

## STRATEGIES FOR MATH ENRICHMENT TO BETTER PREPARE STUDENTS FOR ENGINEERING CURRICULA

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### Abstract

This paper describes several innovative strategies implemented by the Center for Excellence in Engineering Education (CE<sup>3</sup>) at the University of Texas at San Antonio (UTSA) beginning in fall 2006. The focus of these efforts has been improving overall academic success of undergraduates, and in particular, retention and graduation rates. Tactics employed by the CE<sup>3</sup> involve several recognized educational best practices including restructured recruitment efforts, peer mentoring programs, use of Clicker technology in the classroom, newly designed internship programs, immersion camps, expanded use of stipends, Six-Sigma summative evaluation, and multiple math intervention programs. This paper summarizes those strategies focused on mathematics enhancement of incoming freshman students: Jump Start, Just in Time Mathematics (JITM), and Formal Mentoring.

### 1. Introduction

At the College of Engineering (COE) at the University of Texas at San Antonio (UTSA) we recognize that the quality of our undergraduate programs represents the conduit of opportunity for our students, the majorities who are underprepared from low-income families and are first generation College students. In addition, for a university with a Hispanic student population of 57%, the College of Engineering has a relatively small Hispanic student population and in particular, a disproportionately small Hispanic female minority, which is common across the state and country in minority majority communities such as San Antonio, Texas. In particular, ~35% of Hispanic males constitute the total enrollment, while only 5.48% of Hispanic females do. An equally important concern is that ~23% of engineering graduates are Hispanic males and ~7% are Hispanic females. As stated in the university's mission, vision and values statement, as an institution we have a moral and practical need to not leave any student behind as we embark in a quest for national research excellence and to responsibly contribute to increasing the technology workforce in the United States.

Since 2006, we have implemented several strategies in order to improve retention and graduation rates among engineering students. Among comprehensive and integrated strategies that involve several recognized educational best practices include: 1) Structured recruitment; 2) Formal mentoring through peer mentors; 3) Immersion camps/just-in-time mathematics; 4) Jump start mathematics; 5) Formative evaluation through Clicker technology; 6) Academic first year

stipend for rapid engineering immersion; 7) Post first year summer internships for rapid engineering immersion through formal articulated agreements; and 8) Six-Sigma summative evaluation/assessment. This paper summarizes those strategies related to mathematics enhancement of incoming freshman students.

Our initial assessment indicates that our efforts are working. Since 2006 the first-year retention rate for the CoE has improved by 4%; the three-year retention rate has improved by about 5%; and the six year graduation rate has improved by about 2%.

## **2. Jump Start**

At the time of admission to UTSA, less than 20% of science and engineering majors place directly into Pre-Calculus or Calculus I. Many students place into developmental courses after taking math placement examinations even though they have successfully completed Calculus I and Calculus II in high school. Given the importance of accurate initial math placement, Jump Start was implemented in 2008 to help students improve their math placement, and to emphasize mathematics' importance in timely degree progress in engineering and science programs. The Jump Start program is truly a collective effort across the UTSA campus. The program is sponsored by the College of Engineering and College of Sciences, administered by The Graduation Initiative, and collaborative partners include the Department of Mathematics, Tutoring Services, Testing Services, New Student Orientation, Academic Advising and UTSA Housing.

Loosely modeled after a similar program at the University of Texas at El Paso, Jump Start is a one-day intensive algebra review held throughout the summers in conjunction with new student orientation. The program is offered at no cost to students to encourage low income student participation. Students begin Jump Start by taking the Calculus Placement exam the morning prior to the beginning of new student orientation. Students who do not initially place into Calculus I stay for an afternoon of instruction by a senior math faculty member, followed by dinner and optional additional tutoring. During the instruction period students are grouped according to their initial math placement score and instruction is highly focused on the greatest deficiencies within each group. Course instruction lasts 4 hours, and the optional dinner and tutoring lasts an additional 3 hours, bringing the total day of instruction and tutoring to 7 hours. During this short time frame, the goal is not learning new material, but rather refreshing latent skills. Early the next day students take an Alternate Calculus Placement exam. Students go directly from taking the Alternate Calculus Placement exam to new student orientation.

Overall, Jump Start participants have been consistently successful in improving their math placement (see Table 1 below). The mean number of semesters "saved" for summer 2008 and summer 2009 participants was 1.5 and 1.2 semesters, with several students jumping as much as 4 semesters of math from Basic Mathematics to Calculus I. Based on a cost of \$1,002.00 per 3-credit course, summer 2008 students collectively saved more than \$61,000 in tuition and course fees. Summer 2009 participants collectively saved more than \$84,000 based on \$1009.45 in tuition and fees per 3-credit hour course.

Table 1. Math placement improvement of COE participants in Jump Start

	Participants who completed all parts of the program	Participants who improved initial placement		COE participants	COE participants who improved initial placement		COE participants who improved placement into Cal I	
	(#)	(#)	(%)	(#)	(#)	(%)	(#)	(%)
Summer 2008	59	49	83.10%	26	21	80.76%	10	38.46%
Summer 2009	85	68	80.00%	40	32	80.00%	17	42.50%

\*Participants who left the program early or completed only one placement exam are not included here.

In addition to improving initial math placement, Jump Start participants appear to also be successful in fall to spring retention, with 91% of engineering students participating in Jump Start 2008 registering for the spring 2009 semester. Furthermore, Jump Start participants are as successful as their non-participating, similarly situated peers in math course performance. 62.5% of 2008 engineering participants passed their initial math course taken at UTSA. Math performance for summer 2009 participants is not yet available. GPA comparisons of Jump Start participants and all freshman engineering students yielded essentially no differences. In other words, the jumps in initial placement positively impacted initial placement and retention, and did not negatively impact academic performance.

### 3. Just in Time Mathematics (JITM)

We have incorporated the ideas from the newly developed “Model of Engineering Education” at the Wright State University (WSU) as the foundation for UTSA’s entering freshman mathematics program. In essence, the WSU model concludes with the development of a revised engineering math sequence, to be taught by the math department in concert with the College of Engineering and the Accreditation Board of Engineering and Technology (ABET) requirements. The result has shifted the traditional emphasis from math prerequisite requirements, to an emphasis on engineering motivation for math, with a “just-in-time” structuring of the new math sequence. At UTSA, the changes in the engineering courses have been more conservative than the WSU model since the students will still follow the traditional math sequences (Calculus I, Calculus II, *etc.*). However, the prerequisites for some of the core engineering courses have changed from Calculus I to the newly developed math course.

There is strong consensus that mathematics deficiencies prevent engineering students from progressing through their degree programs in a timely manner. The resulting lack of progress is reflected in lower retention and graduation rates for the College of Engineering (COE) and UTSA. Currently, COE students must take a minimum of Calculus I and II prior to enrolling in anything other than the first engineering communications course. This Just-in-Time Math course for engineers prepares students for the entry level engineering courses such as Statics, Dynamics and Network Theory by teaching the math you must know to be successful in the beginning engineering courses. Topics include algebraic manipulation of engineering equations, trigonometry, vectors and complex numbers, sinusoids and harmonic signals, systems of equations and matrices, differentiation, integration and differential equations. All of these math

topics are presented within the context of engineering applications and reinforced through extensive examples of their use in the core engineering courses. Completion of this course will fulfill the pre-requisite requirement for entry level engineering courses.

We have offered the JITM course to selected groups of engineering freshmen since summer of 2008. These students were qualified for registering in Calculus I, but did not have the proper background for the basic engineering courses such as statics and electric circuits. Although a majority of incoming freshmen pass pre-calculus while in high school, some of them will not pass the calculus placement test, and will not be qualified to enroll in Calculus I. This course allows students who are calculus ready to participate in the basic engineering classes in their second semester of study, while traditionally these students would have taken their required math and physics sequence classes before taking any engineering class. As a result, students have a chance to graduate in four, rather than five, years for the traditional curriculum. Currently, we are monitoring the performance of the selected group in order to measure their academic performance in comparison to the performance of their peers that follow the traditional curriculum.

#### **4. New Recruitment Strategy for JITM**

An integral strategy in increasing the diversity of the pool of participants, our new recruiting process involves the identification and selection of a pool of students from Bexar County High Schools (H.S.) with significant numbers of students from low socioeconomic backgrounds. As a result of the success of our previous projects, we have established important relationships with local H.S. math and science teachers, counselors, and local community colleges that will provide the medium to successfully recruit and place the H.S. participants. This is particularly important for increasing the number of females and minorities in the engineering disciplines.

We will recruit 32 newly admitted freshmen engineering students (with emphasis on minority female students) to a summer immersion camp. During the camp the qualified students will be given an opportunity to participate in the JITM course. The camp period will be after their senior year in high school and before mandatory freshman orientation, which occurs in August. Potential participants will be provided a formal application form, which will include contact information, transcripts, and a 2-page essay on the reason for wanting to be a participant. The evaluation and selection committee will be composed of the project team and our industrial advisory council (from companies that are active in our internship program). The selection criteria will be tabulated as follows: high school preparation, extracurricular activities (the better-rounded, the higher the points), neatness (typed, professional application), reason (2 page essay), U.S. Citizenship or Permanent Residence (required). The selection process will be weighted toward the attainment of increasing the participation of minority females from low socioeconomic backgrounds.

#### **5. Formal Mentoring**

Beginning every fall semester one research assistant will be assigned as a formal mentor to 4 summer camp participants. These formal mentors will be required to attend the mentoring workshop developed via Department of Education (DOE) MSEIP Grant (#P120A050003), and

will be paid an additional stipend per semester. The freshmen will also receive monthly stipend (provided by the US Department of Education) for their participations. The formal mentoring will therefore become part and parcel of the student's job as a funded research assistant within an externally funded research project. Among the duties of these mentors will be to hold formal study sessions once per week for a 2-hour period on Saturdays, to provide advising with respect to technical electives and career interests, and with respect to course load and sequencing, help in identifying scholarship opportunities, and providing encouragement. It is an important metric of this proposed process to not only improve retention in the participant's quest toward a B.S., but also to retain the participant for the following year. Another benefit is to the mentors themselves, since some will become faculty members in their own right and can begin developing important skills that contribute to becoming a well-rounded academician and can themselves positively contribute to retention and graduation of all students, particularly those historically underrepresented. Finally, each funded freshman student will be assigned a non-funded participant as a formal study partner, who will attend the Saturday study sessions, workshops, and will receive the same mentoring as the funded participant.

## **6. Summary**

We have discussed several recently implemented programs for improving the retention and graduation of engineering students at UTSA. The strategies discussed include a one-day intensive mathematics workshop (Jump Start) and the implementation of "Just in Time Mathematics" course for the newly admitted engineering students. The primary objective for both of these programs is to help prepare students for the basic engineering courses during their freshman year. In addition, we have described and discussed the recruitment and mentoring processes for freshmen. Our initial assessment indicates 5% improvement in three year retention and 2% improvement in six year retention rates.

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