Revisiting Engineering Identity in a Common Introduction to Engineering Course to Improve Retention

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Abstract

This complete research paper revisits and describes the efficacy of first-year retention interventions focused on engineering identity that were developed for a common Introduction to Engineering course. This research aims to improve retention rates where presently about half of the engineering undergraduate students exit or drop out [1]. The American Society of Engineering Education (ASEE) has indicated that engineering universities should develop retention programs to reduce these numbers [1]–[3]. One of the main recommendations is to develop first-year retention programs [1]–[3]. At one university, two engineering professors developed first-year retention interventions into the common Introduction to Engineering course they teach. The main interventions employed included refocusing the course on engineering identity. To initially measure if these interventions were effective, an engineering identity pre and post survey was given to four common Introduction to Engineering courses, which comprised of 169 high school and undergraduate students who completed the courses taught in 2016 [4]. Four more classes were given the pre and post surveys that were taught in 2017 and 2018 to bring the total number of students surveyed to 273.

The survey instrument used in this study was largely adopted from Prybutok, Patrick, Borrego, Seepersad, and Kiristis [5] who completed a similar study. This paper discusses the quantitative results from these engineering identity pre and post surveys. During the initial look of the courses taught in 2016, the engineering factors that significantly improved from the pre to the post surveys included: performance/competence, design efficacy, recognition by others, and recognition by self [4]. The other engineering factors measured for the courses taught in 2016 that were found to not have significantly improved included: interest, creativity, and caring [4]. By adding the four courses taught in 2017 and 2018, the engineering factors that significantly improved from the pre to the post surveys included: performance/competence, interest, creativity, design efficacy, recognition by others, and recognition by self. The only engineering factors measured from 2016-2018 that was found to not have significantly improved included: caring. These interventions improved the students' engineering identities. Future work should include conducting a paired survey where the participants' pre and post survey results are connected and look at ways to improve the students' engineering identity in the area of caring.

Introduction

Engineering identity is one avenue that engineering educators can use to help improve retention [5], [6]. Engineering identity is described as "the process of identifying with engineering, developing an engineer identity, and becoming an engineer" [7, pp. 1–2]. Engineering identity is identified as an important concept to consider in order to retain females and minority students or those who are underrepresented in engineering [5]–[8]. The goal for incorporating engineering identity in the common Introduction to Engineering course was to help improve retention and persistence of students by having them identify themselves early as engineers.

The survey instrument used in this study was largely adopted from Prybutok, Patrick, Borrego, Seepersad, and Kiristis [5] who completed a similar study. Prybutok, Patrick, Borrego, Seepersad, and Kiristis [5] developed their engineering identity survey based on a physics identity model [9], [10]. This physics model used four factors: performance, competence, interest, and recognition [5], [9], [10]. Performance is where a student believes in their ability to perform tasks specific to engineering [5]. Competence is when a student believes in their ability to be successful in engineering [5]. Prybutok, Patrick, Borrego, Seepersad, and Kiristis [5] described interest as “how motivated a student is in the content and career they are pursuing, often encompassing the motives a student has for pursing engineering” (p. 2). Lastly, recognition is when a student is seen by others as an engineer and then if they themselves recognize themselves as an engineer [5]. Prybutok, Patrick, Borrego, Seepersad, and Kiristis [5], using the physics model [9], [10], developed their own survey that included engineering factors: performance/competence, interest, creativity, design efficacy, recognition by others, recognition by self, and caring.

Initially, for the 2016 surveys, the professors used several tactics to incorporate engineering identity in the common Introduction to Engineering course. First, the professors incorporated more information about each of the four engineering disciplines that are offered at the university to help them improve their engineering interest. Second, students were required to complete daily team activities that helped them explore a topic within each of the engineering disciplines. For example, following a discussion on mechanical engineering, students were asked to design a wheelchair that could operate in both sand and snow. Students would work in teams to come up with a design, how the chair would be powered, and how much the chair would cost. These activities were designed to help improve their engineering performance/competence, interest, creativity, and design efficacy. Third, to help students improve their communication skills, students were also required to present their results from these team activities in front of the class. It is possible that explaining engineering topics in front of the class helps others and themselves seeing themselves as engineers. Fourth, students were also required to develop one-minute engineering identity presentations as their final individual project. Students were asked to explain what kind of engineers they wanted to become (civil, mechanical, etc.), their definition of engineering, why they cared about becoming an engineer, and where they saw themselves in 5 or 10 years. These presentations were designed to help students to start visualizing themselves as engineers or improve their engineering recognition and caring. Fifth, the students were also asked to develop cardboard chairs for their final team project. Students work together in teams to develop the chairs and then present their chair to the class. This project was designed to help students improve their engineering performance/competence, interest, creativity, and design efficacy. Lastly, students were required to complete weekly homework assignments where they personally reflect on topics such as their engineering interests, study plan, and any barriers they can foresee that might prevent them from becoming an engineer. These were designed to improve their engineering performance/competence, interest, and caring.

The results from the 2016 surveys helped the professors consider other tactics to incorporate engineering identity in the common Introduction to Engineering course to help retention. First, the professors developed a lecture that helped students explore the engineering identity element of caring. The professors showed students a video about great engineering achievements such as exploring outer space and developing life changing medical devices to help people hear and walk. Then the students were asked to discuss in small teams which discipline of engineering they were considering and why they care about becoming engineers. Students were then asked to report out why they cared about becoming engineers. Students described wanting a high paying job, wanting job stability, wanting to invent something new, and liking to tinker with machines or figuring out how machines work. Second, instead of having students develop individual engineering identity presentations, they were instead asked to develop engineering solutions to a local, national, or global engineering problem. The students conducted these in small teams and were required to clearly defined the engineering problem they wanted to solve, develop a flyer to sell their engineering solution, and conduct five-minute presentations in class. This project was designed to help students improve their engineering performance/competence, interest, creativity, and design efficacy. Lastly, weekly homework was removed as a requirement so that students could focus on the team projects. This was done because students each semester were withdrawn from the course if they did not complete a minimum required number of assignments. It is possible that students who do not participate successfully in the common Introduction to Engineering course may switch majors because of this adverse experience. Also, many indicated on the course surveys that weekly assignments were asking too much to them for just a one unit course.

Methods

Study Participants

Participants in the study were high school or undergraduate engineering students. High school students voluntarily participated in the common Introduction to Engineering course, so they could receive college credits while they were still in high school. Undergraduate students at this university are typically directly admitted into their specific engineering majors because there are no first-year engineering programs. The common Introduction to Engineering course is a first-year engineering course that is required for all the undergraduate engineering students to complete.

There were 273 students who participated in the pre survey. Of these 273 students, 73 (26.7%) were female. When the post surveys were given, there were students who missed class or withdrawn from the course. Therefore, only 211 students completed the post survey. Of these 211 students, 55 (26.1%) were female. It is also possible that a couple of those that took the post survey were not present for the pre survey. Refer to Table 1 which shows the number and percent of gender and ethnicity of the students that participated in this study.

Table 1. Number and Percent of Gender and Ethnicity of Study Participants

	Pre		**Post**	
	Number	**Percent (%)**	**Number**	**Percent (%)**
Gender				
Female	73	26.7	55	26.1
Male	192	70.3	147	69.7
Prefer not to say	8	2.9	9	4.3

Ethnicity				
Alaska Native/American Indian	39	14.3	23	10.9
Asian/Pacific Islander	28	10.3	22	10.4
Black/African American	7	2.6	4	1.9
Hispanic/Latino	11	4.0	13	6.2
White/Caucasian	120	44.0	83	39.3
2 or More Ethnicities	54	19.8	54	25.6
Other	3	1.1	0	0.0
Prefer not to say	11	4.0	12	5.7
Total	**273**	**100**	**211**	**100**

Survey and Data Collection

The survey instrument used in this study was largely adopted from Prybutok, Patrick, Borrego, Seepersad, and Kiristis [5] who completed a similar study. The engineering factors and questions used from the survey Prybutok, Patrick, Borrego, Seepersad, and Kiristis [5] developed, included: performance/competence, interest, creativity, design efficacy, recognition by others, recognition by self, and caring [5]. The only questions not used from the survey Prybutok, Patrick, Borrego, Seepersad, and Kiristis [5] developed, included the physics and math identity questions.

The survey used in this study had a total of 24 engineering identity questions, of which 23 were Likert scale questions, and one was an open-ended question. Refer to Table. 2 for a list of the engineering factors, 23 Likert survey items, and response scales used. The open-ended question asked the students: “Can you describe why you *care* about becoming an engineer?”. The survey also asked for students to indicate their gender and ethnicity. This survey was given to the students on the first day of class to collect their pre responses and then on the last day of class to collect their post responses. This survey required 5 minutes of class time for the students to complete it.

Table 2. Engineering Factor Survey Items and Likert Response Scales

Engineering Factor	Survey Item	Likert Response Scale
Performance/ Competence	To what extent do you disagree or agree with the following statements? • I am confident that I can understand engineering outside of class • I can overcome setbacks in engineering • I am confident that I can understand engineering in class • I can do well on exams in engineering • I can understand concepts I have studied in engineering	1 for Strongly Disagree 2 for Disagree 3 for Undecided or Unsure 4 for Agree 5 for Strongly Agree

Interest	To what extent do you disagree or agree with the following statements? • I feel good when I am doing engineering • I like to build stuff • I think engineering is fun • I think engineering is interesting • I like to figure out how things work	1 for Strongly Disagree 2 for Disagree 3 for Undecided or Unsure 4 for Agree 5 for Strongly Agree
Creativity	To what extent do you disagree or agree with the following statements? • I like to think creatively (out-of-the-box) • I like to solve problems in creative ways • I like open ended-problems	1 for Strongly Disagree 2 for Disagree 3 for Undecided or Unsure 4 for Agree 5 for Strongly Agree
Design Efficacy	How confident are you in your ability to do the following? • Design a product or process on your own • Design a product or process in a team	1 for Not at all Confident 2 for A little bit Confident 3 for Somewhat Confident 4 for Agree 5 for Strongly Agree
Recognition by Others	Do the following see you as an engineer? • Parents • Relatives • Friends	1 for No, Not at All 2 for Seldom 3 for Sometimes 4 for Often 5 for Yes, Very Much
Recognition by Self	Do the following see you as an engineer? • Yourself • Engineering instructor(s)	1 for No, Not at All 2 for Seldom 3 for Sometimes 4 for Often 5 for Yes, Very Much
Caring	In your opinion, to what extent are the following associated with the field of engineering? • Saving lives • Caring for communities • Protecting the environment	1 for Not at All 2 for A little bit 3 for Somewhat 4 for Quite a bit 5 for Very Much So

These engineering factors, survey questions, and Likert response scales were adopted from Prybutok, Patrick, Borrego, Seepersad, and Kiristis [5].

Analysis Procedures

The data was manually compiled and coded from the surveys collected. Questions where students did not respond were cleaned from the data. Refer to Table 3 for the engineering factors and the corresponding percent response rates. The recognition by self response rates were a bit lower than the other questions. This was because students sometimes left the question for "do engineering instructor(s) see you as an engineer?" blank. It is suspected that this question was left blank because the common Introduction to Engineering course was most likely the first course where the students interacted with an engineering instructor, therefore they did not know how to answer that question during their pre survey.

Table 3. Engineering Factors and Corresponding Percent Response Rate

Engineering Factor	Percent Response Rate (%)	
	Pre	Post
Performance/ Competence	98.3	99.1
Interest	98.7	99.2
Creativity	98.4	99.4
Design Efficacy	96.9	97.4
Recognition by Others	96.5	95.9
Recognition by Self	89.0	94.3
Caring	97.2	96.8

Results

Refer to Table 4 for the engineering factors their corresponding mean responses found from the pre and post surveys, the difference between the pre and post surveys, and corresponding p-values from the t-tests conducted. The engineering factors that improved significantly from the pre to the post surveys included: performance/competence, interest, creativity, design efficacy, recognition by others, and recognition by self. The only engineering factors that did not significantly increase from the pre to post surveys included: caring.

Table 4. Engineering Factors Pre and Post Survey Means and Difference Between Pre and Post Means

Engineering Factor	Mean			P-Value
	Pre	Post	Difference	
Performance/Competence	4.03	4.21	0.179	0.0000*
Interest	4.34	4.46	0.117	0.0001*
Creativity	4.16	4.28	0.116	0.0066*
Design Efficacy	3.63	3.97	0.345	0.0000*
Recognition by Others	3.50	3.75	0.247	0.0002*
Recognition by Self	3.58	3.85	0.261	0.0005*
Caring	4.22	4.32	0.094	0.0645

* p-value < 0.05

Discussion and Conclusion

In conclusion, the engineering factors of performance/competence, interest, creativity, design efficacy, recognition by others, and recognition by self, all significantly improved from the pre to post surveys indicating an improvement in students' engineering identity. The pre and post survey mean for performance/competence, interest, and creativity increased by staying in the Likert scale range of 4 corresponding to a response of "Agree". The pre and post survey mean for design efficacy increased by staying in the Likert scale range of 3 corresponding to a response of "Somewhat confident". The pre and post survey mean for recognition by others and recognition by self increased by staying in the Likert scale range of 3 corresponding to a response of “Sometimes”. Further research could find which specific engineering identity intervention activities were helpful in improving these engineering identity factors.

It is unclear why the engineering factor of caring did not significantly increase. The professors should develop more engineering identity interventions that are specifically directed at the engineering factor of caring. It is also possible that the survey questions in the caring section do not capture all of the reasons why students care about becoming engineers. For example, job stability and a high paying job are not caring response options. Connecting the participants pre and post surveys, or doing a paired study, would have shown which students increased their engineering identity and in which factors.

The professors should also continue to improve the common Introduction to Engineering course and evaluate if these engineering identity interventions are effective. It is possible that these engineering identity interventions could be included in other common engineering courses to help improve retention and persistence of engineering students. The pre survey results indicate that the students’ engineering identity was already high, which may mean that students do not have issues with engineering identity. Therefore, the professors should also look into other areas to improve retention such as mentoring and tutoring [2], [3].

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