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A Creative First-year Program to Improve the Student Retention in Engineering

Dr. Maryam Darbeheshti, University of Colorado, Denver

Ph.D in Mechanical Engineering

Mr. Dakota Ryan Edmonds, University of Colorado, Denver

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Abstract:

In this paper, we study the effect of a new first-year program on student retention rates in engineering. First-year engineering students face unique challenges attending a university. In fact, research shows that the dropout rate among first year students is the highest in engineering programs. To be able to increase retention rates, it is important to understand the reasons engineering students are not completing their programs. This is a rising concern in all engineering programs across the nation. We believe that the lack of hands-on, team-based experiences in a typical first-year engineering curriculum is one of the main reasons students leave the program after completing their first year. Furthermore, it is difficult for the first-year students to connect the concepts of math and science with engineering. Therefore, we need a first-year engineering curriculum that can fill the gap between the fundamentals of abstract math and physics and the application of those fundamentals in solving engineering problems. Thus, we have created a first-year learning community as a solution to low retention rates in engineering. In this learning community, the first-year students take the following courses together:

- An interdisciplinary freshman experiences course, in which we teach the concept of "Design-Build-Test-Improve-Collaborate" to the students. The students take the ownership of their group projects, while working together and building friendships that last.
- An appropriate Math course (Calculus or Pre-Calculus), which is specifically designed to address the applications of math in engineering.
- An English composition class, which focuses on "Writing in Engineering".

The main goal of this research is to improve the retention rate of first-year engineering students, by developing a first-year engineering curriculum that can provide additional support and unique learning opportunities in students' entry-level classes.

Introduction:

Faculty in the College of Engineering and Applied Science (CEAS) at the University of Colorado Denver (CU Denver) have developed a new engineering program for first-year students. The program is titled the Engineering Learning Community (ELC) and is designed to support incoming freshmen engineering and pre-engineering students. In this paper the methods, results and conclusions of the first two academic years of the program are presented. The ELC program was piloted in the fall of 2016 (2016 ELC) and was expanded and run again in the fall of 2017 (2017 ELC).

Background:

Nationally speaking, engineering retention rates are lower than the average retention rates among other disciplines. Data from CU Denver's Office of Institutional Research and Effectiveness (OIRE) indicates that, on average, the first-year retention rate among engineering students is about 10% lower than the first-year retention rate in other programs. Similarly, the OIRE data shows that the 6-year graduation rate in engineering is about 12%, which is lower than the 6-year graduation rate for all other disciplines. From this data it can be concluded that there are disparities in the retention of engineering students that need to be addressed.

Two categories of engineering students exist at CU Denver: the students who are admitted directly to CEAS and the students who are admitted to the "pre-engineering" program. In order for a pre-engineering student to be admitted into the CEAS, they must meet minimum GPA requirements in introductory math and physics courses. One of the biggest challenges for engineering students is the completion of math courses. A strong foundation in math is key to student success in all engineering programs. A first-year engineering student is generally enrolled in either Precalculus or Calculus I in their first semester. These classes can present a challenge to students who have just graduated from high school. University data from the OIRE indicates that 40% of the engineering and pre-engineering students enrolled in a Calculus I course in the fall 2016 semester, did not end up completing the course.

There are several factors that affect retention rates in engineering, including inadequate advising and poor problem-solving and project management skills [1]. The low retention rates can also be caused by lack of recognition and support [2]. Another important factor is the social connections between the new students, their peers, and the faculty. The students who do not feel connected to their peers or to their program department are more likely to leave [3][4]. With the understanding that these are the key factors that are negatively affecting engineering retention rates, a solution was created to address these issues.

The research shows that the implementation of high-impact learning practices is essential to improve retention and graduation rates. High-impact practices can be implemented through first-year seminars, learning communities, writing intensive courses, collaborative assignments, problem-based learning, undergraduate research and service opportunities [5]. Programs using similar methods are currently in practice and successful at other universities. For example, the University of Colorado Boulder has developed a course for first-year engineering students with the goal of encouraging student to continue in engineering. Their program does this through leading the students in hands-on and team-based projects within the students first year [6].

The CU Denver ELC has the necessary elements to promote student success and retention rates. It consists of six courses that are offered in two consecutive semesters. They include two math courses, two English courses, and two introductory engineering courses. The engineering courses focus on team-learning, community building, and hands-on experiences. The students take the series of math, English, and engineering courses together. By the end of their first year, the students have already taken six courses together, have built a strong community, and have overcome the first-year challenges as a group.

Methods:

The CU Denver “Engineering Learning Community” was developed with the intention that students take six linked courses with the same group of peers. The first semester courses included an interdisciplinary first-year experiences course, a math course, and an English course. The second semester courses included an engineering drawing course, a next-level math course, and a next-level English course. ELC students received additional support through connected curriculum, campus resources, smaller class sizes, faculty connections, a unique class community, and peer mentorship.

The ELC was first piloted during the fall of 2016. The pilot learning community consisted of fewer courses linked together (only an introductory engineering course and a Calculus I course). After successful implementation of the pilot, it was decided that the program should become a permanent part of the engineering curriculum. Before offering the ELC in the fall of 2017, several improvements were made to the program. One of the major improvements was to include a Precalculus course in addition to Calculus I, and a core composition English course. The added option of taking either Calculus I or Precalculus allowed all of the students in the learning community to be enrolled in an ELC math course. The improved fall 2017 ELC also included courses for the students to take in their second semester including a second semester English course, a second semester math course and a Solidworks design course. Having linked classes through the entire first year allowed the students to stay with the same group of peers in smaller class sizes.

The interdisciplinary engineering course (ENGR 1208) focused on connecting students to engineering through team-based projects. The projects in this course were also designed to connect the students to the resources available to them within the CEAS and show them what they will be able to do in the future with their engineering degrees. The course included several workshops that allowed the students to get hands on experience. These experiences included exposure to machining, prototyping, soldering, and materials testing. Different faculty members from different departments gave presentations to the students about varying engineering topics, which allowed them to meet a number of the college faculty. The class included theoretical learning, experiential learning, introduction to research, interdisciplinary lectures and an introduction to university resources. The course followed a "Design-Build-Test-Improve-Collaborate" model which allowed students to experience the different processes involved with engineering. One of the student projects was to design, build, and test a miniature solar powered car. This connected the students to the topics of solar engineering and sustainable energy, which were covered in course lectures. Through this project students were able to work with tools such as a laser cutter and 3D printers to design and manufacture the components of their car, based on their own designs. The students learned the process of improving their designs to improve their final product. The solar car project ended with the students giving presentations to their peers, deans of the college, and faculty members. These presentations gave the students valuable presenting experience and allowed them to interact with university leaders. This class also served to connect students to their math course. Students often begin their degrees with math courses and are unable to connect the principles they are learning in their math courses to engineering. Through the projects in ENGR 1208 the students were able to connect basic concepts of Calculus I and Precalculus to real world engineering problems.

The ELC instructors designed the ELC math courses specifically for engineering students. The mathematics department at CU Denver supported the ELC by developing new courses for Precalculus and Calculus I, with an engineering focus. Engineering students at CU Denver generally take the same math courses as all other majors. This has several disadvantages for first-year students. The general math courses typically have a larger number of students which limits the access students have to their instructors. Also, having students of various majors in one class does not allow the instructors to make connections with engineering applications. In the ELC math courses the instructors were able to include important connections for engineering students to make within the curriculum, through in class examples and homework problems. Students also used what they were learning in their math courses in the ENGR 1208 class, which made connections between math and engineering. One example of this was a student project where the students designed a cam component using MathCad, to make a drawing used in the machine shop. The students in these courses benefited from smaller class sizes and having more access to their instructors. The ELC also provided multiple study groups throughout the semester for the students, which were led by teaching assistants. The study groups provided small group settings for the students to ask questions and go over problems before exams.

The ELC core composition English course (ENGL 1020) was designed with an emphasis on writing for engineering. The professor for this course was from the English department and specialized in technical writing for science-based majors. She was able to develop a course that was designed to help engineering majors navigate writing. She worked with an engineering instructor to design a course that would include important kinds of reading, writing, and analysis the students would need for their degree programs and future professions. The professor also worked closely with the English department to ensure the English core requirements from the university were met. The course was engineering focused but was not engineering specific, which gave the students the freedom to write about various topics and helped them to develop a variety of writing skills for topics such as those involving research. In the ELC English course, students covered topics such as purposeful writing, revision and writing process, argument and analysis, critical reading, research and technology, and multimodality. The course also utilized the book *Writing in Engineering: A Brief Guide* by Robert Irish for student reference. This book gives guidelines for writing in engineering and was chosen because it was easy for students to understand and apply concepts from it. The assignments in the course were broken up into steps for the students which included a rough draft process with peer revisions. The ENGL 1020 course also allowed students to get support for the research paper they wrote in the ENGR 1208 course. Students peer reviewed their research papers in the ENGL 1020 course with the guidance of the instructor, which allowed for even greater connections between the ELC courses. Overall this course was designed to help ELC students develop the reading and writing skills they will use in their future courses and later in their professional lives.

Although doing well in classes is an essential component to a students' success in their engineering programs, many of the reasons that students left their programs were not related to academics. The research mentioned previously, suggests that engineering students often leave their programs due to non-academic reasons such as student engagement. In order to address this issue, the ELC connected students to various campus resources including the Learning Resources Center, the Career Center and the Financial Aid Center, who conducted several workshops about

how to be more engaged on campus. The ELC sought to give the students a campus community where they can form friendships and connections with their peers. A unique component of the ELC is that the students are paired with a peer mentor known as a Peer Advocate Leader (PAL). PALs are utilized in the classroom to help connect the first-year students to campus resources and to plan social events to build a class community. These mentors can have a huge impact and can help students adjust to the college environment. The PAL mentors for both runs of the ELC were engineering majors themselves, so they were able to connect students with engineering resources as well. In addition to a peer mentor, the students in the fall 2017 ELC also had access to a teaching assistant. The teaching assistant helped facilitate class activities and workshops and helped to support students throughout the semester.

In order to gain a better understanding of outcomes of the class, an analysis was done for each semester. A total of six different surveys were conducted for both runs of the ELC. The surveys asked similar questions and were given at similar times for both semesters. The six surveys were the Faculty Course Evaluation (FCQ), Early Semester Student Survey, End-of-Semester Student Survey, First Day PAL Survey, Course Curriculum Evaluation, and the Final Exam Survey. The FCQ is a university wide survey that is given for all courses. This survey has a ranking from 1 to 6 and asks questions regarding course aspects and instructor effectiveness. The Early Semester Student Survey and the End-of-Semester Student Survey are provided from the Office of First-Year Experiences at the university and thus are labeled as First Year Experiences (FYE) Surveys. These surveys have questions about learning community components and student transitions to college. The First Day PAL survey was created by the PAL mentor to understand the resources students might need through the semester. The Course Curriculum Evaluation and the Final Exam Survey were created by the ELC instructors to get feedback from students about ELC outcomes. These surveys asked for comments about specific class assignments and projects.

Results:

Various data and information were collected from the students to assess the program's overall progress and success. The components assessed were course ratings, student enrollment after the first semester, student retention in engineering/ pre-engineering, and how the students did in their math courses. The survey results for the FCQ Survey and the FYE Survey for the 2016 ELC and the 2017 ELC are listed in Table 1. The FCQ values are ranked from a scale of 1 to 6 and the FYE Surveys are on a 1 to 5 scale. An important consideration in looking at these survey results is the change in the survey format from paper in 2016, to an online format in 2017. This greatly affected the response rate, which was significantly higher for the 2016 ELC. The response rates are listed in the caption below the table.

Table 1. Survey data from two class surveys 2016 ELC FCQ (18/18), 2017 ELC FCQ (23/35), 2016 ELC FYE Survey (18/18), 2017 FYE Survey (9/35)

Survey	Survey Question	2016 ELC	2017 ELC
FCQ Survey	Rate the course overall	5.3/6	3.3/6
	Rate the instructor overall	5.3/6	4.87/6
	Rate instructor's effectiveness in encouraging interest in this subject	5.5/6	4.43/6
FYE Survey	Do you plan on graduating from CU Denver?	82%	70%
	Would recommend the course to incoming students	94%	25%
	Rate your Peer Mentor (PAL) Overall	4.82/5	4.0/5

Table 2. Percentage of students who had GPA outcomes of above a 2.0 for the 2016 ELC (18 students) and the 2017 ELC (35 students)

Student GPA Range	2016 ELC	2017 ELC
GPA above 2.0	100%	80%

The results of the surveys and student feedback from the 2016 ELC showed overall positive outcomes of the pilot program. The 2016 ELC was composed of 18 students with 6 of those students being classified as engineering, and 12 being classified as pre-engineering. In the final class survey the students in the fall 2016 section rated the course as an average of 5.28/6 overall and 94% of the class said they would recommend the course to incoming students. In order to determine the success of the ELC it was important to look at how the students were doing after the ELC. Although many of the students from the 2016 ELC faced challenges in their first semesters, they all stayed enrolled in the spring 2017 semester. All of the students also had a GPA of 2.0 or above in their fall 2017 semester. Students from the 2016 ELC were also engaged in engineering student organizations, involved in undergraduate research with faculty, and had maintained friendships with their classmates. Two of the students even received paid research positions from an engineering department faculty member. From the 12 students who were listed as pre-engineering, 2 have been accepted into CEAS. From the comments received, one student gave the following feedback: “The class helped me solidify my decision to study engineering, the cam project showed me how math can actually bring me a product in real life. I was able to

concentrate hours on the math (which I didn't really enjoy before) and actually enjoy doing it." The student's comments showed that they enjoyed the connected curriculum and hands on projects the ELC offered.

The results of the 2017 ELC surveys showed the outcomes of program after it had been adjusted and improved. The 2017 ELC was made up of 35 students with 15 students classified as engineering, and 20 classified as pre-engineering. The lower response rate from the students on the surveys for the 2017 ELC group had an impact on the survey data. In the final class survey the students who responded rated the ENGR 1208 course as an average of 3.3/6 overall. When asked to rank the instructor's effectiveness in encouraging interest in this subject the students gave an average 4.43/6 and when asked to rate the instructor overall the students gave an average of 4.87/6. Of the 35 total students in the ELC, 16 were in the ELC Precalculus section and 19 were in the ELC Calculus I section. Out of the students enrolled in the ELC English course, 18 out of 22 passed the class. From the 20 students who were pre-engineering 2 have been accepted into the CEAS for the spring 2018 semester. The comments from the surveys showed that the students enjoyed the hands-on experiences and the fact that they were able to connect with the same peers in all of their classes. Some of the comments from the students indicated that they would have liked to see more structure within the course assignments.

It was also important to look at the completion of math courses to determine the ELC overall success. Figure 1 shows the percentage of students who completed versus those who did not complete the ELC math courses. In the figure it can be seen that the 2017 ELC Calculus I course was the most successful. The 2017 ELC Precalculus section was not as successful and had more students who did not complete the course than those who had completed it. Out of the students enrolled in the Calculus I section for the 2016 ELC, 4 of 6 passed the course. In the 2017 ELC Calculus I course 17 of 19 students passed the course. Among the students enrolled in the ELC Precalculus course 6 of 16 students passed the course.

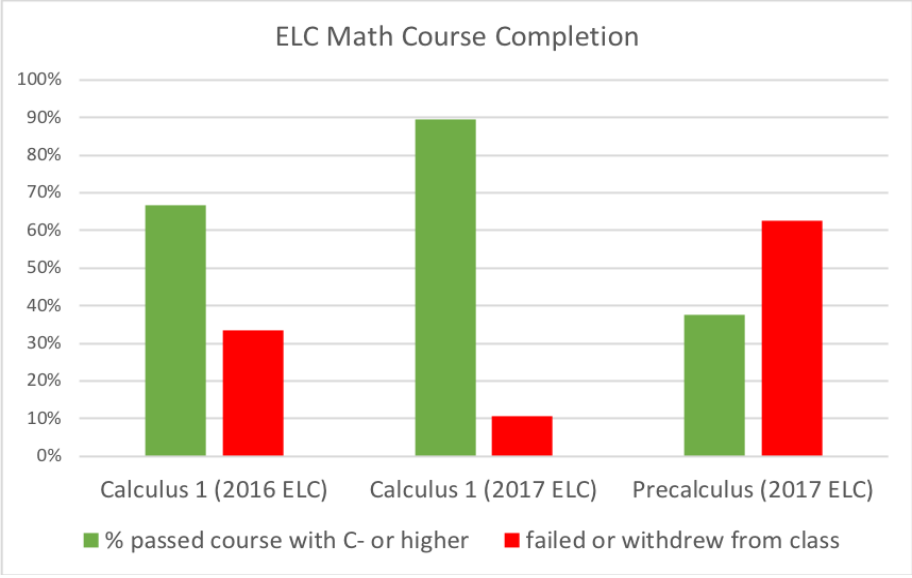

Figure 1. ELC math course completion for Calculus 1 (2016 ELC, out of 6 students), Calculus 1 (2017 ELC, out of 19 students) and Precalculus (2017 ELC, out of 16 students)

The main goal of the ELC is to increase student retention rates. The analysis of the transcripts of the ELC students after their first semester has indicated which students have been retained, and which students have left the university. The data listed in Table 3 and Table 4 are based on spring 2018 university data. Table 3 gives the percentage of students retained versus not retained in engineering and pre-engineering. Table 4 gives the percentage of students who are enrolled versus those who are no longer enrolled in the CU System. Both tables take into account all of the past 53 ELC students. These tables show that 72% are still pursuing an engineering major and 81% are still enrolled in the CU System. They also show that 28% of students are not continuing in engineering and 19% of the students are not currently enrolled in the CU System.

Table 3. Percentage of ELC students retained in engineering and pre-engineering programs (out of 53 students)

Retained in engineering and pre-engineering	72%
Not retained in engineering	28%

Table 4. Percentage of students retained in the CU System (out of 53 students)

Retained in CU System	81%
Not retained in CU System	19%

Conclusions:

The results of these surveys and student feedback highlighted the aspects of the ELC that were successful and aspects that need improvements. The student feedback indicated mostly positive results and showed the students enjoyed the courses and found them to be beneficial to their progress in engineering.

The retention rates of both ELC iterations were higher than the numbers seen in the OIRE data. These retention rates show a level of success for the ELC program. The students who were retained were overwhelmingly the ones who had regular attendance, were engaged in the program and were successful in their courses. The students who were not retained were the ones who were not engaged in ELC program components and had low attendance. The results of the first two years of the ELC indicate connections between the retention rates and student engagement. The goals for the future ELC iterations will be to continue to encourage student academic success and retention by providing academic support and engagement opportunities.

One of the most successful aspects of the ELC was the ELC Calculus I course in the fall of 2017. This course had a passing rate of 89%, which is significantly higher that the fall 2016 pass rate of 60% for engineering students seen in the OIRE data. The success of this course

shows a great improvement when compared to other university Calculus I courses and is a model that should be continued. These results also show a drastic improvement from the 2016 ELC where 6 of the 18 ELC students were in the ELC Calculus I course, however only 4 passed the class. The ELC Precalculus course was not as successful, as only 6 out of the 16 students, or 37%, passed the course.

There were many beneficial differences in the structures of the 2016 ELC and the 2017 ELC. The expansion in the 2017 ELC gave students more opportunities and had a structure that better reflected the learning community concept as a whole. The two math course choices gave students more options and allowed a greater number of students to enroll in the ELC. The English course was very successful in helping the students learn key writing skills that would use in their future courses. In spite of the improvements that were made, there were some aspects of the 2016 ELC that were more successful than fall 2017 ELC. For example, the ENGR 1208 course was rated higher overall by the students in the 2016 ELC versus that of 2017. The course went from having 18 students to having 35 students and the results suggest that trying to keep this course at a smaller class size might be more effective. Another component that was more successful in the 2016 ELC was the retention of the students into their second semester. All of the students were retained into their second semester in the pilot program whereas the 2017 ELC had 9 students that were not enrolled after their first semester. This also suggests that keeping the class size smaller for the ENGR 1208 course might give the students more support than the larger class size.

There will be several main focuses for future ELC at CU Denver. Keeping the class sizes small and focusing on faculty student connections will be a continued goal. Additionally, improvements will be made regarding increasing course structure and connections between the linked courses. Making more resources available to the Precalculus students so that we see an increase in the pass rate of the course, will be a priority. The progress of the students from previous ELC sections will continue to be monitored to see if they successfully complete their programs and/or are retained within the CU System.

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