

AC 2009-1945: INCREASING STUDENT ACCESS, RETENTION, AND GRADUATION THROUGH AN INTEGRATED STEM PATHWAYS SUPPORT INITIATIVE FOR THE RIO SOUTH TEXAS REGION

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Abstract

This paper describes in detail the ongoing activities of the integrated STEM pathways support initiative for the Rio South Texas Region. This initiative is a collaboration between The University of Texas-Pan American (UTPA) and South Texas College (STC), a two year HSI, to facilitate student engagement and success in STEM areas. With a recently funded College Cost Reduction and Access Act (CCRAA) grant from the Department of Education, both institutions are developing and supporting strategies that will facilitate the success of Hispanics and other low income students in STEM areas. The efforts supported by the initiative focus on four activities. The first activity enhances student services to foster success in Calculus I as it is known to be a roadblock for student success in STEM fields. The second activity supports the implementation of Challenge-Based Instruction (CBI) in selected key courses. CBI, a form of inductive learning, has been shown to be a more effective approach to the learning process than the traditional deductive pedagogy. The third activity supports faculty development workshops on CBI techniques and other locally developed teaching tools with a focus on increasing student success, and finally the fourth activity develops and supports pathways to STEM fields between STC and UTPA. This project provides a model that is expected to have a significant impact on the number of STEM graduates and that will be simple to replicate in other geographical areas. Increasing the number of students successfully engaged in STEM fields is a national priority. From an economic competitiveness point of view, it is widely known that the future of U.S. competitiveness hinges on the ability of the educational system to generate the technical workforce that will support the innovation needed to remain competitive. From a regional perspective, the need for STEM graduates is critical to the future sustainability of the development of the South Texas region as a leading manufacturing hub for North America.

Introduction

The Bureau of Labor Statistics reports that for the years 2004-2014 the projected percentage demand in the number of STEM occupations is almost twice the number of all occupations combined. STEM occupations are estimated to grow at about 26% compared with 13% for the total occupation employment rate¹⁷. In 2005, the U.S. Census Bureau reported that Texas became a “majority-minority” state, which refers to a state where the majority of the population is comprised of underrepresented minorities. In addition, the Census Bureau stated that Texas will be one of three states that will contribute to a 46% growth of the U.S. population between the years 2000 and 2030²⁶. Hispanics are not only the largest minority group in the U.S., followed by Blacks, but are the fastest-growing minority group²⁷. Thus, it is not surprising that one of the largest increases in college enrollment is expected to come from the Hispanic population. However, in 2005 Hispanics accounted for 5.8% of the college-degreed workforce and only 5.2% of the STEM workforce. Altogether underrepresented minorities compose 24% of the U.S. population, yet comprise only 13% of college graduates and 10% of the total college-degreed

STEM workforce. It should be noted that every minority group, with the exception of Asians/Pacific Islanders, earns 1/3 of all its bachelor's degrees in STEM disciplines (NSB, 2008). In all, there is an imperative need for minority groups to study science and engineering.

UTPA, a 78-year old, general academic component of the University of Texas System, is a comprehensive university serving approximately 17,500 students annually of which over 85% are of Hispanic origin and are primarily commuter students. UTPA is organized into six schools/colleges: Arts and Humanities, Business Administration, Education, Health Sciences and Human Services, Science and Engineering, and Social and Behavioral Sciences. The College of Science and Engineering offers 10 bachelor degree programs and 10 master degree programs. STC, the partnering institution, enrolls approximately 20,000 students.

In fall of 2007, 86.3% of UTPA students were Hispanic, 5.4% white, 0.14% Native American, 1.1% Asian, 0.6% black, 5.7% non-residents, and 0.8% unspecified. Similarly, at STC, 93.6% were Hispanic, 3.17% white, 0.076% Native American, 1.17% Asian, 0.28% black, 1.02% non-residents, and 0.67% unspecified. UTPA and STC students mostly come from low-income families and most (76%) are also first-generation college students. Almost all of STC and UTPA students require financial aid in order to attend college. At UTPA, the six-year graduation rate (based on the 1996 freshman cohort) remains low at 24.6%, affected by the financial burdens and first-generation status of many students. The first-year retention rate of full-time students was 61.9% in 2001. Approximately 54% of the total UTPA faculty is minority, with 35.2% of the current faculty Hispanic, 46.0% white, and 18.8% identified as other ethnicity. About 58.1% are male and 41.9% are female. The student-faculty ratio is 26.3, one of the highest among state universities, making it difficult for faculty to provide optimum individual attention to students.

Based on the overall need of increasing access to STEM careers and STEM student success, UTPA and STC submitted a proposal to the Department of Education. The project was recently funded in fall 2008 over a two-year period under the College Cost Reduction and Access Act (CCRAA). The project, particularly focused on Hispanic and low-income students, is designed to increase enrollment, retention, and six year graduation rates in STEM fields at UTPA; to increase enrollment, retention, and three year graduation rates at STC and the percentage of qualified STC transfer students to UTPA (and other four year institutions) in STEM fields through strengthened pathways and articulation; to increase the quality of our STEM graduates by developing adaptive experts who are efficient and innovative professionals for life; to train, mentor, and support a cadre of highly qualified STEM faculty in innovative inductive teaching methodologies; and to enhance success of STEM students by providing a strong support program for Calculus 1, the mathematical foundation for their future studies.

The proposed project identifies specific needs to increase enrollment, retention, and graduation rates in STEM fields at UTPA and STC through four activities focused on the need for a STEM orientation and mentoring program and a strong support program in Calculus 1; the need for STEM students to see the relevance of their studies to the real world and to develop adaptive expertise; the need for trained STEM faculty in implementing innovative inductive teaching methodologies; and the need to strengthen STC pathways to prepare transfer students to UTPA and other universities to obtain a Bachelor degree in STEM disciplines.

The efforts supported by the integrated STEM pathways support initiative for the Rio South Texas Region focus on four activities. The following sections describe the ongoing activities of this initiative.

Activity 1: Enhanced Student Services

The first activity enhances student services to foster success in Calculus I as it is known to be a roadblock for student success in STEM fields. It consists of a STEM Orientation and Mentoring Program and a STEM Calculus 1 Student Assistant Support Program, both which were initially implemented in spring 2009. The critical need for a STEM Orientation and Mentoring Program and a STEM Calculus I Student Assistant Support Program falls under the Comprehensive Development Plan (CDP) of UTPA. The CDP describes two major academic weaknesses: academic advisement inconsistent in delivery and access and under prepared incoming students, both first-time and transfer. UTPA and STC hold orientations prior to the fall and spring semesters. Generally, students receive an overview of the disciplines in each of the Colleges, a tour of the campus, and information on academic and nonacademic resources available to students. However, to better serve the needs of particular students, like STEM freshmen, sophomores, and transfer students from STC, a STEM Orientation and Mentoring Program is being developed. In the Mentoring Program, Calculus 1 students are assigned to a STEM faculty mentor within the department of their major. About 20 students are assigned to a mentor who holds monthly one-hour meetings with students to discuss their academic and professional careers and preparation. The first meeting helps to evaluate students' academic standing in Calculus 1 and provide guidance and resources to the students. Additional meetings discuss degree plans, preparing for an internship, and applications of Calculus 1 in STEM fields. It is expected that this activity will help retain freshmen and sophomores in STEM disciplines.

Another enhanced student service is the STEM Calculus 1 Student Assistant Support Program. A reason for the high attrition in mathematics courses required of STEM students is the lack of academic student support in Calculus 1 classes. Calculus 1 forms the foundation for more advanced mathematics courses required by the STEM major and thus plays an important role in the undergraduate curriculum. At UTPA and STC, there are weaknesses in services for Calculus 1 students. Tutoring programs and online materials (available to anyone with an internet connection) exist on both campuses. However, classroom resources for Calculus 1 classes are virtually nonexistent. Data prior to the implementation of these grant activities indicates an average pass rate of 58% for Calculus 1 at UTPA and 82% at STC. While we are interested in increasing the pass rates, the main focus of the activity is to better academically serve and prepare the STEM population for their future careers. Therefore, a STEM Calculus 1 Student Assistant Support Program is being implemented which aids both the instructor and students in providing services to increase student success.

Activity 2: Curriculum Reform

The second activity supports the implementation of Challenge-Based Instruction (CBI) in selected key courses. This activity also focuses on student retention by addressing students' need to see Relevance of Studies to the Real World. CBI, a form of inductive learning, has been

shown to be a more effective approach to the learning process than the traditional deductive pedagogy. The implementation of CBI is built around the framework of the STAR Legacy cycle, which is comprised of six main components: reflecting back and looking forward, generate ideas, multiple perspectives, research and revise, test your mettle, and go public. Research consistently points to the following factors as reasons for minority-STEM students' decision to drop-out or transfer out of STEM undergraduate fields of study: insufficient financial resources^{16,25}, feelings of isolation^{4,24}, academic under-preparedness², and a need to see the relevance of studies to the real world⁶. The need to relate their studies to the real world results because minority students lack an equitable number of career influencers and role models within their families and familiar networks. Thus, when minority students select STEM fields of study, they experience an immediate need to confirm the relevance and compatibility of their studies and seek real world connections to their classroom learning experiences - connections that they do not find in the traditional classroom⁶.

The second activity also addresses the need to develop student adaptive expertise. STEM professionals need not only a solid understanding of the fundamental principles and knowledge in their discipline, but they also need to be able to adapt as opportunities and applications in these fields evolve. Achieving this type of practical adaptability is not trivial. Often, people can develop advanced technical expertise in a field independent of an ability to adapt and innovate when presented with a novel problem to solve. The concept of Adaptive Expertise (AE) can help describe this ability. Hatano and Inagaki¹¹ distinguish between routine and adaptive expertise. Routine experts are technically proficient in their established domains of knowledge and application. They apply their well-developed knowledge base appropriately and efficiently to solve core problems in the domain. However, when they face a novel problem they tend to misapply technical principles, analysis procedures, and outcome interpretations in their attempts to reach a solution^{11,18}. In other words, they fail to adapt their expertise in a new context. Adaptive experts share the core technical proficiency of routine experts. Further, they are flexible in developing appropriate responses and solutions in novel situations. For example, they tend to review multiple perspectives when considering the solutions to new problems, and view their knowledge base as dynamic^{9,11,28}.

Schwartz et al.²¹ have proposed that there are two essential and complementary dimensions of AE: innovation and efficiency. Efficiency covers the taxonomic understanding of the field; innovation involves the ability to perform in novel situations. They have hypothesized that these two dimensions co-evolve in what they have called the "optimal adaptability corridor" (OAC): instruction that develops innovation and efficiency together will lead students to progress further along a trajectory toward AE than instruction that teaches for either efficiency or innovation first. This hypothesis has been validated in studies in CBI Biotransport classrooms²⁰. However, in STEM disciplines the conventional approach has been to teach for efficiency first. Only after students have mastered certain content are they given opportunities to develop innovation in novel real-world settings during their final senior year courses. This approach has some downsides. First, studies have shown that one reason students leave STEM programs in the first few years is that they found too few opportunities to engage in creative activities that relate to the real world²². Other studies have found that focusing primarily on efficiency in early courses can stifle attempts at innovation in later educational experiences¹⁹ and traditional methods can decrease students' innovative performance¹⁴.

Prior association with NSF's VaNTH ERC for Bioengineering Educational Technologies has resulted in the adaption and delivery of one fully populated challenge based instruction (CBI) course, MECE 4380, Introduction to Computational Biomechanics¹. The pedagogical approach in this class is more generally referred to as anchored, inquiry based instruction. The specific approach taken employs posed challenges that are anchored by leading the student through a sequence of learning activities termed the Legacy cycle. The steps in this cycle are; 1. Look Ahead (the learning objectives are presented – an assessment centered activity), 2. Generate Ideas (the students work alone and/or in teams to express what concepts or knowledge they think is important in solving the challenge – learner and community centered), 3. Multiple Perspectives (thoughts of various experts and/or simulations are presented to the students – community and knowledge centered), 4. Research and Revise (reference materials and formative assessment articles are presented to assist the student in exploring the challenge – knowledge and learner centered), 5. Test your mettle (summative instructional events are presented – knowledge and learner centered), 6. Go Public (a high stakes motivating activity such as a presentation is undertaken – learner and community centered), and 7. Reflect Back (the student revisits their initial thoughts concerning the challenge that they expressed in the Generate Ideas phase – learner centered).

VaNTH studies have shown student learning improvement within the Biomedical Engineering student populations of its core institutions (Vanderbilt-Northwestern-Texas-Harvard/MIT). In one common course, MECE 4380, taught as a technical elective in the ME departments at UT-Austin and at UTPA, and solely comprised of VaNTH CBI learning modules, individual student gains were on average greater at UTPA than at UT-Austin. This is most notable and irrefutable for the multiple choice overall course pre- and post-test results. In this case the UTPA class pretest mean was less than the UT Austin class pretest mean, but the UTPA posttest mean was greater than the UT Austin posttest mean. The significance of this difference in learning is illustrated by an individual differences effect size, with UT Austin as the control, of 1.10. The effect size is a statistical measure, closely related to Student's T-test, and an effect size of 1.10 indicates a 78% probability that a person from the UTPA (experimental) group will learn a greater amount than a person from the UT Austin (control) group. The results of this assessment indicate that there is reason to believe that the CBI approach will improve student learning within the ME department at UTPA and served as a prime motivator for the CBI curriculum reform component of the grant.

Hence to address these needs, Activity 2 aims to introduce Challenge-Based Instruction (CBI) into the STEM curriculum to enhance student learning by providing opportunities for students to see the relevance of studies to the real world and to develop adaptive expertise.

Activity 3: Faculty Development

The third activity will support faculty development workshops on Challenge-Based Instruction (CBI) techniques and other locally developed teaching tools with a focus on increasing student success. The need for CBI was described in Activity 2. To implement CBI into the curriculum, Activity 3 will provide the need for STEM faculty development. There are few mechanisms in place in the university environment for coordinated faculty development. Although national

conferences are offered that address pedagogy, most UTPA and STC faculty do not have the time or financial resources to attend meetings that are not directly related to their research publications. Financial pressures from the state on the institution have led to larger classes and labs and a push to decrease the number of credit hours in the curriculum. The pressures have resulted in heavier teaching loads, high student to faculty ratios, and less individual interaction between students and their faculty mentors. The expectations on faculty have also increased as the institution moves towards a greater emphasis on research. The combined effect is that faculty are not able to make significant advances in their pedagogical methods even though tremendous advances have been made in educational research. This is especially true in STEM education where there has been a strong emphasis on funded research. Implementation of the latest research based teaching methods requires training, mentoring, and time.

There are approximately 157 STEM faculty at UTPA and 90 STEM faculty at STC. Widespread implementation that impacts STEM students in this largely Hispanic region will require a coordinated faculty development program that trains, mentors, and supports a majority of the faculty. The issue of faculty development was addressed in a recently completed Title V grant that was awarded to UTPA. One of the goals of the project provided training for faculty through several on-campus professional development seminars including teaching critical thinking , cooperative learning and assessment of student learning outcomes. During the course of the grant over 130 UTPA faculty attended the multiple on-campus trainings. Faculty implemented changes in their courses and proposed changes in their curriculum that reflected the promoted research from the Title V workshops. The success of the previous Title V program has stirred faculty interest in and illustrated the need for continued on-campus faculty development training, mentoring, and support.

The goal of activity 3 is to train, mentor, and support a cadre of highly qualified STEM faculty in innovative inductive teaching methodologies that will have a broad and measurable positive impact on STEM faculty and students. Faculty development activities on CBI support the goal through training offered in two-day workshops on the theory, impact, and design of CBI methods, mentoring workdays provided on CBI implementation, and faculty support through a web-based “Teaching Toolbox” and participant stipends. During the two year period of the grant, four groups of approximately 20 faculty members from UTPA and STC will cycle through each element of this activity. Each group will first attend a planning workday, led by faculty members who have implemented CBI, where they will begin assessing the need for CBI content in their courses and collecting baseline data. Later in the same semester each group will attend a two-day workshop on CBI. The workshop (“How People Learn” Engineering) on designing effective instruction is based on the HPL³ effective learning environment and VaNTH Research. The workshop will be led by a well-qualified research group from the NSF VaNTH ERC and will focus on instructional methods that have been shown to positively impact STEM education. In the following semester, two mentoring workdays will focus on the development of CBI content for the participant’s STEM courses. Each semester a new group of 20 faculty members will begin the cycle. The first group of faculty will be composed of five faculty teams from Activity 2 receiving summer support. The training and workshops will prepare each team for the development of five STEM courses based on CBI. Faculty participating in the second training cycle will be identified and recruited by participants in the first workshop cycle. During the second year, the cycle repeats and another five teams are selected. Faculty members who have

completed the cycle will be encouraged to participate as mentors in subsequent training cycles to share possible failures and best practices.

Each faculty member participating in Activity 3 will receive over 20 hours of mentoring and instruction. Faculty members are provided with assistance from a graduate student and learning science specialist to begin development of CBI content. By the end of the second workday all participants will have developed CBI content that can be delivered and assessed in their course. The objective is that in a span of just two years, CBI methods will be introduced into over 80 courses offered at UTPA and STC. This widespread implementation of CBI will allow for a study of its overall impact on teaching effectiveness and efficiency in learning. As part of the study, participants are required to prepare a pre- and post-assessment of the impact of CBI. The expected outcome is that this implementation of CBI will produce a measurable increase in both student learning and retention.

Activity 4: STEM Pathways Growth and Support

The fourth activity involves developing and supporting pathways to STEM fields between STC and UTPA with an initial focus in the STC Engineering Academy. This activity seeks to strengthen the STEM pathways to prepare transfer students to UTPA and other universities to obtain Bachelor degrees in STEM disciplines. STC dual enrollment programs allow eligible high school students to enroll in college courses while meeting the same requirements as any other college student. These courses are taken in place of, or in addition to, the normal high school course load. In 2006, STC created the Dual Enrollment Engineering Academy (DEEA), which is a two-year program consisting of college courses and internship opportunities for qualified junior and senior high school students who obtain college status as a result of their participation in DEEA. Consequently, DEEA students take an accelerated college career path to accomplish a two-year Associate Degree in Engineering by the end of their senior year of high school.

In the first 2006 cohort, 33 out of 49 (67%) students graduated from the DEEA program in spring 2008. In 2007, 54 students initially enrolled in the DEEA program and 49 (91%) remain in the program. Most recently, in 2008, 278 students submitted applications to the DEEA program, but only 55 (20%) students were accepted. This information shows that there is great student interest to enroll in the DEEA program and pursue a STEM career in engineering. Out of these new 55 DEEA students, 37 participated in Math and Physics courses and orientation sessions during a summer camp held June 9-13, 2008. The purpose of the summer camp is to guide and academically prepare DEEA students who will start the two-year program. Thus this activity calls for 3 particular needs to support DEEA.

As part of Activity 4, a new summer “Introduction to STEM” course is being developed for new DEEA students, and UTPA tutors are currently helping STC students during Friday afternoons and Saturday mornings, in coordination with retention specialists who keep track of and help student performance at STC. STEM faculty members at UTPA and STC are currently developing the course, which will expand and strengthen STEM avenues through the implementation of multidisciplinary activities, experiments, lectures, and assessment materials to promote student motivation, preparation, and interest in STEM careers. For instance, CBI techniques and hands-on teamwork activities will be used in this early career course to engage

students, promote real world understanding of STEM challenges, experimentally validate theoretical concepts, and introduce new topics. Hands-on activities are required to promote STEM interest as a career path and to develop abilities needed to apply concepts and principles to a wide range of problems¹⁴. Engineers and scientists need knowledge and skills in areas such as hardware interfacing, sensors and actuators, electronics, data acquisition, controls, programming, and modeling and analysis of mechanical systems^{7,10}.

Modern industry and new technology have a high and increasing demand for skillful graduates with multidisciplinary experience⁵, and some universities have begun to create classes where students obtain multidisciplinary design challenges. For example, the University of Detroit-Mercy, developed an “Introduction to Engineering Design” course and a “Pre-college Course in Mechatronics” that is offered to students early in their career to increase their preparation and motivation for lifelong learning^{13,29} and Wright State University developed a “Model for Engineering Mathematics” where a significant part of the activities consist of hands-on and experimental practices¹².

Through the “Introduction to STEM” course, students will acquire knowledge and experience through CBI and hands-on activities in the areas of mechatronics, engineering mechanics, chemistry, and reverse engineering. Mechatronics is a combination of technologies and disciplines in engineering, electronics, intelligent control systems, and computer science, which together can contribute to the design of better and smarter products and processes^{8,23}. For example, in one of the Mechatronics sessions, students learn about programmable logic controllers (PLCs) and use them to solve a challenge, like implementing an on/off controller for fans, LEDs, and buzzers based on the state of several inputs. In the process of solving the challenge, students working in teams are expected to create programs for the PLC, connect the PLC and power supply to sensors and actuators, acquire troubleshooting experience, and present the results to the rest of the class.

The challenges for this new course are being developed in 5 hands-on sessions in the area of electronics, mechatronics and renewable energy; 4 sessions in chemistry; 4 sessions in engineering mechanics (2 in statics and 2 in dynamics), and 1 session in reverse engineering. In addition, the new course will include presentations on topics such as STEM professions, system of units and conversions, ethics, economics, and data presentation and graphing.

To achieve the goals of Activity 4, faculty professional development is required to implement CBI. Therefore, faculty members participating in Activity 4 are also encouraged to participate in other activities of this project. Implementing new hands-on activities and challenge-based instruction (CBI) methods requires STC STEM faculty members to acquire training through workshops designed to promote STEM instruction with modern pedagogical approaches. Moreover, Activity 4 also addresses the need for Qualified Tutors for Advanced DEEA Courses. There is a significant need for qualified tutors and mentors to help students enrolled in the most advanced courses (e.g. Calculus I, Statics, and Dynamics) of the DEEA program. This need is evident because STC students graduate soon after taking such courses. A solution to this problem has been the support of the DEEA program by qualified UTPA senior undergraduate or graduate students working as tutors and mentors.

Conclusions

This paper describes the ongoing activities of the integrated STEM pathways support initiative for the Rio South Texas Region:

- Activity 1: Enhanced Student Services – STEM Orientation and Mentoring Program and STEM Calculus I Student Assistant Support Program;
- Activity 2: Curriculum Reform– Curriculum development based on Challenge-Based Instruction (CBI);
- Activity 3: Faculty Development – Faculty development seminars and workshops on CBI; and
- Activity 4: STEM Pathways Growth and Support – Dual enrollment programs at STC.

This project will provide a model that will have a significant impact on the number of STEM graduates and that will be simple to replicate in other geographical areas. This project intends to increase the number of students successfully engaged in STEM fields which is a national priority. From an economic competitiveness point of view, it is widely known that the future of U.S. competitiveness hinges on the ability of the educational system to generate the technical workforce that will support the efficiency and innovation needed to remain competitive. From a regional perspective, the need for STEM graduates is critical to the future sustainability of the development of the South Texas region as a leading manufacturing hub for North America.

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