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Board 287: Exploring the Broader Impact of the NSF S-STEM program on the Culture of a Community College Engineering Department

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Abstract

This paper and corresponding poster describe the impact of implementing a National Science Foundation (NSF) Scholarship in Science, Technology, Engineering and Mathematics (S-STEM) program at the College of Lake County (CLC). The focus is on the overall engineering program culture at this Hispanic-Serving (HSI) community college. Lessons learned in earlier grants, including the importance of intentional advising, strong support services, the value of an internship, and the benefits of a makerspace environment shaped the latest proposal. Building an Academic Community of Engineering Scholars, the current grant program, has continued these efforts along with collecting quantitative survey data.

Scholarships are provided to academically talented low-income engineering students with the intent of increasing retention as well as successful transfer rates in order to graduate with a bachelor's degree in an Engineering or Computer Science (ECS) field. Since the spring of 2020, 43 unique students have been awarded scholarships. At this time, there are 16 active scholars, 18 have already successfully transferred to complete their ECS degree and 50% of those scholars received an additional S-STEM transfer scholarship. The remaining students have switched to applied degree programs or left college to pursue full-time employment.

To develop a better understanding of the factors influencing student success, a series of overarching questions were developed for the program to examine. The focus was on the concepts of self-efficacy and sense of belonging as they relate to tutoring, experiential learning (formally in the classroom and informally), and commitment to their degree program. One particular question has been influential in the pedagogical approach to engineering course design over the last four years. “By engaging students in experiential learning, problem-based activities, and prototyping in the Innovation lab at the beginning of their studies; can we increase both the overall number of students in the ECS program and their persistence rates? Does this hold equally true for women and under-represented minorities?” The effects of this question on the overall engineering curriculum, broader community engagement, as well as the obstacles encountered during the pandemic will be discussed as the first three years of the five-year program are examined.

Background

Since 2006, the College of Lake County ECS program has managed three S-STEM awards. A combined total of 199 students have received both financial and holistic academic support. Each time, the NSF Scholars population has included a higher proportion of underrepresented students, in terms of gender and ethnicity, fulfilling one of the underlying goals of the scholarship program. In addition, a higher mean cumulative GPA and transfer rate for bachelor's degree completion was observed in comparison to other students in the program. This has been accomplished through intentional advising, mentoring, tutoring and a strong cohort model.

Selection of the NSF Scholars is based on a successful formula for student recruitment and designation. Students are recruited from local area high schools and current CLC students. Schools with a significant minority and/or low-income population are targeted. The Program Navigator and contacts within the schools assist with identifying potential candidates, arranging for class visits, and encouraging participation in summer camps and outreach events. Students must meet definite criteria, including full-time status, financial need, and academic qualifications, and must submit an application, an essay, and letters of recommendation.

The current S-STEM program which began awarding scholarships in the spring of 2020, continues to offer the same financial and holistic academic support. The community building theme, which is central to this current award, is an extension of the engineering department philosophy as well as a driving force for improvements. Based on a desire to broaden academic support, the tutoring was expanded to include coverage of any engineering or computer science student at the college. This is accomplished in the form of weekly study hall sessions with engineering, computer science, math and engineering faculty present. The length of time and space was expanded as well; the study hall is now held in two classrooms as well as the Baxter Innovation lab, the campus makerspace.

The Baxter Innovation lab, which has been open since 2018, was designed as a cornerstone for the engineering program. The literature suggests that makerspaces/fab labs could increase retention of students in STEM related fields and improve their confidence when solving technical problems because they highlight the creative aspects of engineering and build a community of practice that increases students' sense of belonging [1], [2]. Thus far, it has provided access to prototyping technology and collaboration space enabling unique team building activities for the NSF Scholars and within the engineering courses. Experiential learning opportunities, both formal and informal, have also increased significantly over the last five years. In addition, as a student run lab, it has created job opportunities for 51 students, 12 of which were also NSF Scholars.

Understanding the impact of the S-STEM award and the engineering curriculum has been the focus of surveys conducted each semester starting in 2020. The survey addresses student background, demographics, goals, sense of belonging and self-efficacy and compares these values with student outcomes. The questions were established using the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) developed via the NSF-funded Assessing Women in Engineering (AWE) project [3]. Some items were modified to maintain relevance to the local community college structure eliminating those referencing junior or senior standing and certain preparation activities. Nine additional questions were added focused on engineering self-efficacy as related to experimental skills, design skills and tinkering [4]. Sense of belonging was addressed with three questions on belonging within the college community and three more on belonging to the specific ECS major [5]. These constructs are based on the students' perceptions, each of which are represented by anywhere from 2 to 5 individual items that students rate on a 4-point Likert scale. A value of 1 indicates little confidence or interest whereas a 4 would indicate a strong sense of accomplishment or belonging.

An initial analysis was conducted on the survey data to determine if any student population was uniquely impacted to date. Using the entire survey data set, t-tests using a 95% confidence level were performed to compare the differences in the constructs for selected student populations

based on gender and NSF Scholar status. A one-way Analysis of Variance (ANOVA) was applied to evaluate the different populations based on ethnicity. In each case, no statistically significant difference was observed [6]. This lack of statistically significant evidence to reject the hypothesis that students, regardless of gender or ethnicity, will self-report the same degree of inclusion and sense of belonging is promising.

These results prompted a closer examination of the changes that have occurred over time in the engineering department. Like many colleges and universities there has been an increased use of active learning in the classroom which has been shown to reduce outcome gaps and improve long term performance [7]. Furthermore, a literature review completed by Theobald et al. [8] compared the impact of external student supports such as tutoring, bridge experiences, psychological interventions to the impact of active learning. The authors determined that well executed active learning was more influential with respect to reducing achievement gap for underrepresented and low-income students in STEM fields.

In addition, with the makerspace lab environment available, it is possible to readily integrate experiential learning. This can occur as an informal practice or as a project-based assignment within a course. The reflection portion of the experiential learning cycle as proposed by Kolb [9] enables the student to transform experience into learning. Thus, begins a reflection on our actions and experiences as a department.

Continuous Improvement Mindset

As a department managed by engineers, it is not surprising that each semester is approached with a continuous improvement mindset. Taking the time to reflect on the successes and challenges of previous efforts. The management of the S-STEM awards broadens those reflections beyond the curriculum content and places more emphasis on pedagogy and holistic supports. The personal connection faculty establish with the NSF Scholars and the engineering interns also offer a new lens for program evaluation. It blurs the lines between the goals set in the NSF proposals with those set by the college faculty to support all their students.

To capture the impact of those improvements a review of engineering program initiatives and culture development over a ten-year period (2012-2022) was conducted. Note that this timeframe overlaps two S-STEM awards where improved student success, retention and successful transfer are key outcomes. In addition, the increase in active pedagogy and experiential learning provides the basis to evaluate the following question “By engaging students in experiential learning, problem-based activities, and prototyping in the Innovation lab at the beginning of their studies; can we increase both the overall number of students in the ECS program and their persistence rates? Does this hold equally true for women and under-represented minorities?”

<u>Curriculum</u>

Between 2015 and 2020, two new courses were added to the curriculum and one course was redesigned based on updated Illinois Community College’s Illinois Articulation Agreement (IAI) requirements. EGR 120: Introduction to Engineering and EGR 140: How to Make Almost Anything were both inspired by successful courses at other colleges. EGR 121 which was

originally Engineering Graphics, was revised to include more design content and then aptly renamed Engineering Design Graphics.

The Introduction to Engineering course, first taught in the fall of 2015, encompasses a wide range of outcomes. They include understanding the engineering profession and specific disciplines, developing an academic plan and student success skills as well as an appreciation of workplace behavior and teamwork. One of the greatest strengths of the course is the opportunity for new students to network and develop friendships in their first year of the program. While it is required for the NSF scholars, on average 90 students enroll in the course over each academic year. This is roughly 40% of the first year ECS student population. The emphasis on developing connections to the engineering profession and fellow students is accomplished with social constructivist pedagogy. Students are encouraged to reflect on their strengths and select topics to research based on their personal goals.

The network is expanded beyond the classroom by the introduction of practicing engineers as guest speakers. The speakers are selected not only based on their discipline but also by examining diverse characteristics such as background, gender and ethnicity. A student favorite is the alumni panel consisting of students who successfully transferred in the last three years. The panel offers advice on academics, the transfer process and general mentor insights. These course activities are intended to enhance the students' sense of belonging, self-efficacy and encourage development of engineering identity.

Engineering students typically associate prototyping or "building things" with the engineering profession. The revision of EGR 121 in 2016 to include additional time and effort on the design process has visibly increased student motivation. Utilizing the continuous improvement mindset, new design projects have been introduced over time. The most recent project series spans the entire semester enabling students to complete the experiential learning cycle [9] of experiencing, reflecting, thinking and acting multiple times. Another benefit of starting team projects within the first few weeks of the semester is the informal study groups that form and continue to work together to complete the weekly homework as well as the labs.

This same desire to "build things", expressed by our students, resulted in the development of EGR140 which was first taught in spring of 2020. This course introduces students to all the equipment available in the makerspace including both digital fabrication devices such as 3D printers, lasers and mills as well as more traditional shop tools such as a drill press, miter saw and scroll saw. The first two-thirds of the course combines small projects with certification tasks to demonstrate proficiency. The remainder of the course is focused on a project chosen by the student. Since the math prerequisite is basic algebra readiness, students often complete this course as part of a pre-engineering exploration. Although, there are also students who complete this as one of their last courses in order to enhance their lab skills prior to transfer.

Open Access to Faculty

As a community college, our faculty view teaching as their top priority. On average our faculty members have 10 hours set aside for student support each week. That being said, many students are still reluctant to seek help. The study hall to support our NSF Scholars is one of the methods used to encourage engagement with faculty. Since this has been effective, in 2020 the study hall

was expanded to serve any current ECS student. Noting that students are more comfortable meeting with faculty outside of their office, also prompted faculty supporting our scholars to conduct office hours in the makerspace and library tutoring center.

The pandemic also impacted the modes available for office hours. From 2020 to spring of 2022, most of the office hours were conducted through Zoom. Noting the student preference for this flexibility, many faculty still offer some of their appointments virtually.

Removing Financial Obstacles

Locating quality open education resources for most of our courses has proven difficult. However, for two of the courses, the department has been able to create and find the resources needed resulting in no textbook expenses for those courses. In addition, for courses using CAD software, the students are directed to the online software guides and videos. For the traditional engineering course series of Statics, Mechanics of Materials, and Dynamics, the department was able to purchase a classroom set of older edition textbooks. This enables students to borrow a text at no charge for the semester rather than purchase it.

Like many institutions our students experienced additional hardships during the pandemic. The college was able to provide financial relief to students who may not have qualified for scholarships otherwise. As a department, the efforts were focused on the technological barriers. Twelve laptops were purchased for NSF Scholars that could be borrowed as needed and an additional fourteen laptops were purchased for any ECS students to borrow. This continues to be a great asset for students who need greater computing power to operate CAD or other course software.

NSF scholars also have the option of applying for a transfer scholarship of up to $5000 to support their first semester as a junior in the bachelor's program. To qualify for the scholarship, students must have been an active NSF scholar in the ECS program, have a cumulative GPA of 3.0, write an essay and continue to pursue an ECS degree. Five scholarships are awarded annually.

Internships

Since the initial development phase of the Baxter Innovation Lab in 2016, over fifty students have been employed. Internships are essential to the operation. The students ensure safe operation of the equipment, inspire newcomers with project examples, document applications and techniques, provide customer support and complete maintenance tasks. An online training system has been developed to organize their tasks, however most of their training occurs in a more traditional fashion. Knowledge and expertise are passed on from one intern to the next. This is a very visible form of self-directed social constructivism as described by Vygotsky [10]. The interns will find themselves outside of their current development zone in an attempt to support a customer and will turn to a “more knowledgeable other” for support. At times the other intern will have the answer and on other occasions the two students will work together to construct a solution. As a community college, we have a fairly rapid turnover of our interns and are always training about half of our staff.

At the end of each semester the students undergo a review. Many of the criteria are provided by the campus career services program and focus on communication, work habits, professionalism and job skills. These are general, yet important skills for any workplace and a good starting point when this is the first work experience for some of our students. It is also an opportunity to discuss lab specific expectations. The review is an open dialog since the students do not have an immediate supervisor present during most of their scheduled hours. In addition, after completing the first semester and the bulk of their technical certifications, students are asked to develop their own learning goals for further development. It is important to recognize that this opportunity is always intended to be a steppingstone in their educational journey.

Recruiting & Community Outreach

The availability of a high-quality engineering education at a community college feels at times like a well-kept secret. In order to increase the visibility of the program, an increased number of public seminars in the form of a STEM series were introduced in 2012. Over time, most of the talks were replaced with interactive events that encouraged broader community participation. Events tend to fall into two categories: recruiting and inspiring.

Each year, since 2013, the engineering department hosts an Engineering Night to enable both local high school students and our college students to explore the various engineering disciplines and learn more about university options. The evening begins with a mix and mingle style hour where students (and their parents) ask questions of and enjoy discussion with practicing engineers. It provides a glimpse into the daily routine of the engineer and some insight into their professional path. This is followed by a welcome speech from the engineering department chair and advice on selecting a college or university. Next, participants attend several talks presented by the college or universities. The event has served to strengthen the community colleges' relationships with the high schools and area transfer universities that our students will attend. A virtual version was conducted during the pandemic to maintain these connections. In addition, smaller information sessions about the engineering transfer program are offered every other month.

Providing inspiration to a larger audience has been accomplished with a variety of family friendly fair style events. Nanotechnology Night was hosted for three years from 2013 to 2015 using materials from the National Informal STEM Education (NISE) network. Robotics Night was also hosted during that timeframe highlighting area robotics teams, robotics in manufacturing and hands on activities. Robotics Night was then transformed into the STEM Innovation Fair for 2016 and 2017 enabling broader content and more community partnerships. Maker Faire Lake County and Make a Thon were offered as virtual events in 2021 and then in person in 2022 with plans for 2023. These latest events are enhanced by a partnership with one of the largest employers in the area, Baxter International.

Another avenue that provides increased experiential learning is summer camps with an engineering focus. Since 2013, a growing number of camps have been offered by engineering faculty. The current S-STEM award supports scholarships for up to 20 middle school or high school students to receive a free camp experience. Not only are the students increasing their awareness of STEM professions, but for many of the students this is also their first opportunity to take a course on a college campus. Camps during the academic year have become an integral

component of the Lake County Robotics Competition (LCRC) organized and supported by the engineering department. The competition is envisioned as a low cost, low barrier introduction to robotics for high school students. It is an alternative to the more formal competitions such as Vex or First Robotics, thus reducing the time commitment for students.

During the 2021/22 academic year, the combined engineering outreach activities were attended by over 900 individuals. In addition, this provided opportunities for approximately 60 ECS students to volunteer and mentor in some capacity.

Engineering Education Research

The results and observations are based on a quantitative survey and student comments either verbal or written provided in a variety of contexts. The survey was designed to evaluate student growth and changes in attitudes from the fall of each year to the spring of the same academic year as an integral part of the latest S-STEM award. Each semester the survey is sent to an average of 480 ECS students. The fall response rate is typically 3 to 4% higher than the spring response rate. The highest response was this fall (2022) with a rate of 12%. This is also the first fall semester where all the engineering courses have returned to an in-person format with some flexibility. The initial spring survey in 2020 was conducted just prior to the pandemic shutdown.

Over the last 5 semesters, 207 unique students have responded. Table 1. provides an overview of the demographics of current students in the ECS program, those who responded to the survey and the community college overall. Note that the ethnicity demographics are reasonably aligned with the college population. As an HSI, it is essential that Latinx students are well represented in rewarding STEM career paths. The gender distribution however is skewed as is typical in engineering programs. Fifty-nine students have responded more than once, thus enabling comparison over time. However, no consistent sense of improvement or decline has been measured. The values instead seem to be a direct reflection of the students' current barriers or successes that semester.

Table 1. Comparison of student demographics

	ECS Program (Spring 2021) N = 419	ECS Survey Students (2020 to 2022) N=207	CLC College Level Students (Spring 2021) N = 9772
Gender			
Male	86%	82%	43%
Female	14%	18 %	57%
Unknown	0%	< 1%	< 1%
Ethnicity			
Asian	12%	14%	7%
Black	4%	5%	8%
Latinx	37%	29%	33%
White	40%	43%	46%
Other or not specified	6%	9%	6%

As mentioned, the previous analysis [6] resulted in no statically significant observations for the student populations based on scholar status, ethnicity or gender. Thus, the survey responses will be analyzed as a complete set in this paper, while acknowledging that 19% of the students who have responded were NSF Scholars. The current investigation focuses on analyzing data with respect to time; considering the incremental pedagogical improvements and enhanced student-centered culture and at the same time the impact of the pandemic.

Table 2. contains the average construct values collected on a semester-to-semester basis. In general, the highest values were observed for the survey conducted prior to the pandemic. However, there is not a statistically significant difference. The psychosocial construct values for Feelings of Inclusion, Coping Self-Efficacy, and Belonging Relative to Community are nearly identical (standard deviation of .04 or less) from spring of 2020 through spring of 2022. The lab focused skill efficacy for Design and Experimental skills, also maintained steady average values with a standard deviation of .04 or less. These values imply, that for the students who completed the survey, the sudden switch to a virtual format was successful in supporting these constructs.

Table 2. Constructs measured in surveys to date

Construct	Average value of mean per semester (S.D.)
Success Expectations	3.5 (.06)
Engineering Self-Efficacy Part 1	3.4 (.10)
Engineering Self-Efficacy Part 2	3.5 (.14)
Math Outcome Expectations	3.5 (.15)
Experimental Skills Efficacy	3.5 (.04)
Tinker Skills Efficacy	3.3 (.07)
Design Skills Efficacy	3.4 (.03)
Feelings of Inclusion	3.1 (.04)
Coping Self-Efficacy	3.5 (.03)
Belonging Relative to Community	3.4 (.02)
Belonging Relative to Major	3.6 (.08)

In order to evaluate the level of student success and persistence, the student's self-reported rating of commitment to completing an ECS degree was compared with their sense of belonging in the community and to their major. At the end of the survey, students expressed their intent to pursue an ECS degree by selecting from the following: option 1, Very confident; option 2, Fairly confident; option 3, 50% chance; option 4, Not very confident; and option 5, Not at all confident. This self-reported value was selected rather than more traditional measures such as GPA or term-to-term retention due to the disruptions that occurred during the pandemic. For three of the five semesters, pandemic grading protocols were in place. Students receiving an F or P grade would have no numerical impact on their GPA calculation. The P grade could represent anything between D and B.

A moderate positive correlation was observed for the intent to pursue and sense of belonging to their major. There was also a moderate positive correlation between feelings of inclusion and sense of belonging to their major. While the correlation does not represent causation, it is the underlying foundation of the program to increase sense of belonging in the hopes that it will result in more students successfully completing their degree. The current S-STEM proposal centered its focus on the concept of community building based on evidence-based practices found in the literature [11], [12], [13].

Meanwhile, a low positive correlation was observed for the intent to pursue and sense of belonging to their community and a moderate positive correlation between feelings of inclusion and sense of belonging to their community. Sense of belonging to the community only indicates that students see themselves as a part of the college and not necessarily as an ECS student; thus, the lower correlation is reasonable. As might be expected a strong positive correlation was observed between the sense of belonging to the community and their major. Interestingly, the number of semesters in the program did not have a significant correlation to any of the constructs.

To provide a more qualitative understanding of the impact of classroom practices and the addition of the Baxter Innovation lab, a variety of student feedback tools were examined. These included not only free response items on the surveys, but also classroom survey tools, assignments and course evaluations. The following statements provide anecdotal evidence of positive impact that can be used to inform further research.

Case 1. A student who participated in an NSF Scholar social which enabled her to operate laser technology for the first time.

"During an NSF workshop, we were making acrylic plaques with a laser-engraved quote. I had never seen nor heard of an epilog laser until going to the lab. I was fascinated by how a machine could take a file from a computer and duplicate that onto the acrylic material. Being able to use a machine like a laser to create a piece of art was really cool. "

The next semester she applied as a lab intern and worked in the lab for the following three semesters. Her understanding that students may be outside of their comfort zone was one of her strengths. She was able to guide students and encouraged them to celebrate their achievements.

Case 2. Anonymous student response on the institution's end of semester course evaluation. This Statics course was taught in a flipped format relying heavily on team-based learning and incorporated a problem based learning exercise.

"[The instructor] did very well at also building a good classroom atmosphere by calling on students to answer questions; this helped me open up to others around me whereas I would have probably been much more reserved in a class where this wasn't the case. The classroom felt like a community of students rather than just a group of students there to plug away at a degree."

Case 3. Anonymous student response from a learning gains survey at the end of the fall 2022 semester for the redesigned Engineering Design Graphics course.

"I have learned how to use Fusion and 3D print solid models. It felt good to be able to make my ideas into life and actually see, hold it. I learned to be able to brainstorm as well and come up with more ideas. Working in a group definitely helped me communicate a bit more and I think my group and I learned to not give up so easily and just keep going."

This statement not only references the technical gains from the project-based assignment, but also shares the students' perceived value of the team experience and community support.

Limitations

Considering the elevated level of commitment to pursuing a four-year ECS degree that was observed, there are some concerns that those students responding to the survey may have a biased perspective. Students with a higher sense of belonging may be more likely to respond as well. In addition, the requirement of NSF Scholars to complete the survey creates an oversampling of that student group and a slightly higher sampling of women.

Although many of our students continually manage obligations outside of the classroom, the pandemic certainly increased the severity of those obligations. Those students with the greatest struggles would be least likely to be included in this data.

Conclusions and Further work

The engineering department has made great strides in improving the level of active learning and more specifically experiential learning available to our students. The anecdotal statements demonstrate that the efforts are indeed creating positive outcomes for our students. As the broader impact efforts have been extended to curriculum, it will be important to examine how different instructors are implementing the active learning pedagogy.

The use of the Baxter Innovation Lab has continued to increase as the students return to campus after the pandemic. This will enable the investigation of the initial S-STEM outcomes to be completed. In addition, the expanded outreach activities enable community members to benefit from these efforts and inspire future generations to consider STEM careers.

To develop a more complete understanding of the students' growth and development with respect to self-efficacy, sense of belonging and overall engineering identity development, interviews need to be conducted with the students. This should include not only students who have persisted, but also those who have stopped out.

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