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Comparing Student Outcomes From Four Iterations of an Engineering Learning Community

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Comparing Student Outcomes from Four Iterations of an Engineering Learning Community

Abstract

This Complete Evidence-based Practice paper evaluates the impact of learning communities on the academic success of first-year engineering students. The Engineering Learning Community (ELC) at a large urban university is a program that purposefully recruits talented high school applicants with financial need. The ELC enrolls these applicants into cohort-specific sections of classes and provides mentoring and additional resources for the students' first year of college. The results of the first three years of the ELC program were presented at ASEE 2020. Currently in its fifth year, the ELC program has undergone numerous revisions and improvements based upon student and faculty feedback, best practices, and increased financial resources. The main feature of the fourth year ELC program is the addition of up to $20,000 in scholarship from a S-STEM NSF award. Another significant change in the fourth year is the re-design of the mentorship program.

COVID-19 hit in the second semester of the fourth year of ELC and added its own challenges to the program. The impact of COVID-19 on the students' response to the pandemic has been studied as well. To take a first look at the efficacy of the ELC program over four iterations, grade point averages (GPAs) of ELC students from each cohort were compared. We hypothesize that students from cohort 4 will have the highest overall GPA given that they have accessed the most recent iteration of the ELC, which includes scholarship funding, improved student-to-mentor ratios and a newly redesigned special topics course. Analysis of Variance of GPAs reveals that cohort 4 has a significantly higher GPA after one year in the ELC than cohorts 2 and 3, but no significant differences between other cohorts were found. Further analysis shows no significant differences in high school GPA between the cohorts, indicating that the improvements in cohort 4 are not due changes in recruiting practices. Additionally, ELC cohort 4 showed greater academic resiliency during COVID-19 than their non-ELC counterparts, as revealed through statistically significant lower utilization of the modified grading policy, as well as higher observed completion rates in Spring 2020.

Introduction

The academic success and retention of undergraduate engineering students has become an issue of critical importance for engineering educators in recent years. At a large urban research university, data from the Institutional Research Office showed that first-year retention for engineering and pre-engineering students was 10% lower than for students in other disciplines at the same university. This trend appears to be, unfortunately, present at a majority of U.S. institutions of higher education [1]. In order to address this critical issue, engineering faculty members at this university developed a program for a subset of incoming first-year engineering students, called the Engineering Learning Community (ELC). The ELC was first implemented in the Fall 2016 semester, and since then has been iterated each academic year based on student feedback, best practices, and, beginning in the Fall 2019 semester, support from the National Science Foundation (NSF) in the form of S-STEM scholarships for financially qualified students. The purpose of this paper is to compare the first four iterations of the ELC to demonstrate that the most recent ELC cohort of students for which data are available (i.e., the Fall 2019 ELC cohort) shows the highest level of academic success after the first year. This provides partial evidence that iterating the ELC model has increasing promise for promoting the academic success and ultimately retention of undergraduate engineering students.

In the Spring 2020 semester, the COVID-19 pandemic forced a sudden shift in the format of classes, in addition to the immense stressors and lifestyle changes brought on by a global pandemic. Given the profound and wide-ranging effects of the pandemic on students, it seems probable that academic achievement could differ before and after the onset of the pandemic. This presents a possible confounding variable for the Fall 2019 cohort, who were unique in that they experienced the pandemic during their first year. For this reason, outcomes for the Fall 2019 ELC cohort are compared not only with outcomes for previous ELC cohorts, but also with outcomes for first-year engineering students who began at the university in Fall 2019 but were not part of the ELC. This additional comparison provides evidence that not only did the Fall 2019 cohort demonstrate higher levels of academic success when compared with other ELC cohorts, but also that students in the ELC appeared to demonstrate higher levels of academic resilience in the face of the COVID-19 pandemic when compared with their non-ELC peers.

Background

Prior research has suggested several potential contributing factors to lower rates of academic success and retention within undergraduate engineering. These include lack of support and recognition [2], inadequate advising [3], and feelings of disconnection to peers and faculty [4]–[6]. In addition to these factors linked with negative student outcomes, research has also identified a host of best practices linked to positive student outcomes. Called high-impact practices, these include learning communities, first-year seminars, writing-intensive courses, problem-based learning, collaborative assignments, and research and service opportunities [7]. Specific to engineering, the use of hands-on collaborative design projects in the first year is also believed to be an effective method to increase student engagement, success, and retention [8]. Grounded in this research, faculty members at a large public urban research university developed an optional program for incoming first-year engineering students called the Engineering Learning Community (ELC), which has been reported on elsewhere [9], [10]. The ELC was first implemented in Fall 2016 and has been iterated each academic year since based on student feedback, best practices, and eventually an S-STEM scholarship from NSF [11]. As each ELC iteration was a bit different, the next few sections will detail what each iteration entailed.

The Fall 2016 ELC Cohort

The first iteration of the ELC was implemented in Fall 2016 and was envisioned as an optional one-semester learning community and first-year seminar for incoming first-year students in the

Engineering College. Students who had a declared major of mechanical engineering or who were classified as pre-engineering (i.e., students who intended to declare an engineering major but did not yet meet the academic criteria to be fully admitted to the Engineering College) could opt in to the ELC. The Fall 2016 cohort had an enrollment of 18 students.

As a learning community, students in the ELC took two courses together as a course bundle: a first-year design course and a specific section of Calculus I. The intention of having students take two classes together was to build community among these students, as having multiple courses together had the potential to increase their familiarity and rapport with each other. The first-year design course included an introduction to research, a review of the engineering design process, and hands-on collaborative project-based learning, culminating in the design of a small car that runs with solar energy. The first-year design course also had an undergraduate teaching assistant (TA), who was a near-peer (which, in this context, is defined as an upper-class student) available for help and support in understanding the content and structure of the course. The specific section of Calculus I that ELC students took had a special focus on applying Calculus I concepts to engineering in a meaningful way.

As a first-year seminar, the design course that ELC students took had several additional features intended to help students adjust to college life. This included content such as getting involved on campus, learning campus resources, and meeting with their academic advisor. Additionally, the design course's status as a first-year seminar included the support of a Peer Advocate Leader (PAL), another undergraduate near-peer engineering major who attended class and offered support to students. The role of the PAL differed from that of the TA, as the PAL offered support in getting socially connected and adjusting to college life in general, whereas the TA offered support in academic assignments and the engineering- and design-specific content of the course.

The Fall 2017 ELC Cohort

The following academic year, the next cohort of the ELC included all the elements of the previous cohort with several important additions. These additions were intended to improve the ELC and were implemented as a result of student feedback from several course surveys as well further examination of best practices. The Fall 2017 ELC cohort was once again open to students with a declared major of mechanical engineering as well as those who were classified as pre-engineering; a total of 34 students enrolled in this iteration of the ELC, which was an 89% increase in enrollment.

Two key changes were made to the Fall semester course bundle of the ELC. First, in addition to the first-year design course, students took a specific designated section of either Calculus I or Precalculus, depending on their math placement. This was an important modification to the ELC as it expanded inclusion to students who were not yet calculus-ready. In the previous iteration of the ELC, Calculus I was the only math option in the course bundle, which meant that students who did not place into Calculus I were eligible for the ELC. For the designated ELC sections of each math option, there was a special focus on applying math concepts to engineering.

Second, in addition to the first-year design course and either Calculus I or Precalculus, the Fall semester course bundle also included an English course, Core Composition I. The designated section of Core Composition I for ELC students had a special focus on engineering-specific technical writing for research audiences. The addition of an English course to the Fall semester course bundle introduced the high-impact practice of a writing-intensive course [7], as well as hopefully increasing a sense of community and belonging among the ELC students.

The final important change in this iteration of the ELC from the prior iteration was that the learning community was expanded from a one-semester experience to a two-semester experience. This means that ELC students took a bundle of courses not only in the Fall semester, but also in the Spring semester. The Spring semester course bundle included a Computer-Aided Drafting (SolidWorks) course, a continuation of the student's math sequence (either Calculus II or Calculus I), and a continuation of the student's English sequence (Core Composition II).

The Fall 2018 ELC Cohort

There were no significant changes to the Fall 2018 iteration of the ELC from the previous academic year. This was due in large part to the breadth and depth of changes that had occurred the prior academic year; faculty and staff felt that they (and the students) would benefit from another year of practicing the ELC as it had been implemented the previous year, which would allow them to make smaller adjustments as they saw fit. Additionally, during this iteration of the ELC, faculty members were applying for a S-STEM grant from the National Science Foundation (NSF), and they were aware that more significant changes to the ELC would be implemented the following year if awarded the grant. The only minor change to the Fall 2018 iteration of the ELC was that eligibility was opened up to students majoring in civil engineering and math, in addition to mechanical engineering and pre-engineering. The Fall 2018 ELC Cohort included 31 students.

The Fall 2019 ELC Cohort

The Fall 2019 iteration of the ELC included several significant changes from the previous two academic years. The ELC was expanded to include students from all engineering departments at the university (mechanical engineering, civil engineering, electrical engineering, bioengineering, and computer science), as well as pre-engineering students. Because of this, the Spring semester course bundle was adjusted, swapping out the Computer-Aided Drafting course used in previous semesters with a new fundamentals of computing course. In total, the Fall 2019 ELC cohort included 26 students.

The largest change for the Fall 2019 iteration of the ELC, however, was that the university gained support from NSF in the form of an S-STEM scholarship awarded to financially qualified students. All students who enrolled in the ELC and demonstrated financial need (by federal financial aid definitions) were awarded the S-STEM scholarship. This scholarship was for up to $10,000 per year for up to two years. The inclusion of this scholarship certainly made participation in the ELC an attractive option for incoming first-year engineering students. However, because the scholarship was need-based and not merit-based, it is reasonable to assume that this scholarship need not impact the makeup of students who participated in the ELC. In other words, there is reason to believe that the introduction of the S-STEM scholarship did not necessarily attract a higher-achieving group of students to the ELC than in previous academic years. Nevertheless, it is important to compare prior academic achievement in high school to evaluate whether there is a systematic qualitative difference between students in the Fall 2019 ELC cohort as compared with prior ELC cohorts due to the introduction of the scholarship.

The final significant change to the Fall 2019 iteration of the ELC was the introduction of a peer mentorship program. Each student in the ELC was assigned a peer mentor who was an engineering student in their sophomore or junior year. The role of the peer mentor differed from the role of the TA and the PAL in several ways. First, the TA and PAL were assigned to assist students in relation to the first-year design course, specifically. In contrast, peer mentors assisted students in more holistic ways including help with their other courses, study habits and time management, and college socialization. Second, both the TA and PAL were assigned to offer academic assistance to all the students in the first-year design course, and though they may have met with students individually, most of their interactions were in a group setting during class time. In contrast, peer mentors were assigned to work individually with a specific student(s) and forged a more individual relationship with students during periodic one-on-one meetings with students. Most students met weekly with their mentor. Third, the TA and PAL were available to students only during their first semester, whereas peer mentors were available to students during both their first and second semesters.

In summary, the ELC was first implemented in Fall 2016 using high-impact practices with the goal of increased success and retention of undergraduate engineering students. Each year following, the format of the ELC was revised based on student feedback and best practices. See Table 1 for a summary of components of the first four iterations of the ELC, from Fall 2016 to Fall 2019.

Each adjustment in each iteration of the ELC was intended as an improvement to benefit ELC students by promoting their academic success and, ultimately, retention within engineering. To examine whether iterating the ELC was associated with better student outcomes, the first research question of this study involves comparing student outcomes between the first four iterations of the ELC.

- RQ1: Were there any differences in mean cumulative grade point average (GPA) after the first year between the first four ELC cohorts?

The fourth ELC cohort (i.e., the Fall 2019 ELC cohort) experienced a significant change and stressor which the first three ELC cohorts did not experience: the onset of the global COVID-19 pandemic. This presented a confounding variable for the current study, as the academic effects of

COVID-19 are represented only for the Fall 2019 ELC cohort. In order to examine how the pandemic may have impacted the academic success of students in the ELC, it is necessary to compare student outcomes for the Fall 2019 ELC cohort with other students who also experienced the pandemic at the same point in their academic career. Further, since the university implemented temporary policies for modified grading options in the Spring 2020 semester, using only GPA as the student outcome for comparison is inadequate; in addition to GPA, comparing utilization of the modified grading policy as well as completion rate will provide a more complete picture of academic outcomes in the Spring 2020 semester. The next section will detail the modified grading options offered in Spring 2020 in order to provide context for the analysis.

Table 1. Summary of Engineering Learning Community (ELC) Components.

	Fall 2016 ELC Cohort	**Fall 2017 ELC Cohort**	**Fall 2018 ELC Cohort**	**Fall 2019 ELC Cohort**
Enrollment	18	34	31	26
Eligible Majors	• Pre-engineering • Mechanical Engineering	• Pre-engineering • Mechanical Engineering	• Pre-engineering • Mechanical Engineering • **Civil Engineering** • **Mathematics**	• Pre-engineering • Mechanical Engineering • Civil Engineering • Mathematics • **Electrical Engineering** • **Bioengineering** • **Computer Science**
Fall Semester Course Bundle	• First-Year Design • Calculus I	• First-Year Design • **Precalculus *or*** Calculus I • **Core Composition I**	• First-Year Design • Precalculus *or* Calculus I • Core Composition I	• First-Year Design • Precalculus *or* Calculus I • Core Composition I
Spring Semester Course Bundle	None	• **Computer-Aided Drafting** • **Calculus I *or* Calculus II** • **Core Composition II**	• Computer-Aided Drafting • Calculus I *or* Calculus II • Core Composition II	• **Fundamentals of Computation** • Calculus I *or* Calculus II • Core Composition II
Near-Peer Involvement	• Teaching Assistant (TA) • Peer Advocate Leader (PAL)	• TA • PAL	• TA • PAL	• TA • PAL • **Individual Peer Mentor**
Scholarship Available	None	None	None	**S-STEM scholarship for financially qualified students**

*Note: Changes from the previous year are denoted using **bold** text.*

Modified Grading Options in Spring 2020

In March 2020, due to the onset of the COVID-19 global pandemic, all university teaching and learning moved remote. This means that all in-person classes were moved to online formats, most frequently a synchronous online experience using a video conferencing platform subscribed to by the university. The shift to remote teaching and learning was sudden, with only a few days for students and instructors to transition. As can be expected, this sudden shift introduced academic challenges for many students, in addition to the immense lifestyle changes and other stressors brought on by the pandemic, including physical, mental, emotional, and financial struggles.

In an attempt to encourage students to remain enrolled in their courses and do the best they could, the university introduced an optional modified grading policy. The gist of the policy was that, after letter grades for the Spring 2020 semester were posted, students could opt to convert any or all of their letter grades to a pass/no pass (P/NP) system[1]. If a student opted to use the modified grading policy, letter grades of D- or higher would be converted to P and grades of F would be converted to NP. Converted P/NP grades would not be included in the student's GPA. Letter grades that were not converted to the P/NP system were included in a student's GPA. Grades of D- or higher (or converted grades of P) were considered completed credits, while grades of F (or converted grades of NP) were considered not completed credits.

For example, suppose a hypothetical student who took four 3-credit classes and earned letter grades of B, C, D, and F. If this student did not utilize the modified grading policy, they would have a Spring 2020 semester GPA of 1.500 and a completion rate of 75%. If this student utilized the modified grading policy on the courses in which they received a D and an F, their grades would convert to B, C, P, and NP; their Spring 2020 semester GPA would be 2.500; their completion rate would still be 75%. Finally, if this student utilized the modified grading policy on all their courses, their grades would convert to P, P, P, and NP; they would not have a Spring 2020 semester GPA, and their completion rate would still be 75%.

While many universities have pass/fail grading options, this modified grading policy was unique in three main ways. First, it was a pass/no pass system, as opposed to a pass/fail system. In traditional pass/fail systems, failing grades are included in the GPA. In this modified grading system, failing grades got converted to NP and were not included in the GPA. Second, students were able to request modified grading after grades were posted, which is extremely late in comparison to most other pass/fail grading options. Finally, the modified grading policy was a direct response to the COVID-19 pandemic, and thus was only an option to students in the Spring 2020 and Summer 2020 semesters.

The modified grading policy was utilized by many students in the Spring 2020 semester, especially students who received grades of D and F, as a way to protect their GPA. This also means that GPA after the Spring 2020 semester – both the semester GPA and the cumulative GPA – may be inflated for students who utilized the modified grading policy. For this reason, it is important to examine the utilization of the modified grading policy for students in the Fall

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[1] The system was actually a pass+/pass/no pass (P+/P/NP) system where a P+ indicated a grade of C- or higher and would thus serve as a satisfactory prerequisite for advancement to the next course in a sequence. However, to simply the current discussion, the P+ and P categories have been collapsed and described as "P."

2019 ELC cohort and their first-year peers in the Engineering College who did not participate in the ELC. It is also useful to inspect completion rate, and not solely GPA, as a measure of student success after the Spring 2020 semester.

- RQ2a: For first-year students who began in Fall 2019 in the Engineering College, was there an association between participating in the ELC and utilization of the modified grading policy in Spring 2020?
- RQ2b: For first-year students who began in Fall 2019 in the Engineering College, was there a difference in completion rate between those who participated in the ELC and those who did not?

Method

This quantitative study compares first-year cumulative GPA between the first four ELC cohorts, as well as utilization of the modified grading policy and completion rate for Fall 2019 first-year students between those who participated in the ELC and those who did not. Approval for this study was granted by the authors' institution's institutional review board (IRB).

Participants

For RQ1, the participants in this study were first-year engineering students who participated in the ELC as part of the Fall 2016, Fall 2017, Fall 2018, and Fall 2019 cohorts. For RQ2a and RQ2b, the participants were first-year engineering students who started in Fall 2019, whether they were in the Fall 2019 ELC cohort or not. For each iteration of the ELC, there were some students who were not in their first year; these students (23 in total) were removed from analysis, as this study is focused on outcomes for first-year students.

Data Collection

Data were collected manually using the institution's student information system. For RQ1, collected data included cumulative GPA after the first year and high school GPA. For RQ2a and RQ2b, collected data included cumulative GPA after the first year, utilization of the modified grading policy (yes or no), Spring 2020 semester GPA, and Spring 2020 completion rate.

Analysis

In order to answer the first research question (RQ1: Were there any differences in mean cumulative grade point average (GPA) after the first year between the first four ELC cohorts?), a one-way analysis of variance (ANOVA) was conducted. Participants were separated into groups by the ELC cohort of which they were a member, and cumulative GPA after the first year was the outcome variable. Assumptions were tested and homogeneity of variance was violated; for this reason, the Games-Howell nonparametric post-hoc test was employed.

To determine if any found differences in first-year cumulative GPA between ELC cohorts could be due to differences in recruiting practices or pre-existing differences in academic achievement, another one-way ANOVA was conducted. Participants were separated into groups by the ELC cohort of which they were a member, and high school GPA was the outcome variable. Assumptions were tested and met.

In order to answer the first part of the second research question (RQ2a: For first-year students who began in Fall 2019 in the Engineering College, was there an association between participating in the ELC and utilization of the modified grading policy in Spring 2020?) a chi-square test of association was conducted. For significant chi-square results, standardized residuals were examined as a post-hoc measure to determine which cells in the crosstabulation were different than expected, using the cutoff of +/- 2.0 [12]. Then, to further understand utilization of the modified grading policy and its impact on Spring 2020 GPA, two independent samples *t*-tests were conducted. The first *t*-test checked for a difference in Spring 2020 semester GPA between ELC students and non-ELC students. The second *t*-test checked for a difference in Spring 2020 semester GPA between students who utilized the modified grading policy and those who did not. For both these *t*-tests, students without a Spring 2020 semester GPA due to a lack of letter grades were excluded from analysis; this includes those with grades of only P, NP, and W.

To answer the second part of the second research question (RQ2b: For first-year students who began in Fall 2019 in the Engineering College, was there a difference in completion rate between those who participated in the ELC and those who did not?), an independent samples *t*-test and a chi-square test of association were conducted. The *t*-test checked for a difference in completion rate between ELC students and non-ELC students, while the chi-square test checked for an association between ELC participation and a Spring 2020 completion rate of 100%.

Results

This study investigated the following research questions:

- RQ1: Were there any differences in mean cumulative grade point average (GPA) after the first year between the first four ELC cohorts?
- RQ2a: For first-year students who began in Fall 2019 in the Engineering College, was there an association between participating in the ELC and utilization of the modified grading policy in Spring 2020?
- RQ2b: For first-year students who began in Fall 2019 in the Engineering College, was there a difference in completion rate between those who participated in the ELC and those who did not?

Research Question #1 (RQ1)

To answer RQ1, a one-way ANOVA was conducted to check for differences in first-year cumulative GPA between the four ELC cohorts. The ANOVA found statistically significant differences in first-year cumulative GPA between ELC cohorts (F (3, 82) = 3.111, $p < 0.05$;

Table 2). Because the homogeneity of variance assumption was violated, the Games-Howell nonparametric post-hoc test was employed. Significant differences in cumulative first-year GPA were found between the Fall 2019 ELC cohort and both the Fall 2017 and Fall 2018 ELC cohorts. These differences can be observed in the means plot (Figure 1) and the descriptives table (Table 3). This one-way ANOVA yielded a partial eta squared value of 0.102, indicating a medium to large effect size [13].

Table 2. One-Way ANOVA, First-Year GPA by ELC Cohort.

	Sum of Squares	*df*	Mean Square	*F*	*p*	Partial η^2
Between Groups	9.212	3	3.071	3.111	< 0.05	0.102
Within Groups	80.935	82	.987			
Total	90.148	85				

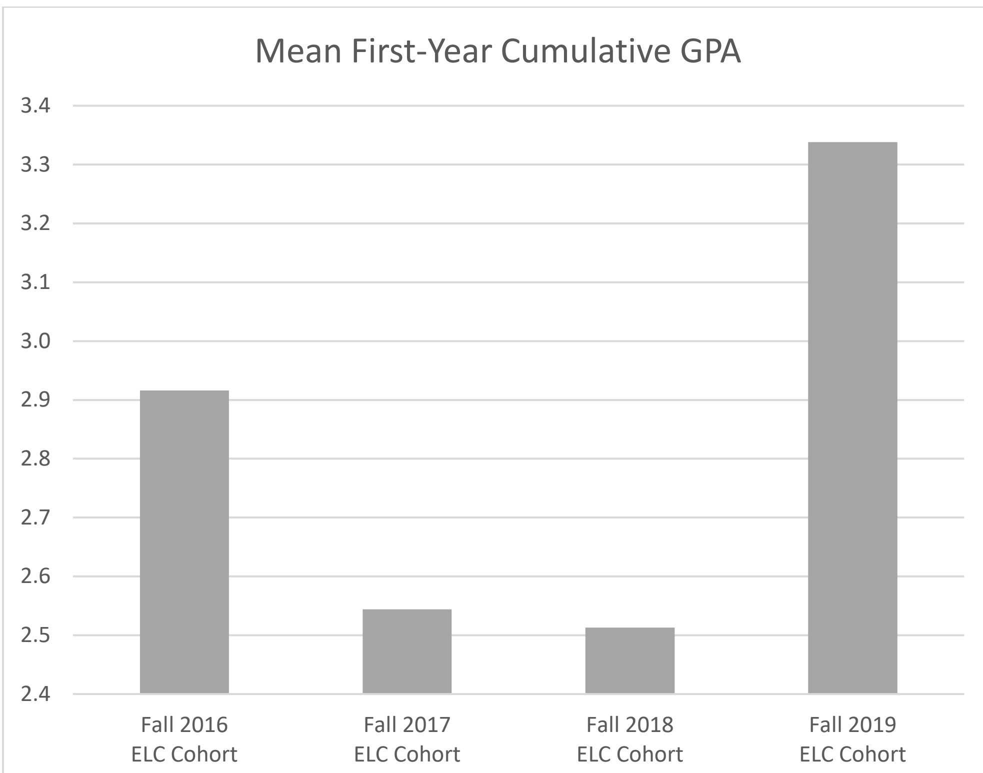

Figure 1. First-year cumulative GPA by ELC cohort.

Additionally, in order to determine if the statistically significant differences in first-year cumulative GPA between the Fall 2019 ELC cohort and both the Fall 2017 and Fall 2018 ELC cohorts could be due to differences in recruiting practices or pre-existing differences in academic achievement, another one-way ANOVA was conducted. Participants were separated into groups by the ELC cohort of which they were a member, and high school GPA was the outcome variable. Assumptions were tested and met. The ANOVA found no statistically significant differences in high school GPA between ELC cohorts (F (3, 80) = 0.736, p = 0.534). These results suggest that differences in first-year cumulative GPA cannot be attributed to pre-existing differences in academic achievement as demonstrated in high school GPA.

Table 3. Descriptives, First-Year GPA by ELC Cohort.

	n	Mean First-Year Cumulative GPA	SD	SE
Fall 2016 ELC Cohort	15	2.916	0.59	0.15
Fall 2017 ELC Cohort	28	2.544	1.08	0.20
Fall 2018 ELC Cohort	25	2.513	1.26	0.25
Fall 2019 ELC Cohort	18	3.338	0.64	0.15
Total	86	2.766	1.03	0.11

Research Question #2a (RQ2a)

To answer RQ2a, a chi-square test of association was conducted. A statistically significant association was found between utilization of the modified grading policy and participation in the ELC ($\chi^2(1) = 7.927$, $p < 0.01$). In reviewing standardized residuals using Agresti's cutoff of +/- 2.0 [12], there were fewer ELC students who utilized modified grading than expected (see Table 4 for the crosstabulation). This chi-square test of associate yielded a Cramer's V value of V = 0.241, indicating a medium effect size [14].

Table 4. Crosstabulation, Utilization of Modified Grading by Fall 2019 ELC Participation.

	Utilized Modified Grading	Did Not Utilize Modified Grading	Total
Fall 2019 ELC Students	2*	19	21
Fall 2019 Non-ELC Students	48	67	115
Total	50	86	136

**Standardized residuals > |2.0|, indicating a different frequency than expected.*

Then, to further understand utilization of the modified grading policy and its impact on Spring 2020 GPA, two independent samples *t*-tests were conducted. The first *t*-test checked for a difference in Spring 2020 semester GPA between ELC students and non-ELC students. While the *t*-test did not yield statistically significant results ($t\,(127) = 0.898$, $p = 0.371$), there was an observed difference in GPA: ELC students had a mean Spring 2020 semester GPA of 3.45, whereas non-ELC students had a mean Spring 2020 semester GPA of 3.27. The second *t*-test checked for a difference in Spring 2020 semester GPA between students who utilized the modified grading policy and those who did not. This *t*-test did yield statistically significant results ($t\,(127) = 2.265$, $p < 0.05$) and yielded a Cohen's d value of d = 0.797, indicating a large effect size [15]; Students who utilized modified grading had a mean Spring 2020 semester GPA of 3.51, whereas students who did not utilize modified grading had a mean Spring 2020 semester GPA of 3.18 (see Table 5 and Figure 2).

Table 5. Mean Spring 2020 Semester GPA.

	n	Mean Spring 2020 Semester GPA
Fall 2019 ELC Students	19	3.45
Fall 2019 Non-ELC Students	110	3.27
Utilized Modified Grading	44	3.51
Did Not Utilize Modified Grading	85	3.18

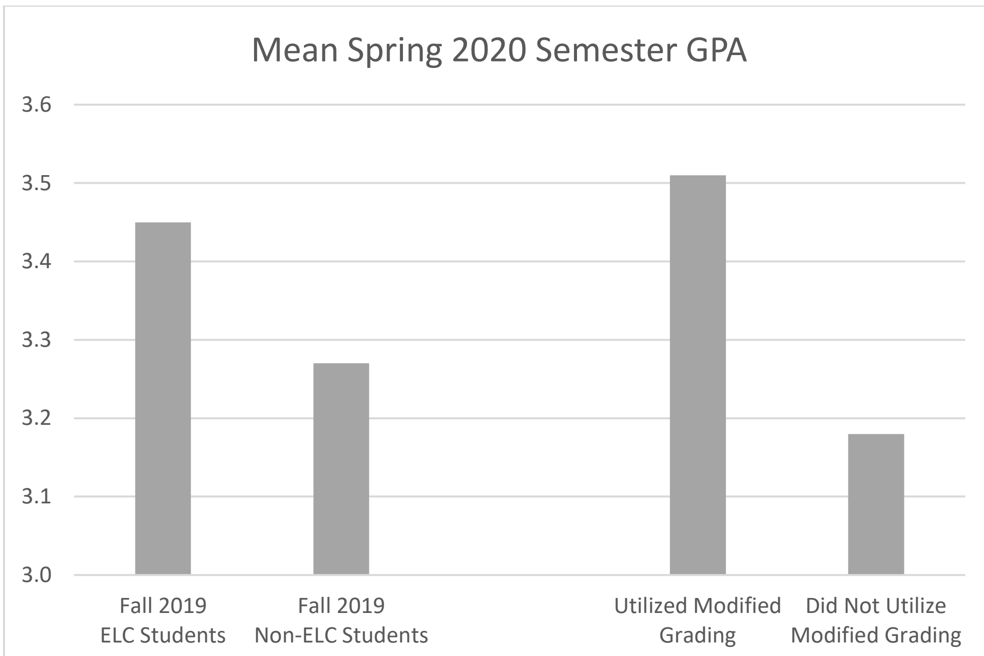

Figure 2. Mean Spring 2020 semester GPA for Fall 2019 first-year engineering students.

The finding that there was a statistically significant difference in Spring 2020 semester GPA between students who utilized modified grading versus students who did not suggests that if modified grading were not an option, perhaps the difference in Spring 2020 semester GPA between ELC students and non-ELC students would have been more pronounced.

Research Question #2b (RQ2b)

To answer RQ2b, an independent samples *t*-test and a chi-square test of association were conducted. The *t*-test checked for a difference in completion rate between ELC students and non-ELC students, while the chi-square test checked for an association between ELC participation and a Spring 2020 completion rate of 100%.

The *t*-test yielded statistically insignificant results (t (134) = 0.782, p = 0.435), but there was an observed difference in completion rate; ELC students had a mean completion rate of 91.97% in Spring 2020, whereas non-ELC students had a mean completion rate of 87.63%. The chi-square also yielded statistically insignificant results (χ^2 (1) = 0.976, p = 0.323), but there was also an observed difference in 100% completion rate; for ELC students, 80.95% had a Spring 2020 completion rate of 100%, whereas for non-ELC students, 70.44% had a Spring 2020 completion rate of 100% (see Table 6 and Figure 3).

Table 6. Spring 2020 Completion Rates by Fall 2019 ELC Participation.

	Spring 2020 Completion Rate	Percentage of Students with a 100% Spring 2020 Completion Rate
Fall 2019 ELC Students	91.97%	80.95%
Fall 2019 Non-ELC Students	87.63%	70.44%

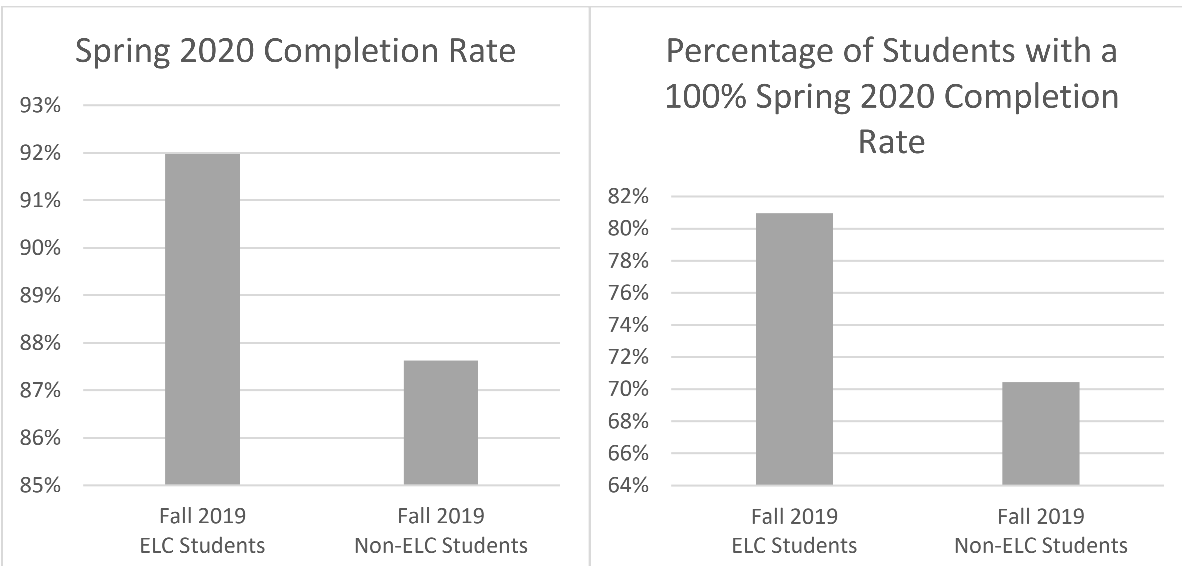

Figure 3. Spring 2020 completion rates for Fall 2019 first-year engineering students.

Discussion

The ELC was first implemented in the Fall 2016 semester in an attempt to promote the success and ultimately retention of first-year undergraduate engineering students. Each academic year since its first implementation, the ELC has been iterated based on student feedback, best practices, and, beginning in the Fall 2019 semester, support from the NSF in the form of S-STEM scholarships for financially qualified students. The purpose of this study was to compare outcomes between the first four cohorts of the ELC to determine if iteration showed increasing promise for promoting student success. In comparing the mean first-year cumulative GPA of students in each ELC cohort, the Fall 2019 ELC cohort did indeed demonstrate the highest GPA, and was statistically significantly higher than GPA for the Fall 2017 and Fall 2018 ELC cohorts (see Figure 1).

However, one observed difference in GPA is that the Fall 2016 ELC cohort had a higher GPA than the Fall 2017 and Fall 2018 ELC cohorts. Although this difference was not statistically significant, it is still a curiosity that deserves attention. One possible explanation for this dip in GPA is that the Fall 2016 ELC cohort was smaller, which perhaps allowed for more focused, devoted attention from instructors. Starting in Fall 2017, there was an attempt to scale the ELC to include more students, as well as an attempt to expand the first-semester course bundle to include an English course and adding a second-semester course bundle for a two-semester experience. It is possible that this expansion in both ELC components and student participation diluted efforts, perhaps resulting in first-year cumulative GPA to dip.

However, a more likely explanation in this observed difference is the change in co-requisite math course. In the Fall 2016 ELC, the co-requisite math course was Calculus I, which meant that students who were not yet calculus-ready were not able to participate in the ELC. Beginning in Fall 2017, the ELC's corequisite math course was either Calculus I or Precalculus, depending on students' math placement. This meant that participation in the ELC was opened to students who placed into either Calculus I or Precalculus, thus including students with a wider range of prior math achievement. This change in math co-requisite was a sustained change in the ELC, meaning that the Fall 2019 ELC also included students with the wider range of prior math achievement. The fact that the Fall 2019 ELC cohort had the highest cumulative first-year GPA of the four cohorts suggests that the improvements made to the Fall 2019 ELC, including the support of the S-STEM scholarship for financially qualified students, was perhaps able to overcome the association between math prior achievement and GPA for undergraduate engineering students. This is an important potential finding, especially in light of research on calculus readiness and undergraduate engineering outcomes. Specifically, prior research suggests that calculus-readiness predicts a higher first-year GPA [16], which in turn predicts graduation in engineering [17], [18]. Additionally, prior research has also demonstrated that students not calculus-ready in their first semester are less likely to graduate from engineering [17], [18]. However, further research on calculus-readiness and the ELC needs to be conducted before a more firm conclusion can be drawn.

The onset of the COVID-19 pandemic during the Spring 2020 semester presented a confounding variable for this study, as only students in the Fall 2019 ELC cohort experienced the pandemic and its stressors, and only students in the Fall 2019 ELC cohort had the opportunity to utilize the modified grading option, which could have inflated both their Spring 2020 semester GPA and their first-year cumulative GPA. However, in comparing Fall 2019 first-year students who participated in the ELC with those who did not participate in the ELC, a clear picture of increased academic resilience emerged for students in the Fall 2019 ELC cohort.

Although students in the Fall 2019 ELC cohort had the opportunity to utilize the modified grading policy and thus protect their Spring 2020 GPA from the impact of lower grades, most did not. In fact, only 2 students (out of 21; 9.52%) utilized the modified grading option, whereas for first-year students who did not participate in the ELC, 41.74% (48 out of 115) utilized the modified grading option. This was a statistically significant association, with fewer ELC participants utilizing modified grading than expected. This finding suggests that ELC students were better able to complete their courses with acceptable grades than were non-ELC students.

Additionally, ELC students had higher Spring 2020 GPAs than did their non-ELC counterparts. The mean Spring 2020 semester GPA of ELC students was 3.45, whereas the mean Spring 2020 semester GPA of non-ELC students was 3.27. This difference is not statistically significant, but because non-ELC students utilized modified grading at a statistically significantly higher rate than did ELC participants, this observed difference suggests that if modified grading had not been an option, the difference in GPAs would likely be more pronounced. The fact that ELC students did not utilize modified grading as much and still demonstrated a higher GPA than non-ELC students points to their academic resilience during the pandemic.

Further, ELC students also had higher completion rates than their non-ELC non- counterparts. Although not a statistically significant difference, ELC students demonstrated a Spring 2020 completion rate of 91.97%, whereas non-ELC students had a Spring 2020 completion rate of 87.63%. Similarly, 80.95% of ELC students had a Spring 2020 completion rate of 100%, compared with 70.44% of non-ELC students. This observation, especially when paired with differences in GPA and utilization of the modified grading option, provides evidence that those who participated in the ELC were better able to stick to their academic plan, complete their Spring 2020 credits, and earn acceptable grades in the midst of a global pandemic than students who did not participate in the ELC.

To summarize, the Fall 2019 ELC cohort demonstrated better academic outcomes than previous iterations of the ELC, as well as higher levels of academic resilience than other first-year students who began in Fall 2019 but did not participate in the ELC. This all provides evidence that the ELC, its high-impact practices, its iterations, and the availability of an S-STEM scholarship for financially qualified students are indeed promoting student success in undergraduate engineering.

Limitations of this study include a small sample size, a timeframe too short to consider long-term retention and graduation outcomes, and the somewhat narrow understanding of complex in-vivo social science phenomena that occurs when only quantitative data are considered. Suggestions for future research include gathering longitudinal data that includes retention and graduation outcomes, comparing ELC participants and non-participants for each ELC cohort (not just the first-year students from Fall 2019), and integrating qualitative data to provide a more complex and nuanced view of the many factors that impact student success and retention in undergraduate engineering programs.

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