

## **S-STEM: Creating Retention and Engagement for Academically Talented Engineers**

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# **S-STEM: Creating Retention and Engagement for Academically Talented Engineers**

## **Introduction**

This paper describes progress to date on a five-year National Science Foundation S-STEM project entitled "Creating Retention and Engagement for Academically Talented Engineers (CREATE)" being conducted at the University of Nevada, Reno, a large western land-grant university. The objectives of CREATE are: **(1)** To implement a scholarship program built on evidence-based curricular and co-curricular best practices that supports low-income, academically talented students with demonstrated financial need through successful program completion; **(2)** To conduct a mixed-methods research study of the effect of the implemented evidence-based practices on the self-efficacy and engineering identity of the cohorts to contribute to the existing knowledge base on student characteristics and issues that help low-income, academically talented students with demonstrated financial need succeed; and **(3)** To transfer the knowledge gained through this study to improve the delivery of engineering education to a broader population of students. The state of Nevada seeks economic diversification, with a vision to develop a strong, flexible and educated workforce, which begins with skilled, talented, and diverse engineers to fill high-tech positions. CREATE will change the propagating effects on society of poverty resulting from poor education by producing graduates to work in regional and national industry through existing strong partnerships between the College of Engineering and industry as well as by preparing these students to enter graduate school. Quantitative measurable outcomes will include increased student retention; increased cohort self-efficacy and identity statistics; higher-than-average graduation rate for the cohorts through evidence-based programs; and successful placement in industry or graduate school. CREATE will have a broad impact on low-income, academically talented students in two key ways (1) Support of 32 students with scholarships; and (2) Implementation and assessment of academic and professional development support mechanisms that are tuned to the needs of these students. Both impacts achieve state/federal strategic workforce diversification goals. Qualitative measurable outcomes will include attaining academic and personal goals; increased leadership skills and confidence levels; and an established sense of community. These outcomes will be an essential contribution to knowledge for recruiting and retaining low-income, academically talented students in engineering. All aspects of the CREATE program are designed to offer a supportive, student-centered environment to aid adjustment to college life challenges and help students achieve their best academic performance. The program has completed its second year and has successfully recruited two cohorts. Each cohort has sixteen students (hereafter referred to as scholars) who are financially supported through CREATE scholarships.

A dedicated team of nine academic and administrative faculty and one graduate student form the management team who work cohesively towards the cohorts' success. A combination of curricular and co-curricular activities was selected according to evidence-based best practices [1-5] and implemented to support the academic development of CREATE scholars through graduation with an engineering degree. Curricular support includes tutoring, intrusive advising, regular progress reports from instructors, and peer and faculty mentoring. Co-curricular support includes community-building activities, a minimum of two mandatory theme seminars based on evidence-based best practices, and two required "choice" activities, including participation in job and internship information sessions, student clubs, engineer's week, K-12 outreach,

undergraduate research, and study abroad. The College of Engineering's vast network of existing support programs is being leveraged in tandem with strategically planned activities to provide the cohorts with academic, financial, and career development, and personal support. Explicitly providing CREATE scholars with the resources that are part of the hidden curriculum [6] will give them additional resources to develop social capital [7- 9] and increase their feelings of belongingness in engineering, especially for first-generation engineering students [10].

As part of the project, a mixed-methods research study is being carried out to examine the effect of the implemented practices on the scholars' engineering interest, self-efficacy, and identity. The research study's goal is to contribute to the existing knowledge about student characteristics and issues that help low-income, academically talented students succeed.

### **Demographics/Cohort recruitment**

Demographics of participants: The scholars identify as 22 male, 10 female, 18 white, 6 Hispanic, 3 multi-racial, 4 Asian, 1 Native American, and 10 first-generation. They come from mostly urban and rural public schools located in four western states, with the largest number of students coming from Nevada. Demographic numbers mirror similar enrollment trends to the College of Engineering with the following exceptions: higher female and Students of Color enrollment in the CREATE program. The scholars are majoring in Biomedical Engineering, Chemical Engineering, Civil Engineering, Computer Science and Engineering, Electrical Engineering, Materials Science and Engineering, and Mechanical Engineering.

Recruitment and selection of the cohorts: For Cohort 1, the pool of students already admitted into engineering programs was utilized to recruit scholars. For Cohort 2, a targeted recruitment process consisting of marketing CREATE via e-mail and U.S. mail to all high schools, teachers, and counselors in the College of Engineering database; the MESA (Mathematics, Engineering, Science Achievement) program; and teachers who had recommended Cohort 1 applicants. This targeted marketing strategy resulted in a much larger pool of applicants for Cohort 2. Cohort selection was based on institutional data criteria to provide the largest pool of academically talented students with financial needs.

### **Program components**

#### **Curricular**

E-FIT (Engineering – Freshman Intensive Training): is a "bootcamp" required of all freshmen engineering majors, the week prior to starting their first semester. It focuses on helping students make a successful transition from high school to college through a realistic orientation that simulates the style, pace, intensity, and rigor of college. During summer 2019, Cohort 1 attended in-person skill-building sessions and lectures, completed homework, projects, and exams together with other first-year engineering students. They were placed in packs with other CREATE scholars and a pack leader. Pack leaders served as role models that helped students adjust to campus life [11, 12].

For Cohort 2, in-person E-FIT was canceled during summer 2020 due to pandemic social distancing requirements. A virtual format was implemented where each engineering department recorded a panel discussion about campus life and their majors. Panelists included professors, recent alumni, and current students. These discussions were posted to an online course for all

incoming engineering students. Additionally, the E-FIT management team posted information about student programs at the university, such as study abroad and Nevada Money Matters.

ENGR 100 (Introduction to Engineering Design): is taken by all scholars. This problem-based and collaborative learning freshmen course focuses on engineering design, stimulates critical thinking, introduces engineering principles via hands-on experiences, highlights the importance of professional ethics, project planning, prototype fabrication, engineering creativity, and previews each engineering discipline. Student teams undertake a design project that involves designing, constructing, and testing an autonomous hovercraft. Work examining the effect of project-based learning by Major and Kirn [13] has shown increased confidence and reduced anxiety to perform engineering tasks. Cohort 1 took this course in-person and worked in teams with at least one other CREATE scholar. Due to the pandemic the course was re-structured and students worked on teams of four to design Rube Goldberg machines. The course emphasized engineering design and teamwork throughout the semester, while upper-level and graduate students mentored the students. The instructors again placed two CREATE scholars on a team to help them feel a sense of community within CREATE and ENGR 100.

CREATE tutor: We have hired one of the Cohort 1 scholars as tutor for the CREATE program. This scholar is advanced in his coursework and a high-achieving student. He offers tutoring sessions that are attended by scholars who desire academic support in their courses, and these tutoring sessions are a place to sustain community during the pandemic.

Faculty mentors: The Principal Investigators (PIs) of the project serve as faculty mentors for the scholars. Each has eight scholar mentees (four each from Cohorts 1 and 2) and meets regularly with them once during the fall and spring semester. They discuss topics ranging from scholars' performance in their courses to their summer plans, including finding an internship, study abroad, and undergraduate research.

Peer mentors: Peer mentoring is an evidence-based practice for helping students adjust to university life [14, 15]. We selected eight upper-division peer mentors based on their academic backgrounds and sharing similar characteristics with the scholars, including first-generation status and demographic identification. The management team assigned each peer mentor four scholar mentees. The CREATE project director conducted a virtual training session for the peer mentors and went over the project's peer mentor training manual. Additionally, she showed them a video created by one of the year 1 peer mentors on how to mentor the scholars effectively. The peer mentors meet with their mentees twice during the semester and fill out reports on their meetings. Faculty mentors use the reports for discussions during their meetings with the scholars.

Intrusive advising: Advising strategies recommended for first-generation students have been implemented [16, 17] for the scholars. This intrusive advising model recommends considering broader issues like family values, socioeconomic status, and limited academic and non-academic preparation. All scholars meet with the CREATE advisor at regularly scheduled meetings and on an as-needed basis. The advisor identifies scholars who need extra academic help. The academic advisor, faculty and peer mentors encourage scholars to take advantage of Peer Assisted Study Sessions, instructor office hours, tutoring at the university and engineering tutoring centers, and the Math center. Instructor-generated courses progress reports are used by faculty mentors in discussions with their mentees. To date, CREATE team members have also conducted interventional Zoom sessions with four scholars from Cohort 1 and four from Cohort 2 who were having academic or motivation challenges.

## Co-Curricular

Living Learning Community (LLC): Most of the 16 scholars in Cohort 1 lived in the Engineering LLC which is the newest residential hall on campus for their first year. An LLC is a residential hall setup in which entire floors are dedicated to students of a particular grouping of majors. CREATE scholars lived on the same floor of the Engineering LLC and had a roommate or suitemate who was also a scholar. Most scholars in Cohort 2 also are currently residing in the Engineering LLC, with a few choosing to live off campus due to the pandemic.

Theme seminars and cohort team building: A requirement of the CREATE program is attendance and participation in two theme seminars/cohort team building activities per semester. The topics covered in the theme seminars are linked to academic success [1 - 3] and scholars' interests. To date, topics covered in theme seminars include: study abroad, time management, money management, scholarships, internships, undergraduate research opportunities, K-12 outreach opportunities, and goal setting. All these sessions were conducted by guests invited from across campus and the project PIs. In addition, design, based on an engineering challenge and hands-on cohort team building activities were integrated into the seminars to promote social interaction. For the design activities, scholars were divided into teams of four, with facilitation provided by a peer mentor. They were given constraints on the materials and supplies they could use. The seminars and design activities were held in person before the pandemic but due to safety guidelines during the pandemic, they were moved to an online video format. All theme seminars and team activities were followed by food and soft drinks. When activities were held remotely, the scholars joined their peer mentors in small groups in a socially distant setting.

Choice activities: Scholars complete two required "choice" activities each semester from a list ranging from attending industry career information sessions and career fairs, getting their resume critiqued, joining an engineering club, participating in CREATE tutoring sessions, attending the Engineering Distinguished Lecture, volunteering with the K12 Outreach program, to pursuing undergraduate research. The PI team curates a list of choice activities for students every semester, and accepts additional activities that the students discover or are presented to the PIs.

Undergraduate Research Experiences: Undergraduate research stipends have been provided in year 2 to scholars in Cohort 1 who were interested in exploring research opportunities in engineering faculty laboratories. An application process brought in five applicants who interviewed with engineering faculty who had indicated interest in taking a CREATE scholar into their laboratories for a research experience. These five scholars will spend 40 hours during the Spring 2021 semester in the research laboratories undergoing an undergraduate research experience. At the end of the semester an evaluation of the scholars' performance will be requested from the faculty research mentors. The performance evaluation incorporates questions that were compiled by the CREATE Principal Investigator team and included: 1. how often they met with the scholar, 2. if they worked directly with the mentee or had them work with a graduate student or post-doc, 3. whether the project was individual or a group project, 4. whether they thought the scholar had potential for performing research and about their engagement in the project, 5. what were their expectations of the scholar and were they met, and 6. would they accept another CREATE scholar in their laboratory.

Internships and career guidance: Based on evidence-based strategies [18 - 20], CREATE will give the cohorts a competitive edge toward their careers as future engineers by strongly encouraging them to apply for internships, get their resumes critiqued, and attend the two annual



engineering job fairs organized by the director of engineering career placement services as well as Evening with Industry events organized by the Society of Women Engineers.

### Engineering Education Research

Based on the mixed-methods research component of the project, CREATE aims to develop their self-efficacy and engineering identity, refine long-term academic, personal, and professional goals, and support attainment of those goals. Weak efficacy expectations can restrict college major and career-related choices. Development of self-efficacy and identity in engineering has been shown to increase students' confidence in carrying out present tasks, persistence in problem-solving scenarios, and graduation rates, and is a critical indication of professional persistence [21 - 25]. In addition, the implemented curricular and co-curricular activities are being studied for efficacy.

The research questions that are being addressed are: (1) How strongly is the implementation of evidence-based programs and activities linked to academic success (based on GPA), increased graduation rate, and change in self-efficacy and engineering identity? (2) Which specific activities and programs lead to academic success, increased graduation rate, and change in self-efficacy and engineering identity? (3) How do the qualitative focus group interviews addressing Question 2 contribute to a comprehensive understanding of the quantitative data obtained from Institutional Analysis and pre- and post-semester surveys addressing Question 1?

The ongoing mixed-methods research study, based on the research questions, will determine whether implementing curricular and co-curricular evidence-based practices improves the self-efficacy and engineering identity of the scholars, and will examine student characteristics and issues that scholars face as they navigate through their curricula [11], hence contributing to the knowledge base in the field. Quantitative data are gathered at the beginning and end of each semester via the Intersectionality of Non-normative Identities in the Cultures of Engineering (InIce) instrument [26] to measure student future-oriented motivations, identities, and career and outcome expectations. Quantitative data will be analyzed to determine the retention profiles of CREATE students using existing retention and performance metrics from Institutional Analysis. The additional data collected from the InIce survey will be analyzed for longitudinal changes in students' attitudes. Shifts will be examined for the entire group and for specific sub-groups in the study (e.g., women, underrepresented minorities). Qualitative data are collected in the form of in-depth focus group interviews (at the end of each semester) with 4 participants per focus group. The semi-structured focus group protocol uses participant survey responses to guide areas for this in-depth exploration via open-ended prompts. Data is also being collected on the effect of the pandemic and the fact that scholars have been deprived of face-to-face interactions with other members of their cohorts, their peer and faculty mentors, and have had to adjust to mainly online learning modes. Pre- and post-surveys have been administered to date for three semesters and focus groups have been conducted at the end each semester of the project (n = 3). To date, the fall 2019 and spring 2020 focus group transcripts have been coded and emerging themes documented. Emerging results from ongoing analysis are outlined in brief below and can be found outlined in more detail in Scalaro et al [27].

### **Results and Discussion**

Cohort 1 has been 100 % retained in the program after year one (2019 - 2020). Cohort 2 has also been retained at 100% after the fall semester of 2020. Emerging results based on data gathered

during the focus groups highlight the importance of several components of our program in improving scholars' experiences. These include: (1) Peer mentors are effective in building valued relationships with their mentees. Additionally, peer mentors who served as E-FIT mentors were very effective in building valued relationships with their mentees. Focus groups revealed that the scholars in both cohorts connected with their peer mentors and view peer mentorship as valuable. As a result, we have employed the peer mentors for more hours in year 2 to meet more frequently with their mentees. (2) Engineering related cohort building activities starting early and occurring in formal and informal environments were greatly enjoyed by the scholars. (3) Cohort 1 built a community during E-FIT. Cohort 2 missed out on this experience and did not establish the same community feeling as Cohort 1. (4) In ENGR 100, Cohort 1 data showed the importance of collaborating to foster engineering identity development and maintaining an engineering community. In spite of the restructuring of the course and project due to the pandemic, most of the scholars in Cohort 2 had a very positive experience with their teams and enjoyed the class. (5) Scholars have taken advantage of all resources that were discussed during advising sessions and have deemed them helpful. The intervention sessions have also been effective in helping scholars work through challenges and stay on track for a four-year graduation. (6) Many scholars have indicated already that their meetings with their faculty mentors have been beneficial and given them the confidence to talk to other faculty and seek resources to make them successful. (7) The LLC definitely helped build community among scholars in cohort 1. The community feeling is not high among scholars in Cohort 2 due to pandemic restrictions in the residential halls. (8) The theme seminars were in general well received by the scholars. Before the pandemic, these activities took place in person, with Cohort 1 benefiting from the social interaction with one another and with the CREATE management team members. (9) Scholars in Cohort 1 have already started obtaining internships based on career guidance provided by CREATE. (10) Scholars in Cohort 1 have taken advantage of undergraduate research opportunities offered by CREATE.

Specific results to date from the mixed methods research data are:

1. For Cohort 1, pre-pandemic conversations around identity and motivation support existing literature. Conversations around performance + competence appear to not align with the switch to online education.
2. The cohort has proven useful to most (if not all) scholars in some way with the biggest influence being a sense of community. For first-generation students, the cohort also acted as an aid in connecting students to resources through mentorship.
3. Scholars typically feel like they belong in CREATE as well as their major as indicated by their degree of interest or competence. Within CREATE, students who are challenged by classes or those who are starting in lower level math classes than their peers who started in Calculus 1 seem to struggle with a sense of fit within CREATE.
4. The pandemic negatively affected most students, many of whom indicate a sense of disconnect from school. CREATE has acted as a connection point for some scholars and helped make school feel "more real."
5. Cohort 1 is much more connected with their peers than Cohort 2; it seems that EFIT and the 1.5 semesters in person were highly influential in developing a sense of community.
6. Cohort 2 seems more positive regarding remote education but they still seem to struggle significantly despite positive attitudes.

Based on emerging trends in the data, changes are being implemented during year 2 of the program to maintain as much peer and faculty mentor interaction as possible with the cohorts. This is being addressed through a mix of in-person and virtual cohort building activities within the guidelines of the university for maintaining social distance. These combined findings and experiences of our scholars add to the literature surrounding best practices for student support models while demonstrating the transferability of previous results across contexts.

While the current five-year project involves the two cohorts of scholars who are given S-STEM scholarships for a period of four years till graduation, we have already started implementing the CREATE peer mentor model for all engineering freshmen entering this fall semester and residing in the Engineering Living Learning Community housed in one of the residential dormitories on campus. The goal is to eventually extend the peer mentor model to all incoming engineering freshmen.

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