Evolving Engineering Education: A Strategy to Improve Student Performance

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Full Paper: Evolving Engineering Education: A strategy to improve student performance

Abstract

Improving student performance is an evolving element in engineering education and this full evidence-based practice paper will discuss some practices that contribute to student performance. A student entering an engineering college in the 1980s may have heard the phrase, "*Look to the left, look to the right, only one of you will become an engineer*." While some of us may have heard that phrase when entering college, today the aspirational objective should be, "*Look to the left, look to the right, all three of you have the opportunity to graduate as an engineer*."

Several factors are creating challenges in meeting this aspirational objective: student preparation, student demographics, and student to college adaptation [1][2][3][4][5].

Student preparation is one of the most challenging elements a college can face. Incoming student population preparation is changing. Over the last 5 years, students that are entering engineering are less prepared in the state of Louisiana because over 20% of all the math and science classes taught are short of adequately prepared teachers [4][6].

The student demographics is also changing. The percentage of first-generation students has increased over 17% since 2012. Underrepresented minorities have increased over 8% and Pell grant recipients has also increased over 8%. These changes in student make-up are positive as engineering expands and diversifies its student population [1].

Strategically, the Louisiana State University College of Engineering (CoE) decided that programs must be implemented to give students the best opportunity for success. As a college, in the heat of the pandemic and with industry support, several programs were developed including a summer academic (calculus) bridge course, peer mentoring programs, and structured first-year student tutoring within the college.

Bridge to Engineering Excellence (BEE) was started as an online program the summer of 2020 to prepare incoming first-year engineering and computer science students for differential and integral calculus, build connections with current successful engineering students, and introduce student success skills. *Big Sibling Mentoring* is a peer mentoring program that builds relationships between freshmen and upperclassmen with similar backgrounds through a formal program. The goal is to provide students with insight that improves the transition to college and to ultimately increase CoE retention and graduation of students. *EXcellence in Calculus/STEM for Engineering Leadership and Diversity (EXCELD)* is a student peer tutoring program that was established in the college for freshman-level math and science courses.

The implementation of these programs for CoE majors at LSU are impacting the retention of students and creating a connected community of students. This paper will present more of a case study assessment of the three programs designed to help engineering students reach success.

Introduction

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Strategically, the Louisiana State University College of Engineering (CoE) decided that programs must be implemented to give students the best opportunity for success through academic self-awareness and academic preparedness. As a college, in the heat of the pandemic and with industry support, several programs were developed including a summer academic (calculus) bridge course, peer mentoring programs, and structured first-year student tutoring within the college.

Bridge to Engineering Excellence (BEE): BEE was started as an online program the summer of 2020 to prepare incoming first-year engineering and computer science students for differential and integral calculus, build connections with current successful engineering students, and introduce student success skills. The program has helped BEE students increase their calculus readiness (ALEKS) math scores, GPAs, and retention.

Big Sibling Mentoring: This peer mentoring program builds relationships between freshmen and upperclassmen with similar backgrounds through a formal program. The goal is to provide students with insight that improves the transition to college and to ultimately increase CoE retention and graduation of students.

EXcellence in Calculus/STEM for Engineering Leadership and Diversity (EXCELD): A student peer tutoring program was established in the college for freshman-level math and science courses. Upperclassman that completed a course with B- or higher tutor freshmen in critical foundation courses for engineering majors. Students in the program have improved their scores in their freshman STEM courses over students not in the program.

The implementation of these programs for CoE majors at LSU are impacting the retention of students and creating a connected community of students and new student leaders. This paper will present more of a case study assessment of the three programs designed to help engineering students reach success.

Project Approach

Discussion here will surround the execution of each of the programs mentioned above including items learned along the way. These programs were not established in an experimental fashion but with more of an approach to solve a problem – *improvement of student success*. So, the discussion is presented in a case study form as opposed to an empirical research project.

The combination of these three programs started in Fall of 2020 when a serendipitous combination of student need and generous corporate sponsorship aligned. Students had an opportunity to report directly to our college's Diversity Board as to the needs of entering diversity, high risk students for additional help with STEM courses. The results of that discussion led to these three programs. Each program will be discussed and then the assessment methods and findings will follow in the results section.

Bridge to Engineering Excellence (BEE) Program Motivation and Structure

The Bridge to Engineering Excellence (BEE) Program developed initially due to the cancelation of an in-person minority focused university wide-residential bridge program due to COVID-19 in 2020 [2]. Since then, each summer the BEE program prepares incoming students for math readiness. The program provides incoming first-year engineering and computer science students content to prepare them for differential and integral calculus, create connections with existing engineering students, and introduce student success skills. The overarching goal of the program is to increase retention and improve academic math performance. Through this program, students were able to develop a strong self-awareness of their skills and need for improvement.

Concern for student preparation in college-level needed math skills was the impetus for the program. This program delivered synchronous math classes over six weeks taking advantage of video conferencing technology that emerged heavily during COVID. In addition, students received daily tutoring sessions, and weekly academic and professional success workshops. A university-based PhD mathematics faculty with extensive experience in these fields covered topics that included inverse functions, logarithms, trigonometry, limits and continuity, differentiation, applications of differentiation, integration, and applications of integration.

Initially course material was presented through a slide presentation format and evolved into the use of a handwriting notetaking application on an iPad delivered through video conferencing software. The later approach provided has the advantage of presenting material in a classical 'whiteboard-like' setting like the traditional classroom. Also, all content was recorded and posted for future study. Breakout rooms were used to encourage interaction with other class members and tutors. In addition, mandatory quizzes and a final exam kept students active in the course material. Students were given numeric grades to give them a sense of their mastery and to

provide motivation, however, no course credit was given. Thus, this approach increased student participation in the assessments along with educating students on their skills that needed improvement.

Students also participated in daily one-hour tutoring sessions. Tutors were current engineering and computer science students and were assigned to the same participants throughout the program. Sessions discussed homework assignments and attendance was required.

In addition to math preparation, students were assigned weekly readings on engineering success and participated in professional presentations from current engineers on topics such as mental health, engineering ethics, and internships. Discussions were held surrounding the weekly topics. Based on the student feedback the book, *The Secrets of College Success*, was integrated into the readings.

Big Sibling Mentoring

The Big Sibling program was created to provide a venue where freshmen could have someone to reach out to with questions about college life, and for upperclassmen to deliberately share their insight via recommended discussion topics. This program grew out of the recognition that one of the variables of great impact that provides students with the ability to navigate and overcome challenges and eventually graduate, is the non-academic knowledge or insight they develop while in college [7][8][9][10]. Throughout a student's college experience a great amount of insight is learned outside of the academic content of courses. This insight is necessary to overcome the many challenges that present themselves in college. The challenge is to have access or learn it in time to face the challenges, rather than as a lesson learned because of the failure to overcome a challenge. Failing to gain this insight can jeopardize a grade, course or ultimately the ability to graduate.

While students eventually develop this insight in college through their own personal experiences, this can sometimes be risky and inefficient. This is an issue that many upperclassmen recognize, yet few freshmen realize it exists. Through their experiences and maturity, upperclassmen recognize the importance of the college-life lessons they have learned and are eager to transfer this knowledge to new students. Yet they have difficulty finding those who need it, and freshmen fail to realize the need to receive this knowledge. This creates a broken system that constantly sheds all this tacit knowledge as cohorts graduate, and new students arrive without realizing what they are missing. Given the number of upperclassmen that applied for the program outnumber by 2 or 3 times the freshmen signing up for the program shows that upperclassmen know how much this knowledge is needed. Our upperclassmen realized through their leadership that they could help incoming freshmen avoid the pitfalls they may have experienced.

Big Sibling was first piloted in the Fall of 2020 and had its 3rd iteration in the Fall of 2022. It is a voluntary program, although it was a requirement as part of the Introduction to Engineering course where undecided engineering students enroll. This is because the perception is that students in this class may have more risk of negative outcomes in terms of retention and graduation. Participants in the program are matched based on their preferences and invited to

participate in “meet-up” events such as kick-off, surveys, and a semester close-out event. Mentors are provided with a training session and with supplemental materials to support their discussions, which are suggested via a discussion topic calendar throughout the semester. Rather than promoting a deep mentorship program, the Big Sibling program allows students to tailor the experience to their needs. While students are promoted and encouraged to meet, it is up to students to set the frequency and depth of their interactions. The Big Sibling program has adapted to lessons learned and feedback is sought from student participants.

EXCELD (EXellence in Calculus/STEM for Engineering Leadership and Diversity)

The EXCELD (EXellence in Calculus/STEM for Engineering Leadership and Diversity) program paired entering freshmen with upperclassmen engineering students who earned at least a B- in the course they are tutoring [11]. Students apply to the program and all applications are accepted. While all students were provided opportunity to participate in the program, targeted marketing went to students from underrepresented minority groups, female, first generation, low socioeconomic status, returning veterans, and students with lower ACT/SAT scores. Students with these characteristics typically contain high performing students yet potentially underprepared individuals who are at risk for not being successful in their first year of engineering and STEM courses. The EXCELD program has evolved from an online-only service during the pandemic to the hybrid platform it is today.

EXCELD began at the height of the pandemic and during a time when traditionally underprepared students were struggling even more with the changing education methods due to school closures and at-home learning. In Fall 2020, the program was strictly online and covered four math courses: MATH 1021 (College Algebra), 1022 (Trigonometry), MATH 1550 (Calculus I) and MATH 1552 (Calculus 2). As a part of the application process both tutors and students sent in their availability to the program director and students and tutors were matched based on this factor. Matching similar majors was a priority but was not possible in about 50% of the pairings. Students were required to meet individually with their tutors one-on-one once per week and attend one group session (with all the students the tutor had been assigned) once per week. The intent of the group session was to create opportunities for students to meet (even if it was only online) to promote the formation of online study groups. One-on-one sessions seemed to be regularly attended, but group sessions were commonly missed. Additionally, students requested that more courses be added to the EXCELD offerings. In Spring 2021, the program expanded to include STEM freshmen level courses such as chemistry, biology, physics, and geology. In Fall 2021, the program was expanded further to include freshmen-level computer-based courses such as: computer aided drafting, java programming and C++ programming.

Listening to our students’ needs is the cornerstone to success of this program. Noting attendance issues and issues with students switching tutors due to miscommunications or changes in availability, led to the team adopting an appointment and tutor matching software in Fall 2021. This has allowed our students to more easily select a tutor who works for them. Further, the requirements for one-on-one and group tutoring session attendance have changed such that students can request which mode works best for them (group vs. one-on-one). One-on-one tutoring sessions availability is limited by the number of students hired and their availability during the week (i.e., some tutors can only take on 2 students, while other tutors can take 6 or

more). Because space with one-on-one tutors is limited, should a student request one-on-one, they must commit to meet with an assigned tutor once per week. Conversely, if a student thinks they only occasionally need help, they can sign up for a group session, any time with any tutor who is available. This system has allowed the program to help students who are waiting for a one-on-one tutor to become available and allows us to let more students into the program.

Results and Discussion

For each program, data was collected to assess the effect of the program. One may consider this quasi-experimental. Instead, this data was more collected to determine if the programs needed to be tweaked and improved over time. Each of the programs has seen success but also identified means of improvement (e.g., continuous improvement).

BEE Outcomes

The BEE program impact has been assessed using multiple outcomes of academic performance and retention: ALEKS scores (Math placement exam), first calculus GPA, first semester GPA, second semester GPA, overall GPA, retention in CoE, and retention at LSU were tracked.

The ALEKS math scores were found to improve through the BEE program. Of the students who did not meet the 76 minimum score to enroll in the first calculus, 66.7 percent of the students increased their scores and the mean score improved to 82.0. When compared to a subset of participants who qualified for calculus prior to the BEE program (e.g., ALEKS > 76), the score was found to be comparable (e.g., BEE students - 82.0; cohort not in BEE - 83.6). A higher ACT score was present in students who qualified for calculus with an ALEKS score 76 or above compared to BEE students.

Grade point averages for calculus (first semester, second semester, and overall year 1 and year 2) was tracked for all participants and those retained in the CoE (Table 1). Our CoE students historically earn a 2.75 mean calculus GPA for their first semester and after the first year has been 2.75 (std 0.80). BEE participants had first semester GPA of 3.20 (std. 0.735), and year 1 GPA of 3.18 (std 0.652). BEE participants performed better academically than the overall CoE students.

Table 1. Academic performance of three cohorts. Mean data presented.

Academic Indicators	Cohort 1	Cohort 2	Cohort 3	All	Retained
First Calculus GPA	2.9	2.6	3.2	2.9	3.0
First Semester GPA	3.1	3.1	3.3	3.2	3.3
Second Semester GPA	2.9	3.0	-	2.9	2.8
Overall GPA Year 1	3.2	3.2	-	3.2	3.1
Overall GPA Year 2	2.9	-	-	2.9	2.9

Retention is a major goal in engineering colleges across the country, so retention has been tracked each year (Table 2). BEE participants from the 2020-2021 and 2021-2022 cohorts are persisting in the CoE at a much higher rate than traditional engineering students in the college (e.g., 10 percent higher for year 2 retention based on 2021-2022 and 2022-2023 cohorts, and 34 percent year 3 retention based on 2020-2021 cohort). Three BEE students changed majors: business majors (2) and art (1). In addition, three BEE participants from the 2020-2021 and 2021-2022 cohorts are no longer LSU students for various reasons.

Table 2. Table 2. Retention of BEE compared to CoE historical data 2008-2019. Year 2 cohorts 2020-2021 (n=9), 2021-2022 (n=17), and 2022-2023 (n=31). Year 4 data only 2020-2021 cohort.

Engineering Retention	Year, n=composite#	BEE All Cohorts (n=57)	Historical CoE Mean
In CoE	Year 2, n=57	84%	67%
	Year 3, n=26	77%	55%
	Year 4, n=9	89%	
At LSU	Year 2	88%	83%
	Year 3	81%	75%
	Year 4	89%	

Multiple BEE participants have indicated that the program benefited them both academically and socially through connections with LSU CoE students that helped students develop an awareness of needed study skills. Student ***HR*** noted she "*would not have survived the first semester without*

BEE." Student ***CW*** said that "*Calculus review and prep made the first month of calculus less stressful and easier.*"

Lessons Learned and Future Plans

The suspension of an in-person learning, and bridge program was the impetus for the Bridge to Engineering Excellence program instead of a well-defined engineering educational hypothesis. However, data was collected to assess its performance. In addition, several lessons were learned; (1) create a program that captures in-person type activities i.e., slides versus whiteboard; (2) using Zoom technology to streamline administrative tasks while the instructor focuses on creating an engaging class. This allowed enforcement of video engagement; (3) simulating the homework, quiz, and test expectations of a credit course, will elicit student behavior as if it were for credit; (4) moving group work to the beginning of class and the addition of attendance points decreases the number students who left class early. Some students were hesitant to participate in group work and would drop off when group activities were held at end of class; (5) scheduling tutoring sessions with the same tutor modeled the expected college-level study habits and allowed the participants to truly connect with a current student. Gathering feedback from tutors provided another source to improve calculus delivery methods, content, and student comprehension level. One example is decreasing the amount of homework type problems done in class.

While leadership was not the project's primary expectation, the program led to multiple BEE participants eventually taking leadership roles: leading student organizations and serving as tutors. Additionally, several (14) received the National Action Council for Minorities in Engineering (NACME) scholarship.

Big Sibling Mentoring Results

Big Sibling's first iteration resulted in 53 freshmen, but an overwhelming 300+ upperclassmen mentors (Table 3). The large upperclassmen response showed the desire for them to provide leadership to new students along with sharing their experience regarding the struggles many freshmen experience. This created a great opportunity to match freshmen with someone meeting most of their criteria. At the same time this did create a great deal of disappointment from those upperclassmen who were not selected. In later iterations of the program, more students have signed up, but the recruitment of upperclassmen has changed. Now they are more directly approached via mailing lists attempting to match the profiles of the entering freshmen. This has eliminated the number of upper classmen that are not paired.

Table 3. Program Applicants

Year	Little Siblings	Big Siblings
2020-2021	53	350
2021-2022	135	275
2022-2023	146	137

The program was primarily promoted to underrepresented minority students in its first iteration but made available to anyone who wanted to join (Table 4). In its current iteration the program has been expanded and targets all freshmen which has reduced the percentage of underrepresented minority students. Nonetheless the number of underrepresented freshmen has increased in volume, yet the participation of upperclassmen has decreased. This may be a reality of the limited number of upperclassmen underrepresented minority students, and anecdotally, the socioeconomic challenges many face (e.g., work or family obligations that limit the number of programs they can participate in).

Table 4. Proportion of Underrepresented Minority Students (URM) in the program

Year	URM Freshmen		URM Upperclassmen	
	%	N	%	N
2020-2021	94.0	50	77.0	27
2021-2022	40.5	51	36.0	99
2022-2023	44.1	61	38.6	49

Some trends are observable in the gender profiles (Table 5) of the freshmen participants where the percentage of females has trended downward, yet the profiles of the upperclassmen remain consistent.

Students are matched based on their ranked preferences as best as possible. Students are asked to rank order the variables with which they wish to be matched. In general, the majority of student across years overwhelmingly rank their major (ranging 54% to 74%) as their first matching priority. The other three optional variables are rated first as follows: Academic Interests (ranging 12% to 17%), Race or Ethnicity (5% to 10%), and Gender (4% to 12%).

Table 5. Gender Distribution in the program

		2020	2021	2022
		%	%	%
Freshmen	Male	38	56	72
	Female	60	42	29
	Prefer not to answer	2	1	0
	Self-Identify	0	2	0
Upperclassmen	Male	51	55	52
	Female	49	42	46
	Prefer not to answer	0	1	2
	Self-Identify	0	2	1

The program was instantiated as a year-long commitment initially but it experienced significant drops in participation during the Spring semester. Feedback revealed that students wanted to have the Spring as an optional commitment. Following cohorts were Fall semester commitment only, although students are encouraged to continue their relationships to their benefit. Anecdotally, we have observed several students who continue to interact with their Big Sibling

long after the program ends and depend on this relationship as an expansion of their network. One of the challenges of any similar program is on tracking participation and encouraging students to meet or take advantage of the mentorship opportunity. For this program, periodic emails are used to remind students to meet and discuss topics. Meeting "challenges" or encouragement have been used with relative success (e.g., post a picture of your meeting, offering food on select evenings on campus). In addition, a simple participation point system has been utilized to encourage participation by allowing students the opportunity to earn items (e.g., t-shirts).

In the future the program will continue to evolve and adjust to meet the students' needs and encourage freshmen to connect with those ahead of them in their programs.

EXCELD Results

The EXCELD program was primarily advertised to students involved in bridge programs, specifically targeting underrepresented minorities to the College of Engineering in Summer 2020 and just before classes started in August 2020. As a result, the program attracted more URM students in Fall 2020. As the reputation of the EXCELD program grew and a wider audience was tapped for advertising (e.g., entering freshmen recruiting events, CoE resource fairs, websites and cold emailing the CoE freshman class), the EXCELD program's ethnic and race demographics now more closely match the CoE's demographics (Figure 1). The gender demographics were heavily weighted in with more females in the program at first, but as the program was more widely advertised, more males were applying and being offered spots in the program (Figure 2).

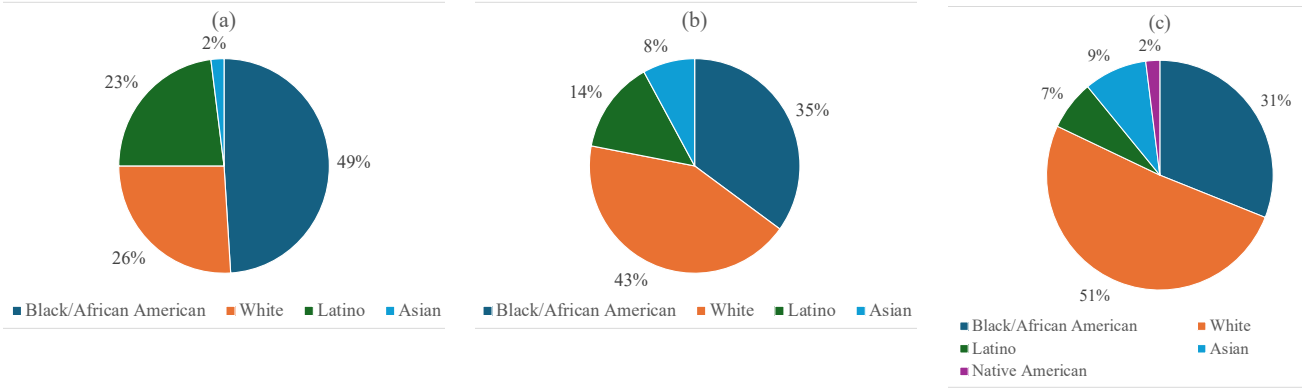

Figure 1. Race / Ethnicity demographics of the EXCELD program: (a) Fall 2020, (b) Spring 2020, (c) Fall 2021

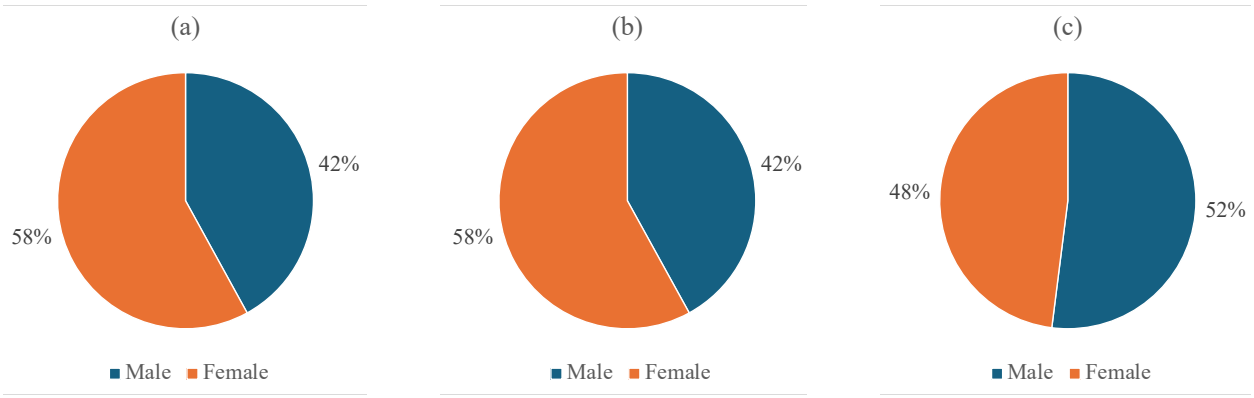

Figure 2. Gender demographics for EXCELD Program: (a) Fall 2020, (b) Spring 2020, (c) Fall 2021. (Note CCC has not adopted a non-binary choice for selection in the student information data collection for gender).

One of the major impacts the program made at first was with students' confidence in math. On the application for the program, students were asked to rate their percent confidence in math and given the options of: 0%, 20%, 40%, 60%, 80% and 100%. The students were also asked to rate their confidence in the program after the completion of the first semester. In Fall 2020, students self-rated their confidence in math to be approximately 42% on average. By the end of Fall 2020 semester, students rated their confidence in math to be 75% after using the EXCELD program. Unfortunately, the data collection in subsequent terms was not incentivized for post-semester analysis and there were not enough respondents to show an adequate representation of the population. Anecdotally, students who did complete the post-semester review did mention an increase in math confidence. Further, in Spring 2021, the performance of engineering students in MATH 1550 (Calculus I) was analyzed and students in EXCELD were compared to those that were not. Students in the EXCELD program tended to get more A's than those who were not (Figure 3). While it was alarming at first that the DFW rate for EXCELD students seems to be higher than that of students who were not in EXCELD, further analysis determined that the EXCELD students who earned a D, F, or W either sought help too late in the semester to turn their grades around or did not regularly attend EXCELD tutoring sessions as they should.

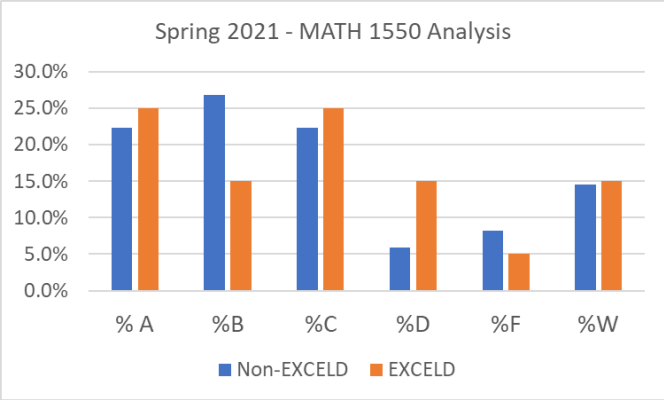

Figure 3. MATH 1550 (Calculus I) performance for engineering students in Spring 2021

The performance of engineering students in both CHEM 1201 (Freshman – STEM Major Chemistry) and MATH 1550 was analyzed again in Fall 2021. We implemented a new tutoring matching program and worked with students to get matched with their tutors before the semester started. We were able to determine attendance of students much earlier and encourage attendance earlier in the semester. As such, more students were attending sessions and more students in the EXCELD program were earning A's and B's in CHEM 1201 and MATH 1550 than non-EXCELD students (Figure 4). This early intervention also appeared to positively affect the DFW rate for students in these classes as well.

(a) (b)

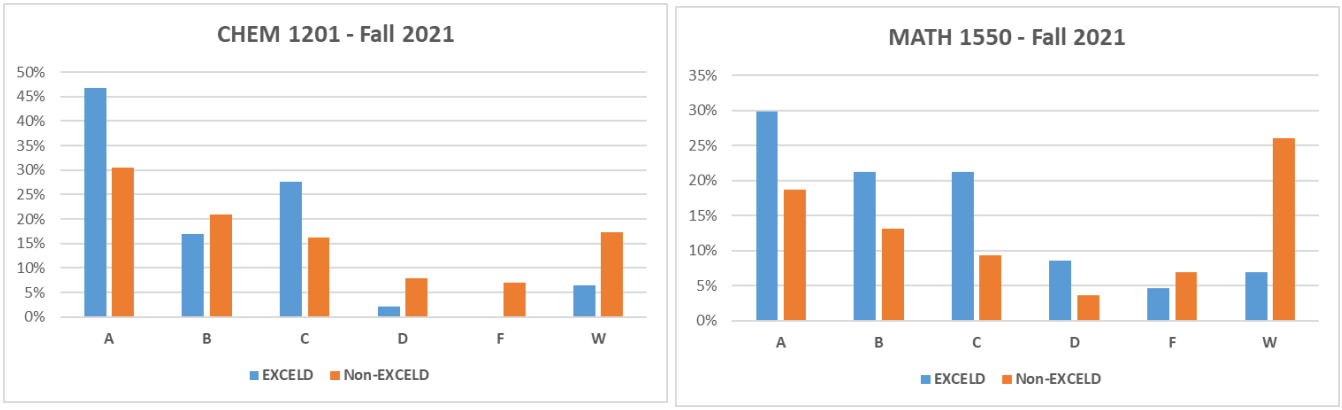

Figure 4. Freshman student performance in (a) CHEM 1201 (Freshman General Chemistry for STEM Majors) and (b) MATH 1550 in Fall 2021

Conclusion

Three programs developed during the COVID period were intended to affect student success. Bridge to Engineering Excellence (BEE), Big Sibling Mentoring, and EXcellence in Calculus/STEM for Engineering Leadership and Diversity (EXCELD) are three programs that continue to improve with time. While they were grown out of a significant milestone in our history, COVID, they show the path forward for helping more students become engineers. The easy answer for any engineering college is to only admit high achieving, financially secure, and emotionally (e.g., college adaptive) ready students. However, our country deserves better than that and our economy demands more engineers, not less. Additionally, all three of these programs could be easily adopted at other institutions.

A side benefit of the programs was student increased confidence and the development of leadership skills for both existing and new freshmen students. While leadership was not directly assessed, strong anecdotal evidence reflected students engaging in leadership activities (e.g., officers in student organizations). This benefit will be better assessed in the future to determine its impact.

As engineering educators, we must continue to evolve and find ways to help students achieve success. Experimenting and evolving is important for us as engineering educators. It is the nature of the fields we have chosen as professions.

Colleges can create programs like these, but students must participate. The old saying you can lead them to water but can't make them drink is true. What these programs have revealed is that where there is success, students will follow. Each of these programs have seen students attracted to them over the short time due to success. In addition, students must bring their passion and perseverance for programs like this to work.

Great engineers are built and not born. Programs such as this will allow us to continue to build great engineering leaders.

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