*	*b*	*SE*	*β*	*p*	*b*	*SE*	*β*	*p*
Model A																
Intercept, β_0	5.85	0.04		0.00	6.07	0.04		0.00	6.33	0.03		0.00	6.33	0.03		0.00
Teacher Effect-A, β_1	-0.19	0.12	-0.07	0.12	-0.07	0.10	-0.03	0.47	0.21	0.07	0.12	0.00	0.21	0.07	0.12	0.73
Teacher Effect-B, β_2	-0.07	0.10	-0.03	0.51	0.03	0.08	0.02	0.71	0.14	0.06	0.10	0.02	0.14	0.06	0.10	0.56
Model B																
Intercept, β_0	5.84	0.07		0.00	6.06	0.05		0.00	6.34	0.04		0.00	6.34	0.04		0.00
Teacher Effect-A, β_1	-0.19	0.12	-0.07	0.12	-0.07	0.10	-0.03	0.47	0.21	0.07	0.12	0.00	0.21	0.07	0.12	0.75
Teacher Effect-B, β_2	-0.07	0.10	-0.03	0.51	0.03	0.08	0.02	0.71	0.14	0.06	0.10	0.02	0.14	0.06	0.10	0.53
Time, β_3	0.01	0.04	0.01	0.87	0.01	0.03	0.01	0.78	0.00	0.02	0.00	0.93	0.00	0.02	0.00	0.07
Model C																
Intercept, β_0	5.82	0.09		0.00	6.09	0.07		0.00	6.35	0.05		0.00	6.35	0.05		0.00
Teacher Effect-A, β_1	-0.19	0.12	-0.07	0.12	-0.07	0.10	-0.03	0.47	0.21	0.07	0.12	0.00	0.21	0.07	0.12	0.74
Teacher Effect-B, β_2	-0.07	0.10	-0.03	0.52	0.03	0.08	0.02	0.70	0.15	0.06	0.10	0.02	0.15	0.06	0.10	0.53
Time, β_3	-0.01	0.05	-0.01	0.82	-0.02	0.04	-0.02	0.66	-0.05	0.03	-0.07	0.11	-0.05	0.03	-0.07	0.07
Intervention, β_4	0.04	0.13	0.02	0.75	-0.06	0.11	-0.03	0.60	-0.04	0.08	-0.03	0.63	-0.04	0.08	-0.03	0.09
TimeXInt, β_5	0.04	0.07	0.03	0.60	0.05	0.06	0.06	0.34	0.10	0.04	0.14	0.02	0.10	0.04	0.14	0.46

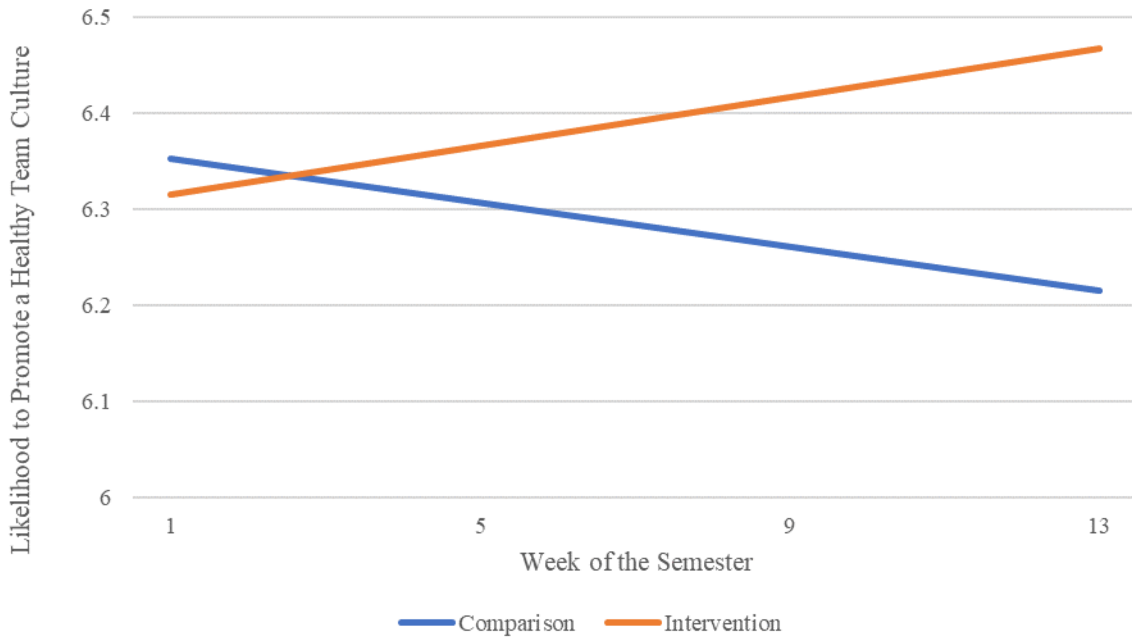

Figure 1. *Model Implied Likelihood to Promote a Healthy Team Culture across the first semester of engineering for students in intervention and comparison classes*

Discussion

In this National Science Foundation (NSF) funded study, we take a different approach to changing the chilly climate in engineering. There are many research-supported programs that provide additional supports specifically for underrepresented students. We seek to augment those programs by addressing ***all*** engineering students to make the environment warmer.

These results indicate students in the intervention and comparison sections did not differ at the first time point across any of the subscales, and students in the intervention were statistically significantly higher in indicating a likelihood to enact behaviors that promote a healthy team culture by the end of the semester.

In our opinion, the intervention activities represented a substantial effort from the instructors and researchers to help engineering students value diversity in engineering and enact inclusive behaviors. The fact that there were only small effects of the interventions on one of the constructs of interest was somewhat discouraging, but we maintain hope. Students generally started very high on the constructs, so getting any kind of increase may have been difficult due to potential ceiling effects. Researchers should consider alternate ways to assess the effects of diversity, equity, and inclusion activities.

Further research is needed to address other ways in which students were impacted. For example, are students who participate in intervention classes more likely to persist in engineering programs, and do the interventions have the same impact on majority students (e.g., White, Asian, male, and gender conforming) as traditionally non-majority students (e.g., Black, Latinx, female, or gender non-conforming)?

Change is difficult. These interventions are the first in a series of activities the students will be exposed to as they progress throughout the engineering curriculum. It is our hope that continued exposure to similar curriculum paired with critical experiences with diverse students will support the development of these engineering students into engineers who are inclusive. Much work remains to be done.

Epilogue

We made some changes in spring 2019 to the sequence of activities in the course described in this study. The faculty implementing these activities are doing so because the activities have been integrated into the common curriculum for this course. After some discussions with the faculty at the end of fall 2018, we moved the panel of engineers to the second course in this first-year engineering series. The faculty felt the content of this activity was a better fit with the curriculum in the second class. Also, this second class only had three grant related activities, and moving the panel better balanced the distribution of activities across the two classes.

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