
AC 2012-3695: A COMPREHENSIVE PLAN TO IMPROVE RETENTION AND GRADUATION RATES IN ENGINEERING FIELDS

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A Comprehensive Plan with Emphasis on Math Preparation to Improve Retention and Graduation Rates in Engineering Fields

Introduction

This paper describes the implementation of a comprehensive engineering education improvement plan which includes a fusion of strategies with the long-term objective of minimization of factors that adversely affect academic performance of entering minority freshmen [1-3]. These strategies are intended to minimize the impact of deviations that, if too great and side effects too many, then the probability of the desired outcome becomes far removed. As a result, its predictability becomes entirely uncertain, particularly for students from low socio-economic groups and historically underrepresented minorities [4-5]. The most important desired outcome is graduation, and as importantly, graduation in 6 years or less, which the state of Texas has mandated to be 53% by 2016.

Thus the purpose of this project at UTSA is to increase post secondary enrollments, retention, and the number of engineering graduates, and to increase collaboration between UTSA's engineering departments and the private companies in Texas who employ these graduates. The priorities of this effort are:

1. Develop, grow and maintain the engineering bridge program targeting Hispanic female pre-freshmen entering Biomedical, Civil, Computer, Electrical, and Mechanical engineering.
2. Improve student learning in the freshman mathematics curriculum and thereby increase retention and graduation time by facilitating a "just-in-time" pedagogical approach to non-calculus ready students, which the majority of our minority students are.
3. Maintain and strengthen the engineering mentoring programs, with the particular focus of increasing the numbers, retention, and graduation time and rates of Hispanic female engineering students.

The plan includes a comprehensive and integrated strategy that involves fusing 5 recognized education best practices as follows: 1) recruitment; 2) formal mentoring through peer mentors; 3) summer immersion camp/engineering math prep and workshops; 4) academic year stipends; and summer internships in local and regional companies. Most of the above mentioned strategies have been discussed in the previous publication [6]. In this paper, the emphasis is mostly on the math preparation strategy for those freshman engineering students who are not calculus ready.

Just In Time Math Strategy

Although the majority of our incoming freshmen pass Pre-calculus while in high school, unfortunately, about 75% of them fail the placement test and are not qualified to register in the Calculus I course. Typically, students have to take Calculus I followed by Calculus II and Physics classes in order to satisfy the pre-requisite requirements for the core engineering classes. Considering mathematics and science deficiencies among our students, it usually takes several semesters for the majority of them to register in the basic engineering classes. Through the previous funded projects, which provided opportunities for undergraduates to participate in

research laboratories, it is learned that when students interact with engineering faculty and peers at the early stages of their studies, they have a better chance of graduating within 4-6 years. Thus, the Just in Time Math (JITM) strategy has been implemented in order to increase the interaction between freshmen and engineering faculty and peers during the initial semesters. As a result, more engineering students have shown more enthusiasm about engineering, and better retention and graduation rates have been realized. In addition, since students graduate at a faster pace, the implementation of the new curriculum will reduce the overall cost of college education for both the institution and students.

In the JITM strategy the ideas from the newly developed course, known as EGR 101 “Introductory Mathematics for Engineering Applications” at the Wright State University have been incorporated to create an introductory mathematic course, known as JITM at UTSA, for students who are math and physics deficient. Taught by engineering faculty, the JITM course includes lecture, laboratory and recitation components. Using an application-oriented, hands-on approach, the JITM addresses only the salient math topics actually used in the core entry-level engineering courses. These include the traditional physics, engineering mechanics, electric circuits and computer programming sequences. More importantly, the JITM course replaces traditional math prerequisite requirements for the above core courses, so that students can advance in the engineering curriculum without first completing the required calculus sequence. This will shift the traditional emphasis on math prerequisite requirements to an emphasis on *engineering motivation* for math, with a "just-in-time" structuring of the new math sequence. The course content consists of the mathematical prerequisite for the following core engineering courses: Engineering Physics I, Statics, Network Theory, and Computer Programming with Engineering Applications. In the traditional curriculum, all of these courses require a minimum of Calculus I, while some require Calculus I-III and Differential Equations. However, only a handful of topics from these traditional math courses are actually applied in the above core engineering courses. Moreover, the above core courses also include engineering mathematics concepts not found in the traditional calculus sequence, including basic operations in vectors, complex numbers and matrix algebra. We have included the following topics in the JITM course: Linear and Quadratic Equations; Trigonometry; 2-D Vectors; Complex Numbers; Sinusoids and Harmonic Signals; Systems of Equations and Matrices; Basics of Differentiation; Basics of Integration; and Linear Differential Equations with Constant Coefficients. In order to teach these topics motivated by their direct engineering application, we have appointed an engineering faculty to coordinate and teach the course. In addition, course material are emphasized by physical experiments in the classroom and laboratory, and are thoroughly integrated with the engineering analysis software Matlab. The topics for laboratory experiments includes physical measurement of the velocity in free-fall (derivatives), angular movement of robot arm (trigonometry), direct current (DC) measurements in electric circuits (algebra and systems of linear equations), alternative current (AC) measurements in electric circuits (manipulation of sinusoids), spring work (integral), leaking bucket (first order differential equations), and spring-mass (second order differential equations).

Table 1 shows the traditional engineering curriculum versus the JITM curriculum. The underlined courses are the deficiency classes and the courses shown in bold are the basic engineering courses that are required before taking higher level engineering courses. The courses

shown in *italic* are either new or redesigned courses. The classes indicated as “Core” are the required general courses for the entire university population.

Table 1. Traditional Curriculum vs. JITM Curriculum

(Underlined indicates deficiency class, *Italic* represents new or redesigned course, and bold represents basic engineering course)

Semester	Traditional Curriculum	JITM Curriculum
1	<u>College Algebra</u> , Core	<i>Just in Time Math</i> , Core
2	<u>Pre-calculus</u> , Core	Statics , <i>Calculus for Engineers</i> , Physics I, Computer Programming, Core
3	Calculus I, Core	Calculus II, Circuits , Dynamics , Physics II, Core
4	Calculus II, Physics I, Computer Programming, Core	<i>Applied Engineering Analysis I</i> , Required Engineering Courses, Core
5	Statics , Applied Engineering Analysis I , Physics II, Core	Engineering Analysis II , Required Engineering Courses
6	Dynamics , Circuits , Engineering Analysis II , Core	Required Engineering Courses
7	Required Engineering Courses	Elective Engineering Courses
8	Required Engineering Courses	Elective Engineering Courses
9	Elective Engineering Courses	
10	Elective Engineering Courses	

Thus, the main objective for creating the JITM course is to provide an appropriate background for incoming freshmen in order for them to advance in the lower division engineering classes in a faster pace, compared to the traditional way, as can be seen in Table 1. Then, to achieve our vital goal of improving retention and graduation rates, we have modified the pre-requisite requirements for the basic engineering courses. The modification allows students to register in Statics, Calculus for Engineers, Physics I and Computer programming upon successful completion of JITM. In addition, the Department of Mathematics and College of Engineering have established a fruitful collaborative relationship. At the request of the College of Engineering, the Department of Mathematics has begun a reconstruction of the Calculus sequence generally with particular emphasis on the development of calculus sections focused on students pursuing degrees in Engineering. There is much more to be done, but to this point Mathematics has set aside special sections for engineering students in which there have been some curricular changes (e.g., increasing the focus on applications), re-sequencing of some topics and the engagement of instructors with an understanding of the engineering perspective.

To further improve students’ readiness for more advanced engineering classes, we have incorporated application of math in engineering topics by adding physical measurements to the content of the Applied Engineering Analysis 1 (EA1) course. The EA1 focuses on the application of mathematical principles to the analysis of engineering problems using linear algebra and ordinary differential equations. It also emphasizes the usage of software tools to facilitate the learning process. Topics covered in this course include: mathematical modeling of

engineering problems; separable ordinary differential equations (ODE's); first, second, and higher-order linear constant coefficient ODE's; characteristics equation of an ODE; systems of coupled first-order ODE's; matrix addition and multiplication; solution of a linear system of equations via Gauss elimination and Cramer's rule; rank, determinant, and inverse of a matrix; eigenvalues and eigenvectors; solution of an ODE via Laplace transform; and numerical solution of ODE's. We have utilized the Matlab tools to incorporate engineering applications in this course by creating several simulation modules that can be used throughout the semester. Examples of such modules include time and frequency analysis of electric circuits (first, second and higher order ODE's); stability analysis of control systems (matrix algebra); and deformation of solids by forces (eigenvectors).

Assessment

The three dependent variables that measure quality (GPA), system reliability (Retention - RET), and time (Progress Toward Degree - PTD) are used for the assessment purposes for two groups of students: Pilot and Traditional groups. Retention is defined as the ratio of those cohorts in engineering versus the total number that began. PTD is especially important given the impetus placed on 6 year graduation rates by the State. Loosely defined, it is quantified as the ratio of number of degree catalog hours earned to the targeted number of degree hours at any point in time. The pilot program has been in place for the last 4 years; thereafter, based on the preliminary assessment, a full implementation can be undertaken; that is, all engineering students would go through the new process.

The JITM was initiated with 12 pre-freshman students in the summer of 2008 at UTSA. Since then, the course has been taught regularly at least twice per year, either during fall and spring or fall and summer semesters. The average grade distribution for the class is A (30%), B (36%), C (25%), and D, F, and W (9%). The overall average GPA for the course is 2.85/4.0. The data collected at the end of each semester indicate that the retention rate and cumulative GPA for cohort students who participate in the JITM project are superior compared to those of the traditional cohort. Table 2 exhibits the results for the last 3 years.

Table 2. Retention rates for JITM students vs. traditional students

	JITM Cohort		Traditional Cohort	
	Retention	GPA	Retention	GPA
1 st year	92%	2.90	71%	1.87
2 nd year	82%	3.10	63%	2.79
3 rd year	72%	3.02	48%	2.75

Summary

We have briefly discussed several recently implemented programs for improving the retention and graduation of engineering students at UTSA. The strategies discussed include the

implementation of “Just in Time Mathematics” course for the newly admitted engineering students, which is discussed in more details. The primary objective for JITM is to help prepare students for the basic engineering courses during their freshman year. Our initial assessment indicates a substantial improvement in the retention rates among JITM cohorts in comparison to the traditional cohorts.

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