An Ecosystem for Success in Engineering and Computer Science

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Abstract

Supported by a National Science Foundation STEP grant, our activities continue to establish a regional ecosystem for STEM success by targeting barriers to student achievement and creating opportunities for enhanced student engagement. Description of the activities and results obtained during the 4th year (2016-2017) of this grant are presented in this paper. Students participated in the following activities: 1) a targeted, STEM-focused, concurrent-enrollment program; 2) accelerated pathways to Calculus-preparedness; 3) engagement and guidelines in gatekeeper courses; 4) peer-led, mentoring and teaching, and activity 5), which is a recent supplement to our grant and consist of an entering-transfer-student bridge to Engineering or Computer Science. Activity 1 establishes a process for providing early-college students already participating in a summer Engineering and Computer Science camps the opportunity to participate in an Engineering-focused U-PREP program during the summer prior to their Junior and Senior years. Activity 2 is to accelerate the Calculus readiness of incoming students who do not test into Calculus. Many students who have high school credit for Pre-Calculus or even Calculus do not place into Calculus based on entrance or college readiness exams. This activity is being expanded in partnership with neighboring two-year colleges to provide accelerated pathways to Calculus. Activities 3 and 4 are to improve persistence and adequate progression for key "gatekeeper" courses, and provide students with specialized online and in-person mentoring and supplemental instruction that target common misconceptions and improve mastery of key fundamental concepts. The team and participating instructors developed metrics for early identification of at-risk students to better target interventions. As a supplement to the grant, Activity 5 targets students in transition from the regional two-year programs to the University's Engineering and Computer Science four-year programs. It provides transfer students scholarships for tuition to attend sophomore-level Engineering or Computer Science courses they have yet to complete. In year 4 of this grant, a total of 499 students participated in our grant activities: 24 in Activity 1 during summer 2017, 44 in Activity 2 during summer and fall in 2017, and 431 in Activity 3 during fall 2016 and spring 2017. Also, activity 1, recruited and trained 22 mentors, tutors, and resident advisors, and activity 4 also had 10 mentors. Additionally, in activity 5, 11 students have been involved so far in the bridge to engineering program and additional efforts are being made to recruit more.

Introduction

The goal of this project is to establish a sustainable ecosystem of success in STEM in the Rio South Texas (RST) Region by targeting major barriers to student success and creating opportunities for enhanced student engagement. To attain this goal, the grant is addressing problems such as diminished college preparedness, in particular, Calculus readiness; subpar standardized exam performance and language barriers; reduced awareness of STEM pathways and careers; lack of role models in STEM fields; and decreased achievement in foundation courses. The grant activities were selected based on their potential to deal with the challenges RST students face in progressing and persisting in Engineering and Computer Science. Furthermore, the activities are linked to promote precollege pathways, improve transition from the lower to upper division, and maintain sustained student engagement throughout. **Error! Reference source not found.** illustrates that Activities 1 and 2 provide new precollege paths – one to increase the number of high-achieving

students who enter Engineering and Computer Science, and another for students declaring an Engineering or Computer Science major but who are not Calculus ready. Activity 3 provides interventions to help students in gatekeeper courses. It is expected that some high achievers entering the upper division become mentors in Activity 4 and serve as role models. The mentors also support Activities 1-3 through peer teaching.

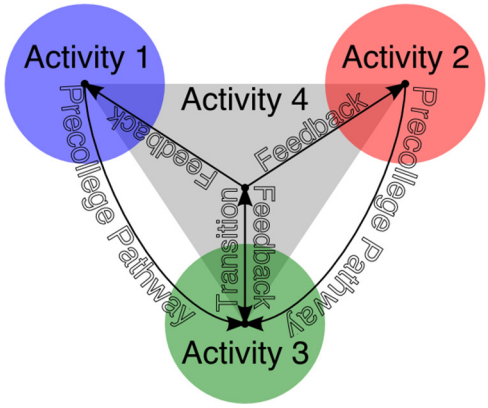

Figure 1. Activity Pathways

Activity 1: A targeted, STEM-focused, concurrent-enrollment program

During year 4 of this project (in 2016-2017) several recruitment activities were conducted with the Texas Pre-freshman Engineering Program (TexPREP) students and their parents throughout the year to inform them of the program and assist them with the application process for U-PREP program. TexPREP students are required to have high math scores to enter the program and have already expressed interest in engineering by participating in at least three years of a seven-week engineering summer program. As part of the proposed plan, students who had not taken College Algebra or English I were required to take those courses in this activity. Most students were grouped together in those courses so that the U-PREP students could better form a learning community and facilitate an accelerated pace for the course. Seventy percent of the students took College Algebra or a higher-level math course. Students who had completed those courses were advised to take other science and math courses that were part of their engineering degree plan. The goals of these activity are: a) extracurricular activities and a supportive learning environment are designed to give students a beneficial and positive college experience that would encourage them to continue pursuit of their degree upon graduation from high school; b) recruit 30 TexPREP graduates who are not yet in their final year of high school to the program and who have been accepted to the concurrent enrollment program; c) offer two special target courses that will help students make progress toward an engineering degree and stimulate interest in engineering; d) have 30 students complete six hours of summer of courses that help the students make progress toward an engineering degree and that will stimulate interest in the pursuit of engineering; and provide a supportive learning environment for students that includes a residential learning community with mentoring and tutoring.

Recruitment of students began early in the fall 2016 semester to give students time to deal with the lengthy acceptance process for the concurrent enrollment program. Several informational meetings with students and parents were held in the fall and spring semesters to promote the program and to assist families with the application process. The early start on recruitment led to

an increase in enrollment in the program and fewer students that were not able to attend because of an incomplete application. This past year was the second year that part of the recruitment activity was to introduce the program to students who will not be eligible for one or two years to go to the University. This activity may also have led to increased participation as it gave students the opportunity to bring up their grades or test scores to the high level required for the concurrent enrollment program. It was determined that to accomplish the targeted enrollment goal it is required to continue the recruitment of students early in the year to address the lengthy acceptance process for the concurrent enrollment program.

Thirty-five students applied to the U-PREP program for summer 2017, of which twenty-four students were admitted and participated in the program. Sixty two percent of the participants were female. Fifteen of the students were declared as engineering majors, five were undecided, and the rest were in other STEM majors. All 24 students completed six or seven hours (average of 6.7 hours) toward required courses for engineering majors. Some students took courses other than the targeted courses of College Algebra and English I because they already had obtained college credit for those courses. The cumulative grade point average of all students was 3.1. All the students lived in the dorm for the duration of the program. Eleven tutors, seven mentors, and four resident assistants provided supervision, academic assistance, and social activities for the students. Twenty-two students participated in a two-day field trip to University of Texas San Antonio and Six Flags Fiesta Texas. During such trip, students also toured several of the engineering labs at UTSA and were especially fascinated by the Mechanical Engineering Computer Visualization Lab where they could interact with several state of the art 3D visualization tools. At Six Flags students did several experiments on the roller-coasters measuring forces and acceleration and applying some of the math that they learned in their summer math course. A mechanical engineering professor, accompanied the students on the field trip, and such trip was a highlight for many of the students.

Twenty-four high school students are now closer to getting an engineering degree and their positive summer experience makes them more likely to do so. Even though not all students who participated had declared engineering as their major they had a positive experience with a group that was predominately engineering focused, this experience may encourage them to consider engineering. Although some staff returned from the previous year, the majority of student staff were new to the program. The mentors, tutors, and resident advisors, the majority who are STEM majors had a useful summer experience managing themselves, the students, and focusing them on being better students. The development of maturity in people management skills among the college student staff was clearly evident by the end of the summer. The leadership skills developed among the staff will be of great benefit as they graduate and enter the STEM workforce.

Activity 2: Accelerated pathways to Calculus-preparedness

The Bridge to Calculus is part of a nationwide effort to examine the types of Precalculus preparation needed by students. The evidence from our project and many others indicate that some students if selected carefully and properly coached can be accelerated beyond the traditional and long sequence of courses such as the College Algebra – Precalculus, 7-credit, sequence used at UTRGV. Our recommendation is that students with unsuccessful high school experiences in advanced mathematics courses, Precalculus or Calculus, can be advanced at a significantly faster pace than the traditional College Algebra – Precalculus sequence. We have designed a 4-credit

course that covers content from both our College Algebra and Precaclulus course. The course is designed as an emporium style class. For cohorts 1-2 we used the ALEKS (http://www.aleks.com) software; however, for cohort 3-5 we have designed a WebWork (http://webwork.maa.org) template for the course. Details on cohorts 1-3 can be found in [1, 5].

Table 1. Bridge to Calculus activity results

Grades	ABC of Bridge	DFDrW grades of Bridge	Percent ABC grades of traditional Precalculus
Fall 2017 Bridge	15 (88%)	2 (12%)	60%
Summer 2017 Bridge	21 (95%)	1 (5%)	89%
Summer 2016 Bridge	36 (100%)	0 (0%)	65%
Summer 2015 Bridge	22 (95.7%)	1 (4.3%)	76%
Summer 2014 Bridge	17 (77.3%)	5 (22.7%)	62%

For the first 4-cohorts, the bridge to Calculus ran as a summer intervention for incoming students, however, in cohort 5 we recast it as a program in the Fall semester. Students pass the course at a higher rate than the traditional Precalculus course (statistically significant for cohorts 2-3 and 5, see table 6) and have significantly better attendance rates. Throughout the life of the project we have had a total of 6 missed student-days. Bridge students from cohort 1-4 are as successful in their Calculus 1 course as students in that course from the traditional pre-requisite sequence or placement [1, 5] if they take the course, we do not yet have data on the success of students from cohort 5 in their Calculus 1 course in Spring 2018.

WebWork is a free online homework software supported by the Mathematical Association of America, we run a server at UTRGV that hosts courses for university and local high school mathematics students. Change to WebWork for the Bridge to Calculus after the first two cohorts was needed to reduce the cost of the intervention in order to open a Brownsville section (in summer 2015, our university changed its name to UTRGV and opened a second campus in Brownsville, Texas). Cohorts 3-4 had sections in both Edinburg and Brownsville. The change to the Fall 2017 semester for Cohort 5 was needed because of a significant decline in the target population for the summer intervention. This decline is due to the increase in dual enrollment course offerings in South Texas high schools. We are finding lately that students with a high school advanced mathematics of Precalculus or Calculus 1 were likely to have taken those courses as dual enrollment, and so would have placement into the courses at UTRGV. By changing our course to deliver in the Fall semester we have enough students in our target group available for the course and we can have classes that are large enough to run. Even with the course in the Fall semester, we are still shortening the mathematics sequence by three-credits and one semester for participating students. For engineering and computer science students this will have an impact on their degree plans and time to graduation.

In addition to advertising and attracting enough students with the necessary background, another significant difficulty we encountered in cohorts 1-2 was to have successful students take Calculus

1 in the following Fall semester (now the Spring semester for cohort 5). We added material to the course that asks students to report on their upcoming semester's schedule and emphasizes the importance of taking Calculus 1 and the following mathematics classes as soon as possible. This has successfully increased the proportion of successful students matriculating to Calculus 1 immediately following the bridge. Twenty-nine out of 36 of the students completing the summer program in cohort 3 took a Calculus 1 course in the Fall. This represents a significant improvement over years 1 and 2. We also experience some attrition from the Calculus sequence with students who change their major after completing the bridge class. It remains to be seen if this is a bigger or smaller problem with the Fall implementation of the bridge to Calculus program.

The bridge to Calculus successfully demonstrated that holistic advising, in this case placing students in their mathematics courses based on unsuccessful high school experiences, can be effective in reducing the number of credits students are required to take. In the course of our program, 90 students have been successfully transitioned to placement into Calculus 1 three-credits earlier than would be usual, and at a higher rate than College Algebra or Precalculus traditionally advance students at. These students are as successful in Calculus 1 as the general population. An important broader impact of our project has been repackaging the WebWork template for the course as Precalculus template for local high schools. Twenty regional high schools in the seven surrounding counties of South Texas are using this template in their courses.

Activity 3: Engagement and guidelines in gatekeeper courses & Activity 4: Peer-led, mentoring and teaching

Activity 3 focuses on lower-level engineering gatekeeper courses to provide students with guidelines and information to promote successful independent learners with best study practice skills [2]. In particular, most of the results presented in this study were obtained in the Statics course because it is one of the first fundamental engineering courses in almost all engineering careers. The first step in the intervention was to develop online assessments for students to review physics and math prerequisite material. Based on the assessment results, at-risk students were identified and interventions were performed to encourage best study practices to improve knowledge integration, retention, and passing rates. At-risk students are considered to have higher failing probability in lower level gatekeeper courses. The identification of at-risk students in lower-level engineering courses in this project is based on assessment of student prerequisite knowledge retention, student past performance, and/or student self-efficacy [8]. As part of Activity 4, supplementary instruction in the form of mentoring sessions was also provided to help students solve homework. The mentoring sessions were recommended to all students in the course; but, they became mandatory for at risk students. In addition, the developed early at-risk identification system allowed the instructors to determine the preparation of the students at the beginning of the semester to tailor the instruction during the semester. It is argued that the described activities have increased and will continue to increase student engagement in learning and their persistence to pass the Statics and other gatekeeper courses. Online formative assessments were developed to engage and help students to persistently study the course material to retain and integrate knowledge and apply it to solve problems throughout the semester. Another intervention in the gatekeeper courses consisted of developing challenges with real world context problems to motivate students to learn the material and acquire adaptive expertise. Consequently, it is expected that by combining

best study practice guidelines, online assessments, real world context challenges, and peer-led mentoring sessions, student performance and passing rates in the gatekeeper courses are improved.

During year 4 of this project, work was also performed to create interventions, following the work performed in Statics, including peer mentoring, in the following gatekeeper courses:

- MECE-2303 Statics, Fall 2016; 38 students (12 female, 38 underrepresented)
- MECE-2303 Statics, Spring 2017; 59 students (18 female, 58 underrepresented)
- CMPE-2330 Digital Systems Eng. I, Fall 2016; 37 students (8 female, 34 underrepresented)
- CMPE-2330 Digital Systems Eng. I, Spring 2017; 33 students (9 female, 30 underrepresented)
- CHEM-1307 Chemistry for Engineers, Fall 2016; 118 Students (25 female)
- CHEM-1307 Chemistry for Engineers, Spring 2017; 88 Students (20 female)
- CSCI-1370 Eng. Comp. Science I, Fall 2016; 26 Students (4 female, 24 underrepresented)
- CSCI-1370 Eng. Comp. Science II, Spring 2017; 32 Students (8 female, 28 underrepresented)

The following materials and tools were developed and implemented for the Statics course intended to create a model of intervention that could be adapted in other gatekeeper courses:

- Lectures to review prerequisite material and prepare for the pre-test
- Online homework to review prerequisite material and prepare for the pre-test
- Test about prerequisite material
- Identification of at-risk students
- Online concept inventory implemented at the beginning and at the end of the course
- Motivational, socioeconomic, and demographics survey
- Online assessments as formative assessments throughout the course
- Face to face and online mentoring sessions
- Develope challenges to integrate knowledge
- Identification of online resources that could be used as supplementary instruction

Table 2 shows that the Statics sections passing results vary between 61% and 72% since Fall 2014, and before the intervention the passing rate was 59% in the spring of 2013. It is important to note that the results may be dependent on the number of students in the course and their pre-requisite preparation and knowledge retention as shown by online review and pretest average [2,7,8]. Interventions, including peer mentoring, have contributed to increase passing rates as well as the number of students receiving final grades of A or B, and also not a significant number of students are dropping the course.

As part of activity 4, every peer leader student received training that included an introduction session, weekly preview sessions, and a final lesson learned session. The introduction session involved faculty engaging peer leaders in cooperative-style learning exercises and mentoring best practices that are subsequently applied in the activities. Weekly preview sessions with "gatekeeper" course faculty covered course content and pedagogical approaches. Ongoing challenges and lessons learned were documented in a final session with all mentors and faculty involved. The number of mentors in the fall 2016 were four, in spring 2017 were five and in the summer 2017 was one.

Table 2. Comparison of Statics results before and after the implementations
Of the interventions that started in Fall 2014.

	Spring 2013	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016	Spring 2017*
Class Size	62	45	63	58	58	38	59
GPA average		3.05	2.94	3.18	2.98	3.26	2.98
Online Review Average		80	70	78	78	85	72
Pretest Average		83	70	70	78	79	71
Online HW Average		90	74.6	79	79	91	84
Passing Rate	59%	72% (75% excl. DP)	61% (72% excl. DP)	71.20% (76.4% excl. DP)	68.30% (71.9% excl. DP)	68.40% (70.3% excl. DP)	66.10% (67.2% excl. DP)
Drops	17(27%)	2 (4%)	9 (14%)	4 (7%)	3(5.2%)	1(2.6%)	1(1.7%)
A & B grades	35%	44%	44%	50%	41%	55%	31%

Activity 5. An entering-transfer-student bridge to Engineering or Computer Science

Activity 5 is a supplementary activity for our grant and 11 students have been involved in the bridge to engineering program so far. However, South Texas College (STC) has reorganized a plan to help students transfer to UTRGV. An STC Math faculty oversees the design and implementation of a summer bridge to Calculus program. Students participate in a minimester course that help those who have STEM-declared majors, and who need to complete a Calculus I course, accelerate to and through the Calculus sequence. The bridge to Calculus recruitment focus on STEM students who are currently enrolled at South Texas College and have a "C" or better in College Algebra or a non-passing grade in Pre-Calculus. In addition, a bridge to Engineering program, overseen by an STC Engineering faculty member, creates and offers to support students who are interested in completing freshman and sophomore -level coursework at South Texas College and seamlessly transfer to a UTRGV Engineering program. Supplemental instruction (SI) leaders/mentors are identified and recruited by South Texas College to support both projects. Supplemental instruction and student leadership training are provided to all SI Leaders/Mentors. Supplemental Instruction (SI) is a learning support program that recruits high-achieving students in a discipline to attend specific class sections to learn classroom structures and instructional techniques and then relay them to the students of that class in a SI Leader guided study session. Grant benefits are shared with students, including free software usage, e-book support and other resources to help increase student interest. Mathematics software is used to help cover and re-enforce mathematical and scientific concepts related to STEM-education. The software provides general practice problems as well as visual graphics and applications to enhance students' learning across the STEM-related disciplines.

Conclusions

Based on experiences of implementing Activities 1 and 2 we have made some adjustments to our strategies for recruiting participants and to offer Activity 2 in the fall semesters instead than in the summer. Additionally, we plan to expand some of these practices in collaboration with regional community colleges; we are seeking to focus the efforts of these collaborations on facilitating the transition of transfer students into our Engineering and Computer Science programs. Though articulation agreements already exist that insure transfer of nearly all the students' credits, other issues exist that would be well-served by adopting some of the activities we have implemented. The programs at the two-year institutions struggle to recruit and retain mentors for key gatekeeper courses because many of those who are qualified have either transferred or are in the process of moving on to a four-year program. Thus, we are seeking ways of providing face-to-face and web-enabled peer mentoring sessions. Also, the Bridge to Calculus model is being adopted at STC. As part of the supplement to the grant with Activity 5, a similar model is being developed to offer a bridge to Engineering or Computer Science where transfer students come to UTRGV and take a sophomore level course or junior level course not offered at the community college. Besides that, what we are performing in Activities 3 and 4 is intended to help all gatekeeper courses, like Statics, to identify at-risk students at the beginning of the semester and to intervene by providing complementary instruction, like peer mentoring and online assessments, in order to help the students.

Acknowledgements

The authors would like to acknowledge the financial support of the National Science Foundation Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) Graduate 10K+ program (grant number DUE-0311349) with special funding from Intel and General Electric, under which this project is carried out.

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