Multi-year Cross-sectional Study of Perceptions of and Self-confidence in Engineering as a Major and Profession of Female First-semester First-year Students

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Abstract

This Complete Research paper will describe how first-semester first-year female engineering students perceive the engineering profession and its associated career opportunities, as well as their confidence in their choice of both engineering as a career and their specific major. This study examines quantitative data gathered over a decade from nine cohorts of female first-year engineering students from a large Midwestern research institution. At this particular institution, all engineering students begin in First-Year Engineering (FYE) and typically transition into their specific engineering discipline at the start of their sophomore year. Students enrolled in a Women in Engineering seminar were surveyed in the first and last weeks of their first semester in FYE. The assessment instruments were designed to measure their perceptions of the engineering profession and career opportunities and their self-confidence in selecting engineering as a career and their specific major.

Results indicate that female students gain a better understanding of the engineering profession and the various career options for engineering majors during their first semester of college. At the conclusion of their first semester, they are also more confident in their selection of engineering as both a career and a major. However, their excitement towards future engineering classes has significantly diminished. Also noteworthy is that over the past decade, initial understanding of the profession and awareness of career options for engineers has steadily increased implying that students are now entering the university better informed about the field of engineering.

This paper will explore first-year female students' perception of and self-confidence with respect to engineering. Results and conclusions from this study may be used to improve the support and resources provided to first-year women in engineering with the ultimate goal of increased persistence.

Introduction and Related Work

A student's perception of and self-confidence in engineering have been shown to influence their persistence in undergraduate degree programs. College students with a strong understanding of the engineering profession are more likely to persist in engineering, however, those without may switch

majors and exit engineering[1]. The more familiar students are with the variety of engineering occupations that are available to them, the higher their confidence in their personal choice[2]. In addition, a student's career optimism[3,4] is related to their personal academic satisfaction. Such findings illustrate the importance for first-year students to understand the engineering profession and various career possibilities.

Interest is also an important factor in deciding on and succeeding in an engineering major; interest-major fit can affect a student's persistence in a major[5]. Interest is known to be correlated with academic success[6], and, in general, students' high self-confidence has been correlated with their interest in the subject being studied[7]. However, it has been found that self-confidence[7] and interest[8] in engineering drops in the first year. Knowing that women who leave engineering majors have overall lower self-confidence[9], it is vital to understand first-year students' self-confidence and interest in engineering.

It has been shown that an understanding of engineering career options, optimism, self-confidence, interest, and academic persistence are related. This quantitative assessment study provides a better understanding of the confidence that first-year female engineering students exhibit with respect to their choice to study engineering and their perceptions of engineering majors and careers. These insights may then, in turn, be utilized to develop impactful tools, resources, and/or support networks for female students pursuing engineering degrees with the goal of increasing persistence.

Methods

This study is focused on the perceptions and self-confidence of female first-year engineering students from 2008 to 2018 at a large research institution where all engineering students begin in a First-Year Engineering (FYE) program. Participants for this study elected to enroll in a one-credit Women in Engineering seminar course designed to provide students with an understanding of the engineering profession and strategies for success. Demographic, perception, and self-confidence data were collected through pre- and post-surveys given on the first and last days of class, respectively. Study participants were first-year female engineering students who matriculated to an engineering discipline.

Research Questions

This research is guided by the following research questions:

- How do first-year female students' perceptions of engineering change by entering cohort?
- How do first-year female students' self-confidence in engineering change by entering cohort?
- Can a first semester seminar course targeted to female students significantly strengthen perception of or increase self-confidence in engineering?

Data Collection

The first iteration of the assessment instrument was developed by an expert in the field of student success in the Fall of 2000 to measure the impact of the seminar course. Over the next several years, the developer, after analyzing the data, added and modified questions to better gauge changes in the students' perceptions. The pre- and post-survey in use today was finalized in the Fall of 2007. While the survey has not yet undergone rigorous validity and reliability testing, it was developed by an expert in the field of study and results gleaned from more than a decade of consistent data collection can provide meaningful insight into the perceptions of the sample population.

This study examines data collected from Fall of 2008 to the Fall of 2018 from female first-year engineering students. Only aggregate data, not the individual student surveys, were retained from Fall of 2000 to Fall of 2007, rendering this data unusable for this study as we were not able to systematically verify that students who took the survey were female and first-year and in engineering.

The surveys gathered demographic information and responses to eight questions that were rated on a 5-point Likert scale from 1 (Completely Disagree) to 5 (Completely Agree). Questions 1, 2, 3, and 6 (Q1, Q2, Q3, and Q6 respectively) focused on perceptions of engineering and Questions 4, 5, 7, and 8 (Q4, Q5, Q7, and Q8 respectively) on self-confidence in engineering. The questions are listed below.

1. I feel I have a good understanding of the engineering profession.
2. I am aware of the various career options for engineering majors.
3. I am excited about the job opportunities available for engineers.
4. I am confident about choosing engineering as a major.
5. I feel confident that I have selected the best area of engineering for me. (If concentration still uncertain, circle 1).
6. I am looking forward to my classes in engineering.
7. I am confident that I can develop close relationships with other women engineering students.
8. I am confident that I can be an engineer who will do great things for society.

The sample size for each cohort year is shown in Table 1. The 2014 individual participant pre-survey data was not retained and only aggregate data exists. The 2016 individual participant post-survey data was not collected on the last day of class. Rather, it was collected via email well into the following semester. The response rate was extremely low (less than 20%) and since this was after the students received their semester grades, responses could have been biased. Therefore, the 2016 post-survey data was not used in this study. Finally, Q4 on the 2018 pre-survey was inadvertently omitted. This was rectified on the 2018 post-survey.

Table 1: Cohort Sample Size

Year	n
2008	117
2009	109
2010	141
2011	186
2012	199
2013	131
2014	159
2015	189
2016	249
2017	167
2018	185

Data Analysis

Paired t-test results were used to determine if a significant change (α = 0.05) existed between the pre- and post-survey scores within each year. Note that 2014 and 2016 were excluded due to missing pre-surveys and post-surveys, respectively.

To examine the changes in perception of and self-confidence in engineering by entering cohort, pre- and post-survey annual averages were analyzed and a linear regression model used to create lines of best fit. A regression slope test was completed to determine if there was a significant change in averages by entering cohort.

Results

The pre-survey and post-survey averages for the eight Likert scale questions for each cohort are provided in Table 2.

The paired t-test results are provided in Table 3. Questions 1, 2, 4, and 5 saw a significant increase from pre- to post-survey averages in all cohorts. The pre- to post-survey differences found in Q6 are significant in five of the nine cohorts, and when significant, it is always with a decrease in post-survey scores. Significant increases for Questions 3, 7, and 8 were typical in the early cohorts however, any changes seen in the more recent cohorts are rarely significant.

Regression slope test results for perception related questions are shown in Figure 1(a) through 1(d) and the self-confidence related questions in Figure 2(a) through 2(d). Questions 1 and 2 show a significant increase and Q5 a significant decrease in pre-survey average scores from 2008 to 2018. Questions 1, 3, 4, 7, and 8 each show a significant decrease in post-survey average scores over the same time period.

Table 2: Pre- and Post-Survey Averages for Each Cohort by Question

Cohort/Question	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
2008 Pre	3.68	3.66	4.64	4.08	3.13	4.45	4.45	4.47
2008 Post	4.57	4.63	4.88	4.55	4.10	4.32	4.63	4.66
2009 Pre	3.78	3.84	4.72	4.20	3.17	4.45	4.49	4.52
2009 Post	4.55	4.64	4.86	4.57	4.04	4.36	4.64	4.69
2010 Pre	3.72	3.76	4.77	4.23	3.09	4.47	4.57	4.54
2010 Post	4.50	4.67	4.85	4.55	3.98	4.38	4.74	4.72
2011 Pre	3.68	3.72	4.75	4.20	3.09	4.48	4.51	4.58
2011 Post	4.61	4.69	4.88	4.60	4.05	4.36	4.69	4.74
2012 Pre	3.74	3.79	4.79	4.24	3.05	4.32	4.54	4.64
2012 Post	4.50	4.67	4.88	4.63	3.96	4.35	4.69	4.72
2013 Pre	3.77	3.82	4.77	4.17	3.11	4.39	4.51	4.54
2013 Post	4.55	4.66	4.76	4.54	4.11	4.25	4.52	4.64
2014 Pre	-	-	-	-	-	-	-	-
2014 Post	4.40	4.69	4.82	4.58	3.98	4.37	4.57	4.73
2015 Pre	3.80	3.92	4.80	4.20	3.01	4.59	4.52	4.57
2015 Post	4.48	4.59	4.77	4.39	3.93	4.34	4.42	4.50
2016 Pre	3.82	3.83	4.79	4.19	3.02	4.54	4.60	4.59
2016 Post	-	-	-	-	-	-	-	-
2017 Pre	3.82	3.92	4.76	4.20	2.84	4.49	4.50	4.55
2017 Post	4.53	4.66	4.87	4.51	4.09	4.39	4.52	4.56
2018 Pre	3.76	3.90	4.76	-	3.04	4.58	4.48	4.47
2018 Post	4.31	4.42	4.68	4.15	3.90	4.35	4.45	4.58

Table 3: Summary of Paired T-Test Significance

Cohort/Question	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
2008	<.0001*	<.0001*	<.0001*	<.0001*	<.0001*	.0444^	.0058*	.0047*
2009	<.0001*	<.0001*	.0055*	.0001*	<.0001*	.2302	.0168*	.0088*
2010	<.0001*	<.0001*	.0628	<.0001*	<.0001*	.1364	.0007*	.0008*
2011	<.0001*	<.0001*	.0030*	<.0001*	<.0001*	.0310^	.0042*	.0013*
2012	<.0001*	<.0001*	.0146*	<.0001*	<.0001*	.6055	.0030*	.0434*
2013	<.0001*	<.0001*	.8535	<.0001*	<.0001*	.0464^	.9098	.0716
2015	<.0001*	<.0001*	.4547	.0019*	<.0001*	<.0001^	.0430^	.2097
2017	<.0001*	<.0001*	.0076*	<.0001*	<.0001*	.1026	.6874	.9017
2018	<.0001*	<.0001*	.0592	-	<.0001*	<.0001^	.7205	.0452*

(*) Indicates statistically significant increase (^) Indicates statistically significant decrease

Discussion

These data have been collected for almost two decades from first-year female engineering students who elected to enroll in a Women in Engineering seminar course. The assessment instrument, while perhaps rudimentary, has resulted in consistent responses indicating the students' understanding of the questions has not changed over the years.

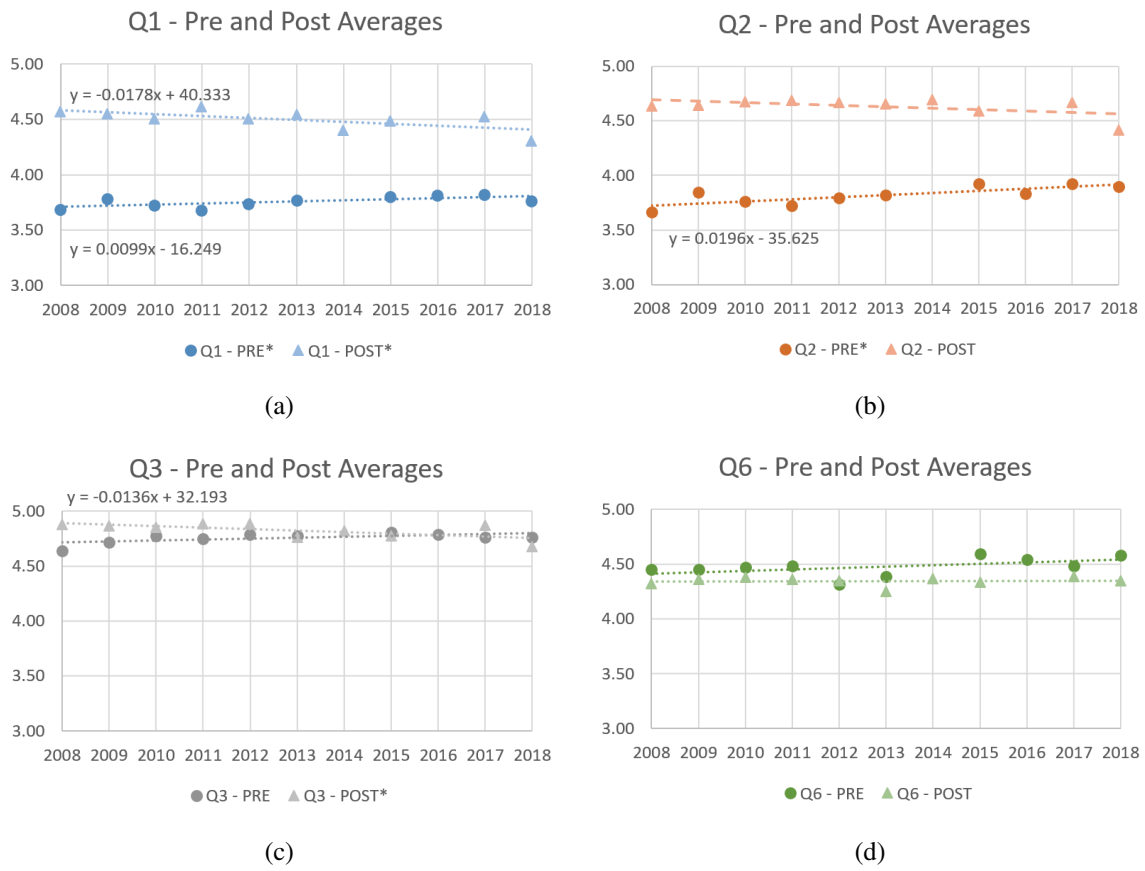

Figure 1: Pre- and post-survey averages and lines of best fit by cohort for perception related questions. Equations for the lines of best fit with significant slopes are provided. (a) Q1, (b) Q2, (c) Q3, and (d) Q6. (* indicates significant increase/decrease of best fit line.)

Perception of Engineering

Participants' perception of and interest in engineering was measured by questions around understanding the profession (Q1), various career options (Q2), job opportunities (Q3), and upcoming classes (Q6).

Each cohort saw a significant increase from pre- to post-survey averages in both Q1 and Q2 (Table 3). Material that students are exposed to during their first semester increases their understanding of the profession and various career options, and should aid them when selecting their specific engineering major. Over the past decade, however, post-score averages for Q1 have steadily decreased (Figure 1(a)). It is also interesting to note that Q1 is the only question in which both the pre- and post-survey best fit lines show a significant trend. The trend of the pre-survey averages is increasing while the post-survey is decreasing resulting in the difference between the two, while significant, to be decreasing. This indicates that students entering the institution today feel they have a better understanding of the engineering profession and various career opportunities than their predecessors and, over the course of the semester, are significantly increasing this understanding and awareness. This could be attributed to the institution's collective efforts to paint

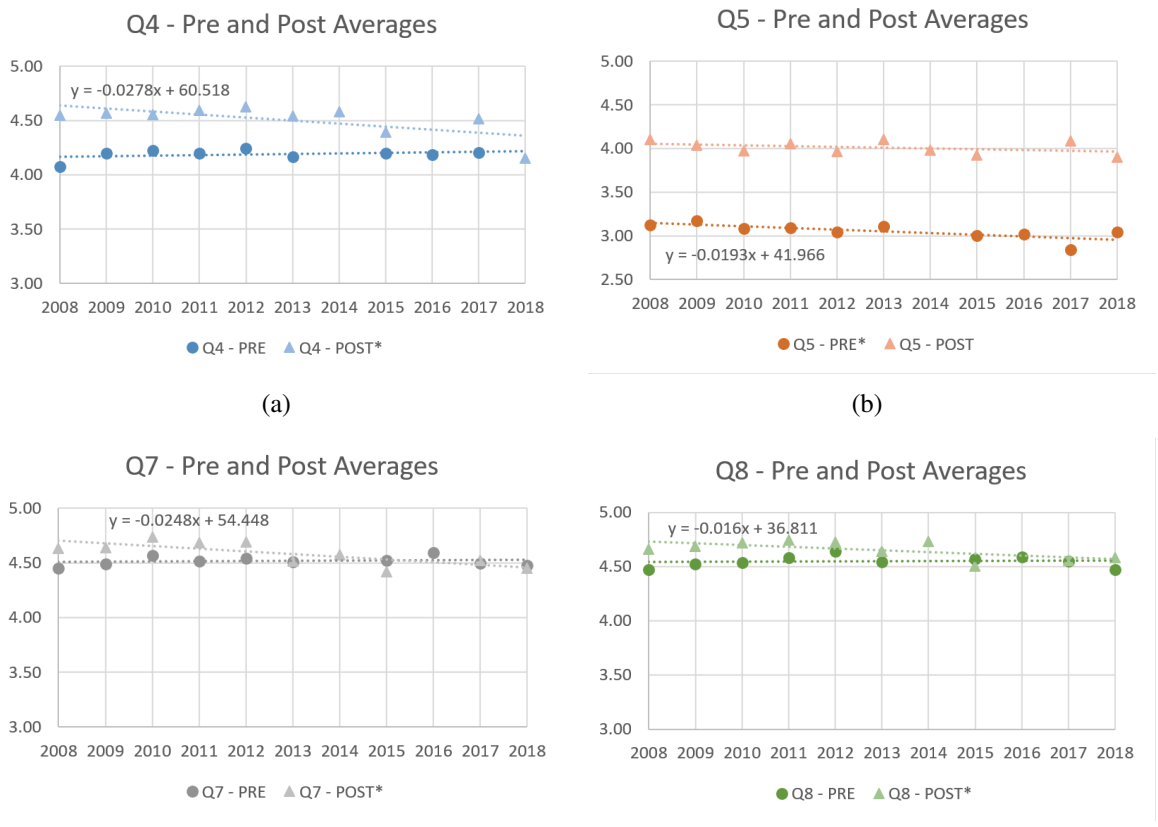

Figure 2: Pre- and post-survey averages and lines of best fit by cohort for self-confidence related questions. Equations for the lines of best fit with significant slopes are provided. (a) Q4, (b) Q5, (c) Q7, and (d) Q8. (* indicates significant increase/decrease of best fit line.)

a complete picture of the engineering profession to FYE students.

More than half of the cohorts saw a significant increase between Q3 (excitement around job opportunities for engineers) pre- and post-survey scores. In addition, there is also a significant downward trend in the post-survey scores (Figure 1(c)). Due to this downward trend, significant increases have been rare in recent years. However, Q3 has recorded the highest pre-survey average for every cohort. In fact in the past two years, the average pre-survey scores were 4.76 out of a possible 5.00 leaving little room to measure a significant increase over the course of the semester. This shows that students are entering the institution very excited about job opportunities which could be attributed to previous education on engineering, outreach conducted by universities or programs, or the concerted efforts in the United States to change the conversation about engineering [10].

A significant decrease in pre-survey to post-survey scores was found in five of the nine, and three of the last four, cohorts for Q6 (looking forward to upcoming engineering classes). It is important to also note that the Q6 best fit lines have neither an upward nor downward trend indicating that over the past decade student responses have been consistent (Figure 1(d)). Hence, the students' excitement toward their upcoming engineering classes declined over the course of their first

semester. While a qualitative study would help to identify reasons for this decline, these findings are similar to Jones et. al.[11] who found that students' expectations for success in engineering courses, their engineering self-efficacy, and their identification with engineering decreased over the first year for both men and women alike. While this is concerning, it is important to note that all Q6 post-survey averages were at or above 4.25 on a 5.00 scale (Table 2).

Self-confidence in Engineering

Participants' engineering self-confidence was considered by examining confidence about pursuing the engineering field (Q4), choosing their specific engineering major (Q5), developing close relationships with other women engineers (Q7), and being an engineer who will do great things for society (Q8).

All cohorts' pre- to post-survey results show a significant increase in both confidence for choosing the engineering field (Q4) and for selecting the best engineering area (Q5) (Table 3). Students becoming more self-confident in their choice to study engineering (Q4) after only one semester is promising, but the significant post-survey average decreases over time are of concern (Figure 2(a)). This will be a point of investigation in future cohorts, but given that the institution's high retention rates to engineering for first-year engineering students throughout the investigation time frame range from 84.0% to 90.3% (unpublished institutional data), this may not warrant further attention.

Responses to Q5 (confidence in choosing a specific major) consistently registered a positive significant increase between pre- and post-surveys, however it is important to note the wording of the question: 'If concentration still uncertain, circle 1'. On average 25% of respondents entered 1 on the pre-survey and 7% entered 1 on the post-survey. The significant increase from pre- to post-surveys indicates that students become more confident in selecting a specific major, but this result is almost guaranteed due to the wording of the question. In addition, Figure 2(b) shows a significant downward trend in incoming confidence on selecting the best area of engineering. However, due to the nature of the institution's FYE program where students decide on a major during their second semester, and the fact that institutional data shows that more than half of the FYE students select a major different than what they originally planned, these results were not unexpected.

Question 7 investigates the female students' confidence in developing relationships with other female engineers, and Q8 investigates their confidence in doing great things for society as engineers. Both showed significant increases between pre-survey and post-survey scores from 2008 through 2012, but rarely recently. The post-survey averages are significantly decreasing for both of these questions over time, indicating that current students are not gaining as much confidence in these areas compared to previous years (Figures 2(c) and 2(d)). However, both the Q7 and Q8 pre-survey averages are at or over 4.50 on the 5.00 Likert scale and the lowest post-survey average was 4.42. This shows that students are entering college with high confidence in both of these areas and that confidence remains high during their first semester. Alpay et. al.[12] found that female engineering students had 'making a difference to the world' as a key aspiration which is similar to these Q8 results.

Entering Cohorts

It is interesting to note that four (Q1, Q2, Q4, and Q5) of the eight questions consistently measured statistically significant increases between pre- and post-survey results. The other four questions (Q3, Q6, Q7, and Q8), however, all had a 'tipping point' between cohorts 2012 and 2013 of whether the data consistently measured statistical significance. Two notable observations are made regarding these entering cohorts. First, institutional disparities between application gains and admission gains raised questions about equity in the admissions process, and the admission policies were shown to be in favor of men[13]. As a result, new institutional admissions criteria were implemented in Fall of 2011. After this, an increase in the number of admitted and enrolled female students was seen. Secondly, the 2013 cohort is typically considered the first incoming class of Gen Z'ers (those born 1995 or later)[14]. Seemiller and Grace describe Gen Z'ers as entrepreneurial, innovative, and independent learners concerned with effecting social change[14]. Gen Z'ers are considered to be more realistic and social change-oriented than the Millennials. Therefore, this data set could potentially provide interesting insights between female engineering students from the end of the Millennial generation and the beginning of Generation Z.

Conclusions

This multi-year cross-sectional study explores first-year first-semester female engineering students' perception of and self-confidence in engineering as a major and a profession. Previous research has shown when female students leave high-profile STEM majors such as engineering, they are not necessarily leaving STEM overall[15], and that students are not switching between STEM majors due only to academic difficulties, but also due to major and department fit[16]. Therefore, understanding the perceptions and self-confidence of female first-year engineering students could aid program leaders in developing interventions to increase persistence.

This study demonstrates that over the course of the first semester, female students' perception of engineering strengthens. They saw both the engineering profession and various career options in a more favorable way. However, more than half of the cohorts were less excited about future engineering classes. This could be a function of the student body at the study institution where the incoming median GPA of the freshmen engineering student body is 4.0 on a 4.0 scale, meaning the majority of the students have never earned a high school grade lower than an A. The first semester of college may seem particularly challenging in comparison to high school and therefore cause some discouragement. More effort will be put in to preparing the students in the seminar course for the expectations and challenges of the first-year engineering curriculum.

This study also demonstrates that, over the course of their first semester, first-year female engineering students are becoming more confident in their choice of pursuing the engineering field as well as their specific engineering major. This is encouraging as previous research indicates that females' self-confidence in engineering drops in the first year[7].

In this multi-year cross-sectional study, five of the questions examined show a significant negative trend in the post-survey averages. A 5-point Likert scale, which is known to be subjective, was used by the students to rate the degree to which they agreed or disagreed with each question. The large

sample size could potentially mitigate this concern. However, a deeper investigation into the ceiling effect may be warranted as the majority of the most recent (2017 and 2018) post-survey cohort averages were greater than a 4.15 on the 5.00 Likert scale.

It is noted that the conclusions from these survey results do not take into account the other courses and experiences of the first-year engineering student body. It would be interesting to survey male first-year engineering student and/or female first-year engineering students not enrolled in the seminar course to examine their changes in perception of and self-confidence with regard to engineering. This would also allow for a more thorough understanding of the impact of the seminar course itself. Ultimately, results from this study may be used to improve the tools and resources provided to increase persistence of first-year women in engineering.

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