10-2005

Work in Progress: The WSU Model for Engineering Mathematics Education

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Abstract - **This paper summarizes progress to date on the WSU model for engineering mathematics education, an NSF funded curriculum reform initiative at Wright State University. The WSU model seeks to increase student retention, motivation and success in engineering through application-driven, just-in-time *engineering* math instruction. The WSU approach involves the development of a novel freshman-level engineering mathematics course EGR 101, as well as a large-scale restructuring of the engineering curriculum. By removing traditional math prerequisites and moving core engineering courses earlier in the program, the WSU model shifts 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. This paper summarizes the development to date of the WSU model for engineering mathematics education, including a preliminary assessment of student performance and perception during the initial implementation of EGR 101. In addition, an assessment of first-year retention results is anticipated in time for the conference.**

Index Terms - Engineering, Mathematics, Freshman, Retention

MOTIVATION

The traditional approach to engineering mathematics education begins with one year of freshman calculus as a prerequisite to subsequent core engineering courses. However, only about 42% of incoming freshmen who wish to pursue an engineering or computer science degree at Wright State University (WSU) ever complete the required calculus sequence. The remaining 58% either switch majors or leave the University. This problem is not unique to WSU; indeed, the inability of incoming students to successfully advance through the traditional freshman calculus sequence is a primary cause of attrition in engineering programs across the country.

As emphasized in a recent presentation by the NSF Director of Engineering Education and Centers [1], the traditional engineering curriculum has been essentially unchanged for half a century - heavily front-loaded with classical math prerequisites, with too little engineering early in the curriculum. This makes engineering unattractive to potential recruits, and difficult to endure for those brave enough to give it a try. This is particularly so for members of traditionally underrepresented groups, including women and minorities, whose enrollment and retention in engineering has not kept pace with the demands of an increasingly diverse society. As such, there is a drastic need for a proven model which eliminates the math-related constraints of the traditional engineering curriculum, yet can be readily adopted by engineering programs across the country. Such is the focus of the current research.

EGR 101: INTRODUCTORY MATHEMATICS FOR ENGINEERING APPLICATIONS

The WSU model begins with the development of EGR 101, "Introductory Mathematics for Engineering Applications," a novel freshman-level engineering mathematics course. The goal of EGR 101 is to address only the salient mathematics topics *actually used* in the primary core engineering courses, thereby fulfilling math prerequisite requirements within the context of a single course. This has opened the door for students to advance in the engineering curriculum without first completing the traditional calculus sequence.

The content of EGR 101 consists of the mathematical prerequisites required for core sophomore-level engineering courses, including the traditional physics, engineering mechanics, electric circuits and computer programming sequences. In the traditional curriculum, all of these courses require a minimum of Calculus I, while some require Calculus I-III and Differential Equations. Clearly, it is impossible to cover all topics in Calculus I-III and Differential Equations within a single course, let alone a freshman course. However, only a handful of these topics 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.

After consultation with faculty from around the College, the following math topics were slated for inclusion in EGR 101: Basic Algebraic Manipulations; Trigonometry; 2-D Vectors; Complex Numbers; Sinusoids and Harmonic Signals; Systems of Equations and Matrices; Basics of Differentiation;

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0-7803-9077-6/05/$20.00 © 2005 IEEE **October 19 – 22, 2005, Indianapolis, IN**

Basics of Integration; Linear Differential Equations with Constant Coefficients. The EGR 101 course is taught by *engineering* faculty, with all mathematical topics motivated by their direct application in the core engineering courses. Moreover, course material is emphasized by physical experiments in the classroom and laboratory, and is thoroughly integrated with the engineering analysis software MATLAB. The prerequisite requirement for incoming students to register for EGR 101 is a minimum mathematics background in Trigonometry, as indicated by a combination of math placement scores and high school transcripts, or by the completion of MTH 131 (Trigonometry) at WSU.

RESTRUCTURED CURRICULUM

The primary goal of EGR 101 is to facilitate a large-scale restructuring of the engineering curriculum, where students can advance in the program without having completed a traditional freshman calculus sequence. In the restructured curriculum, only the first calculus course remains in the freshman year, with the remainder of the calculus sequence delayed until the sophomore and junior years. This has enabled the placement of formerly sophomore-level engineering courses within the freshman year. Such courses include ME 220 Introduction to Manufacturing Processes and ME 202 Engineering Graphics. These are hands-on, application-oriented engineering courses which will go a long way toward making incoming students feel like they are actually *doing* engineering. This is in contrast to the traditional freshman calculus sequence, which effectively precludes all too many students from exposure to sophomore-level engineering courses.

REVISED MATH SEQUENCE

In order to accommodate EGR 101, the various engineering departments have been required to free up additional credit hours in their respective degree programs. Towards this goal, it was initially proposed to streamline the existing calculus sequence into three quarters, with greater emphasis on engineering application. However, there was significant concern among Math department faculty that streamlining the calculus sequence cannot be done without jeopardizing student learning, including the development of problem solving skills so critical to engineering.

In light of these concerns, the revised engineering calculus sequence is to remain four quarters long, but with separate sections designated for engineering students (where possible), and with a greater emphasis on engineering application. As previously described, Calc I is part of the freshman curriculum, with the remaining courses delayed until the sophomore and junior years. The exact locations of the remaining courses are specific to each major in the College, as determined at the department level. In Mechanical Engineering, the revised Calc II and III courses occur in the sophomore year, while Calc IV is reserved for the first quarter of junior year. In addition, the traditional Differential Equations and Matrix Algebra courses have been combined into a single 5-hour course, "MTH 235 Differential Equations with Matrix Algebra," to be offered during the sophomore year. The result of the new math sequence is a more just-in-time, application oriented approach to engineering mathematics, which is expected to have a significant effect on student retention, motivation and success in engineering.

PRELIMINARY ASSESSMENT

The EGR 101 course ran for the first time in the Fall quarter of 2004, and has run each quarter since. Nearly all eligible incoming freshmen in Mechanical Engineering, Materials Science and Engineering, Industrial Engineering, Biomedical Engineering, Electrical Engineering and Engineering Physics have been enrolled in the course. Student performance has been assessed through graded homework and labs, block midterm exams in weeks 5 and 8, and a block final exam following week 10. Final grades have been administered according to a standard University scale (A: 90-100, B: 80-89, C: 70-79, D: 60-69, F: <60), with minor adjustments for borderline cases. In addition to student performance, an assessment of student perception has been obtained through surveys distributed at the end of the course. Specifically, students have been asked whether EGR 101 had increased their motivation to study math and engineering, and whether EGR 101 had increased their chances of success in future math and engineering courses.

Through Winter quarter of 2005, a total of 114 students have been enrolled in EGR 101, with very encouraging results. Student performance has confirmed the feasibility of the course, with over 78% of the initial enrollment completing the course with a grade of "C" or better. This suggests the potential for a dramatic improvement over the 42% of WSU engineering students who have traditionally advanced past the freshman calculus sequence. Moreover, student perception following the first two runs of EGR 101 has been extremely encouraging. On average, students have confirmed that EGR 101 increased their motivation to study both math and engineering, as well as their perceived chance of success in future math and engineering courses. A more detailed discussion of these assessments is provided in [2]. The ultimate effect of EGR 101 and the restructured engineering curriculum on student retention and success in core courses remains to be seen, and will be closely studied in the months and years to come.

ACKNOWLEDGMENT

This work has been supported by the National Science Foundation, Division of Engineering Education and Centers, Grant Number EEC-0343214.

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