Work in Progress – ENGR 101 - Application Oriented Course to Help First Year Students Make the Connection Between Engineering and Mathematics

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Abstract **- A key factor in lower than expected retention and graduation rates in engineering schools across the country, including New Jersey Institute of Technology (NJIT), is the high failure rate in first year mathematics. A prime reason for this is that students are unable to see the connection between math and engineering and thus loose the drive to succeed especially in math courses. Wright State University has successfully utilized a model that helps increase student motivation and success in engineering through an application-oriented, hands-on introductory course in engineering analytical methods. The principal idea is to offer a first-year engineering mathematics course addressing only the salient math topics actually used in core engineering courses. This course will serve as a pre-requisite for some of the second year engineering courses and thereby remove the "first year calculus bottleneck". Our group at the NJIT proposes a Fall 2016 pilot using this model to help students succeed in mathematics and engineering courses. This paper will present information about the proposed plan, target population and the plan of action to set up such a pilot in STEM schools**.

Index Terms – First year introductory course, Application-driven, Increase student retention and motivation.

INTRODUCTION

Incoming first year students at mid-size STEM institutions like New Jersey Institute of Technology (NJIT) are required to take at least one year of calculus to advance to sophomore level core engineering courses. However, a large percentage of the first year students are placed into remedial pre-calculus courses and do not reach calculus until their second semester or second year. Moreover, a good portion of those placed into calculus fail to finish these pre-requisite mathematics requirements in their first year to progress ahead in a timely fashion. A key detrimental factor contributing to this is that a good portion of the incoming first year students are considered to be underprepared in mathematics. NJIT is exploring various options to help these students reach calculus I (recommended starting point for all NCE students) as soon as possible. Pre-calculus summer boot camp is one of programs successfully implemented at NJIT [1]. However, even students placed into Calculus I lose their drive to do well in the course as they find it difficult to establish a connection between mathematics and engineering and they struggle to keep up with the coursework. In addition to loss of motivation, any delay in entry to Calculus I or failure in Calculus I is almost automatically equivalent to an additional year of stay at NJIT. This leads to a lot of students dropping out of engineering as well as from college. In pursuit of solving this problem, the Newark College of Engineering at NJIT has decided to offer an "Engineering 101" introductory course, based on the Wright State University (WSU) engineering mathematics education model, which will be offered in Fall 2016. The goal of this class would be 1) to allow students to be more engaged in the first year by teaching math in an application-based environment, 2) alleviate the "first year calculus bottleneck" by having this course as a pre-requisite to second year engineering courses, and 3) to increase the retention rate in the Newark College of Engineering.

WRIGHT STATE UNIVERSITY MODEL

Wright State University (WSU) has developed a model with NSF funding to increase student retention and motivation and is currently being tried or adopted in 40+ engineering schools nationwide [2-3]. The idea is to teach mathematics to incoming first year students using an application-oriented, hands-on introductory course. All topics covered in the course are driven by engineering applications taken directly from core engineering courses. Taught by engineering faculty, this course has lecture, recitation and laboratory components.

This course provides an overview of relevant topics in engineering analytical methods that are most heavily used in the core sophomore-level engineering courses reinforced through extensive examples of their use in lab exercises. Topics include algebraic manipulation of engineering equations; use of trigonometry, vectors and complex numbers, sinusoids and harmonic signals, systems of equations and matrices in engineering applications; basics of differentiation, integration and differential equations in engineering applications. All topics are presented within the context of an engineering application and are covered only to the extent that they are actually used in core first and second year engineering courses, including physics, statics, dynamics, strength of materials, electrical circuits, and other upper divisional courses.

The WSU model was first implemented in 2004 and has successfully being used since then. At WSU, every department requiring this course saw an increase in first-year retention in 2004-2005, as compared to baseline data averaged over the prior four years. Overall, WSU saw first-year retention increase from 68.0% to 78.3%. In addition to first-year retention, this model has had a significant impact on student performance in calculus at WSU. Of the students ultimately enrolled in Calculus I, 89% of those who had formerly taken this course earned a "C" or better, compared to only 60% of those who had not [4].

PROPOSED ENGR 101 OUTLINE

The new course, ENGR 101, will be a 4 credit course meeting for 90 minutes of lecture two times a week, and 90 minutes of recitation and 90 minutes of lab meeting once a week. The total population of students will be divided into a group of 90 students per lecture and 30 students for both recitation and lab. The structure of ENGR 101 will loosely follow the WSU model [5]. A tentative course outline for both the lecture and lab portion is shown in Table I and II.

TABLE I
TENTATIVE COURSE OUTLINE FOR THE LECTURE PORTION

Week 1	Units; Engineering Constants and Notations; Application of Algebra in Engineering
Week 2	Application of Trigonometry in Engineering (e.g. One and Two-Link Planar Robots, Unit Cells in Crystals)
Week 3	Introduction to Vectors, Free Body Diagram, Dimensions in Engineering
Week 4	Introduction to Complex Numbers in Engineering
Week 5	Sinusoids and Signals in Engineering
Week 6	Systems of Equations and Matrices in Engineering (e.g. The Two-Loop Circuit, Mass Balance on a Mixing Unit)
Week 7	Introduction to Derivatives in Engineering; Exam #1
Week 8	Application of Derivatives in Engineering (e.g. Electric circuits, Sphere Falling in Fluid, Velocity and Acceleration)
Week 9	Application of Derivatives in Engineering (e.g. Strength of Materials); Introduction to Integrals in Engineering
Week 10	Application of Integrals in Engineering (e.g. Electric circuits, Catalytic Reactions)
Week 11	Application of Integrals in Engineering (e.g. Work and Stored Energy in a Spring; Melting Ice); Exam #2
Week 12	Introduction to Differential Equations in Engineering
Week 13	Application of Differential Equations in Engineering (e.g. Chemical & Mechanical Systems)
Week 14	Application of Differential Equations in Engineering (e.g. Electric Systems); Summary and Review

TABLE II
TENTATIVE COURSE OUTLINE FOR THE LAB PORTION

Week 1	Introduction and Meet the Lab TAs; How to use scientific calculator
Week 2	Lab #1: Application of Algebra in Engineering: The One-Loop Circuit
Week 3	MATLAB Supplemental Instruction
Week 4	Lab #2: Trigonometric Relationships in One and Two-Link Planar Robots
Week 5	MATLAB Supplemental Instruction
Week 6	Lab #3: Measurement and Analysis of Harmonic Signals
Week 7	Lab #4: Systems of Equations in Engineering: The Two-Loop Circuit, Mass Balance on a Mixing Unit
Week 8	Lab #5: Derivatives in Engineering: Velocity and Acceleration in Free-Fall, Catalytic Reaction
Week 9	MATLAB Supplemental Instruction
Week 10	Lab #6: Integrals in Engineering: Work and Stored Energy in a Spring
Week 11	MATLAB Supplemental Instruction
Week 12	Lab #7: Differential Equations in Engineering: The Leaking Bucket, Efflux Time
Week 13	Lab #8: Differential Equations in Engineering: Spring-Mass Vibration
Week 14	Make-Up Lab Sessions

The course was approved as an additive course to our engineering curricula and each engineering department can decide whether their students will participate or not.

ENGR 101 EVALUATION

For the Fall 2016 semester, first-year students from biomedical engineering, chemical engineering, civil engineering, computer engineering, electrical engineering and engineering science programs who are not placed into Calculus I will be enrolled in ENGR101. The industrial engineering and mechanical engineering programs have opted not to participate in the program and this would allow us to use their students as a control group in the longitudinal study. It is expected that about 150-170 students will enroll in ENGR 101 for Fall 2016.

A longitudinal study will be conducted on ENGR 101 and include student surveys and interviews, progression in mathematics courses, progression in engineering courses, performance metrics in subsequent mathematics and engineering courses, retention rates, graduation rates, and faculty feedback. The results will help evaluate the course, student success and how much it may have contributed to that success.

SUMMARY

The objective of this paper is to develop a pilot course to increase student retention, motivation, and success in engineering through an application-oriented, hands-on introduction to engineering analytical methods. This course will implement an applied approach to teaching analytical concepts that are essential to introductory engineering courses that has been proven to improve the retention of students in engineering majors from the first to second year and beyond. The course will be run for the first time at NJIT during Fall 2016. The authors plan to share their findings and make suggestions and recommendations in a later study.

REFERENCES

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