AC 2009-565: AN INTEGRATED PROJECT-BASED COURSE IN MATHEMATICS AND ENGINEERING TECHNOLOGY

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An Integrated Project-based Course in Mathematics and Engineering Technology

Abstract

Engineering Technology faculty regularly encounter undergraduates taking courses in their professional field of study who lack adequate preparation in mathematics. Research indicates that students face difficulties in the application of mathematical concepts in engineering and technology. There appears to be a lack of articulation between the two disciplines. A recent National Action Council for Minorities in Engineering (NACME) [1] report by a select group of engineering technology educators and industry leaders demands (or requests) that substantive and more innovative measures be undertaken to recruit and educate engineers for the 21st century

Furthermore, the study suggests changes that need to occur in developing curricula with a more interdisciplinary approach that is relevant to the careers of students, attractive to a more diverse student population, and connected to the needs of society. In response to these issues and the growing demand to retain minority students in engineering and technology programs, we are in the process of developing a problem-solving based mathematics course. The goals for creating this course are to: 1) increase retention rates of minority students enrolled in engineering and technology programs, 2) introduce engineering problem-solving methodologies in mathematics courses, and 3) promote team work among students. This paper describes our course structure, course activities, E-Team projects and initial evaluation of the effectiveness of this course. Analysis of the results of this study (or initial study) provides strong evidence that the mean scores of an integrated project-based course in mathematics and engineering technology and the control group are not equal. Also, the data proves that, on average, post-program grades are greater than pre-program grades. Furthermore, female averaged scores were higher compared to male scores, showing a significant difference (up to 10 points)

Introduction

Several authors have recently cited the importance of considering retention in the course development process. A research conducted by Klingbeil et al describes an NSF funded initiative at Wright State University (WSU) to redefine the way in which engineering mathematics is taught, with the goal of increasing student retention, motivation and success in engineering. The approach begins with the development of a novel freshman-level engineering mathematics course (EGR 101). Taught by engineering faculty, the course is composed of lecture, laboratory and recitation components. Using an application-oriented, hands-on approach, the course will address only the salient math topics actually used in a variety of core engineering courses [2]. At Indiana University—Purdue University Fort Wayne faculty have developed ETCS 101—Introduction to Engineering, Technology,

and Computer Science, a freshman success course for students in the School of Engineering, Technology, and Computer Science. The main objective of this course is to increase retention. The course aims to provide students with sufficient computer and personal development skills and to help them develop the right mental attitude conducive for academic success. Features of the course include projects of software and hardware nature, extensive use of the Internet and Web software tools, and a team-teaching format. As the main project of this course, small teams of students design, build, program, and test an autonomous mobile robot using LEGO® parts, sensors, and the Robotic Command eXplorer (RCX) controller [3]. A study conducted at Colorado School of Mines reports on the long-term results of a two-year experiment in which a group of "average" engineering students was recruited for a first-year program that integrated curricula and fostered a learning community. Students who participated in the *Connections* program graduated at a significantly higher rate than their peers and reflected retrospectively that the program had a strong positive effect on their college careers [4]. Another, study supported by NSF at University Alabama UA consisted of faculty from the departments of chemistry, mathematics, mechanical engineering and physics. The primary goal of the faculty developing the curriculum was to improve student learning. Course topics were substantially rearranged to achieve better integration between engineering, chemistry, mathematics and physics. Results of this study show a larger percentage of students graduated in engineering than students from the comparison group [5]. Furthermore, it is more expensive to recruit a new student than it is to keep a current one. Clearly, a variety of factors influence student retention and success in engineering, most notably a lack of preparation in high school. Moreover, engineering retention is of particular concern among members of traditionally underrepresented groups, as well as among transfer students and nontraditional students returning to school from the workplace. This has led engineering educators to introduce early intervention programs aimed at increasing retention among incoming students [6, 7].

Without a doubt, the introduction of early intervention programs and application-oriented freshman engineering courses are significant steps toward increasing student retention, motivation and success in engineering. Nonetheless, the correlation between low retention rates and the inability of incoming students to progress through the required calculus sequence cannot be ignored. This problem is not unique to Savannah State University and in recent years has received substantial attention in the engineering education literature [8, 9].

Curriculum development is traditionally a product of isolated efforts of various departments. Consequently, the curricula as developed by the mathematics department are not designed to optimize students' learning in their major fields of interest. Savannah State University is a small regional university; and therefore, the mathematics curricula are designed to serve all programs in the university. All sciences and engineering students have the same curricula as the mathematics majors. In the current curriculum, engineering students take mathematics courses during the first two years. Because of the general nature of teaching mathematics courses to all students with little or no known application, mathematics courses taught become a filter and obstacle thus causing, many potential students to drop out of engineering technology programs. This is unlike the approach implemented by the Georgia Institute of Technology that has customized mathematics curricula to meet the needs of engineering majors. Their students start taking engineering courses during their sophomore year. Beginning engineering courses do not require a lot of advanced mathematics. Basic algebra, trigonometry, statistics, Boolean algebra,

and linear algebra are the mathematical topics required for students to complete the first two years of their engineering programs. Courses in those topics should use an applications-based approach instead of the traditional approach, considering real-life problems that demonstrate the application of mathematics in the field. More applications and more technology should be incorporated into mathematics courses and there should be more emphasis on teamwork and communication skills.

As we mentioned above that mathematics curricula at Savannah State University are for all programs of the institution. It is a filter that discourages under-prepared minority students entering engineering programs. A customized mathematics curriculum can help optimize the retention rates of students in engineering programs.

The general consensus, thus far, is that the traditional approach of teaching students the required mathematical theory simply as a prerequisite to subsequent engineering application is unsatisfactory, and that a more integrated approach is required.

The Experiential Team (E-Team) based interdisciplinary course is designed to combine and integrate material from introductory courses in mathematics and engineering. This material is normally taught in a stand alone format targeted for freshmen students. The integrated course employs considerable use of computers in an active learning environment that encourages team learning. E-teams of two to four sophomore students in engineering and technology programs worked on projects with faculty and industry mentors. The expected outcome was an annual rate increase of 10 to 20% in the number of minority students (including women) enrolled in engineering and technology programs at Savannah State University.

The following sections will discuss the structure for the new course, and E-Team projects.

II. Course Structure

A team led by Mathematics and Engineering Technology faculty developed a freshman-level integrated project-based course (ENGT 1101) in Engineering and Mathematics which leads to entrepreneurship. Using an application-oriented, hands-on-approach, ENGT 1101 addresses only those salient math topics that have an actual application in a variety of core engineering and technology courses. These include traditional physics, engineering mechanics, and electrical circuits. ENGT 1101 replaces the traditional math prerequisite requirements for the above courses; therefore, students can advance to the engineering curriculum without having to complete a traditional freshman calculus. This creates a shift from the traditional emphasis on math prerequisite requirements to an emphasis on engineering motivation for math.

The content of ENGT 1101 consists of the mathematical prerequisites for the following core engineering courses: Physics I, Statics, Dynamics, Strength of Materials, and Circuit Analysis. In the traditional curriculum, all of these courses require a minimum of Calculus I, while some require Calculus II. Clearly, it is impossible to cover all topics in Calculus I and II within a single course, let alone a freshman course. However, only a handful of topics are actually applied in the above core engineering technology courses. Moreover, the above courses also include

engineering mathematics concepts not found in the traditional calculus sequence, including basic operations in vectors, complex numbers and matrix algebra.

After consultation with faculty from the College of Sciences and Technology, the following math topics were slated for inclusion in ENGT 1101: Basic Algebraic Manipulations; Trigonometry; 2-D Vectors; Complex Numbers; Sinusoids and Harmonic Signals; Systems of Equations and Matrices; Basics of Differentiation; and, Basics of Integration. The course structure is 3 credit hours (2 hours lecture, 1 hour lab), plus a mandatory project section. The course is taught with all mathematics topics motivated by their direct application in the core engineering courses. Moreover, course material is augmented by physical experiments and projects in collaboration with industrial partners. The course was also integrates the engineering analysis software, MATLAB, into the fabric of the class. Table 1.0 outlines the details of the ENGT course over a period of ten (10) weeks, below:

Table 1.0: Schedule and outline of ENGT 1101 course

WEEK 1 **Lecture**: Course Introduction ; Application of Algebra in Engineering Technology – Linear Equations; Application of Algebra in Engineering – Quadratic Equations **Lab**: Introduction to MATLAB; Slope Measurement of Edge of Pavement of a Parking Area.	**WEEK 2** **Lecture**: Trigonometry: Angles Trigonometry; Trigonometric Functions; Unit Circle in Trigonometry; Inverse Trigonometric Functions; Law Sine and Cosine. **Lab** Current and Voltage in Star and Delta Connections; Applications in Surveying and slope measurements of highway profile
WEEK 3 **Lecture**: 2-D Vectors in Engineering Technology; Complex number in Engineering Technology **Lab**: Measurement of trigonometric relationships in One and Two-link Planar Robots; Application of Vectors in Statics; Determination of Acceleration and Deceleration lane length in Highway Design	**WEEK 4** Lecture: Sinusoids and Harmonic signals in Engineering Technology; Systems of Equations in Engineering Technology Lab: Measurement and Analysis of Harmonic Signals
WEEK 5 **Lecture**: Introduction to Derivatives in Engineering Technology; Application of derivatives Velocity and Acceleration in Dynamics. **Lab**: Velocity and Acceleration in Free- Fall	**WEEK 6** **Lecture**: Matrix algebra and Vectors in Engineering Technology **Lab**: System of Equations in Engineering Technology: The two-loop circuit; Determination of Beam Reactions Using Matrix analysis
WEEK 7 Lecture: Introduction to Integrals in Engineering Technology. Applications of Integrals in Statics, Dynamics and Electrical Circuits. Lab: Work and Stored Energy in a spring; RLC circuit.	**WEEK 8, 9, and 10** Lecture: Entrepreneurship and E-Team Projects. Lab: E-team project. Animatronics and Emotional Face Displays of Robots; Visualization tools for a simply supported and cantilever beams.

III. E-Team Projects

Currently, internships and co-operative education agreements are the primary methods of moving students' experiences from the university to the private sector. This allows students to gain some amount of private sector experience before graduation through short stays within industry settings. The introduction of E-Team project initiative in the proposed course integrates the private enterprise knowledge into the university classroom setting. To this end, the Electronics and Civil Engineering Technology programs at Savannah State University partnered with local companies to establish an initiative which creates an undergraduate experiential experience within the EET/CET curricula and creates collaboration between public and private sectors. A team of Electronics Engineering Technology faculty, students and industry mentors design/develop animatronics and emotional face display of robots. The design experience includes the artistic design of a robot using mathematical concepts. Students are challenged to develop models with the purpose of creating interest in learning Science, Technology, Engineering, and Mathematics. The Civil Engineering Technology faculty, students, and industry mentors develop hands-on visualization tools for use in mechanics courses. The tools are comprised of simply-supported and cantilever beams that will interface with load cells to which students can apply various loading conditions. The long term goal is to allow students to create product prototypes that can then be commercialized by an entity external to the University. The E-Team project concept will lay the foundation for the future development of senior design projects in conjunction with industry with prospects leading towards entrepreneurship.

IV. Assessment and Evaluation

To assess the impact and effectiveness of the Integrated Project-based Course in Mathematics and Engineering, the performance of the students enrolled in the course are compared with those students (control group) who took the stand alone mathematics course as shown in table 2.0. These comparisons include earned grades and attrition rates. In addition, the students enrolled in the proposed course and traditional pre-calculus course completed the student satisfaction survey as indicated in table 3.0. The results provide feedback for a continuous improvement plan.

Table 2.0: Grades and Attrition rate of the control group and proposed course

Course	Grades	Attrition rate
Pre-Calculus (Control Group)	0% (A) 20%(B) 40%(C)	40%
Integrated Project Based Course in Mathematics and Engineering	8%(A) 30% (B) 50%(C)	12%

Table 3.0: Student Responses to Project Integrated Course Assessment Questions

Questions	**M**	**sd**	**5**	**4**	**3**	**2**	**1**
The course increased my familiarity with engineering and technology profession	4.47	.87	14	4	2	1	0
The course introduced me to different branches of engineering and technology	4	1.04	9	7	3	1	0
The labs provided me the hands-on experience in Civil and Electronics Technology	4.71	.56	16	4	1	0	0
The course helped me better understand the application of mathematics in engineering and technology	4.57	.81	15	4	1	1	0
The E-Team Project helped me integrate mathematics, engineering and business in project design	4.66	.57	15	5	1	0	0
The course helped me to develop the skills to work in teams	4.38	.83	15	3	1	1	0

M = *mean* sd = standard deviation
Scale: 5-Strongly Agree, 4-Agree, 3-Neutral, 2-Disagree, 1-Strongly Disagree

Future Work

Future research plans include relating the reliability of implementation of the Integrated Project-Based Course in Mathematics in Engineering to student learning outcomes. The future plans of the project are to recognize, assess, classify, and distribute resources (via a Web site) for Engineering and Technology educators wishing to incorporate hands-on learning into their curriculum to encourage students to pursue careers in Engineering and Technology. By helping students make connections between Mathematics and Engineering subjects and real-world issues, these strategies are likely to enhance student interest in Engineering and Technology disciplines, improve learning experiences for students, and enhance teaching skills of mathematics, engineering and technology educators on the content and application of Science, Technology, Engineering and Mathematics (STEM) subjects. The ultimate outcome of the Integrated Project-Based Course in Mathematics and Engineering on student retention and success in core courses remains to be seen, and will be closely studied in years to come.

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