Work in Progress: Do It Early and Do It Often – Engineering Math for First-Term EE Students

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Abstract

This work in progress paper introduces a first-year introduction to electrical engineering course at the Milwaukee School of Engineering (MSOE) along with a data analysis plan. The purpose of the course is three-fold: to introduce new students to the major through a number of engaging laboratory exercises, to introduce new students to other students in their cohort and to electrical engineering faculty at the university, and to reinforce high-school-level mathematics in the context of engineering problems.

This work-in-progress paper will provide the history of the introduction to electrical engineering course and how it has been modified within the past three years. This paper will also introduce the analysis plan to obtain information on the effectiveness and impact in subsequent courses caused by implementing engineering mathematics into this introductory electrical engineering course. In general, the proposed study will consist of a grade comparison between students who took the introductory course in the three years before the inclusion of engineering math content and those who took the introductory course in the two years after the addition of engineering math content.

Introduction

In 2004, Klingbeil, et al., introduced a model of an introductory general engineering course that was application oriented and incorporated a hands-on approach [1]. The model was originally developed to increase retention and motivation within the engineering field. The outcome of this study is referred to as the Wright State University (WSU) model for engineering mathematics [2-3]. In this model, as discussed in [3], WSU replaces a mathematics course with their developed engineering mathematics course and moreover revised their curriculum stemming from this initial change. Researchers at various institutions have fully adopted the WSU model, in which they incorporate mathematic material with engineering application problems that are then tightly coupled with labs. The researchers from Lafayette College and University of Arkansas, [4] and [5] respectively, implemented the WSU model with adjustments to better fit a semester based academic calendar and piloted the course to all engineering majors. In [5], Schluterman, et al., also did a comparison study between students that took traditional precalculus versus those that took the "Engineering Applications of Mathematics" course. Their study showed promising results in favor of their new course. Salzman, et al., also adopted the work done by Klingbeil in modifying their "Introduction to Engineering" course, with one of the bigger changes to their original course being a shift from open-ended design projects to mathematics focused projects. The data provided in [6] anecdotally shows that the math focused course was beneficial for the following mathematics and science courses. There have been other studies on the impact of an introductory mathematics course centered around engineering applications on student retention, motivation, and ability in later courses as seen in [7- 9] among others.

Introducing precalculus material with engineering applications as the base has been shown to improve retention, motivation, and ability in later courses. This work-in-progress paper

introduces the history behind modifying a two-credit Introduction to Electrical Engineering course focused around lab experiences, to a four-credit course that delves into the fundamental precalculus knowledge required for electrical engineering students while retaining its lab aspect. This course is specifically for electrical engineering freshman rather than all engineering students and is taken within their first quarter. Most lectures are based on the text developed by Rattan and Klingbeil [10], focusing on (but not limiting to) the electrical engineering examples throughout the text. This course differs from those above by not fully adopting the WSU model but using the precalculus engineering application concepts throughout the text to drive our lectures while maintaining the laboratory experiments that were previously developed. In particular, this work in progress will analyze the course's effect on students' performance within the circuit sequence at MSOE. A study is proposed, in which we will perform a grade comparison between students who took the introductory course in the three years before the inclusion of engineering math content and those who took the introductory course in the two years after the addition of engineering math content.

Course evolution

First-Term Electrical Engineering at MSOE

For a number of years, the electrical engineering program at MSOE offered a two credit Introduction to Electrical Engineering course (EE100) in the fall term. The course was aimed at first-term traditional students, with the purpose of cultivating interest in the major through hands-on lab activities. Students attended a one-hour lecture introducing an area within the field of electrical engineering. The students then completed an associated laboratory activity in a two-hour lab period. Topics included microprocessors, motors, signals, and basic circuits. Students gained experience with measurements and soldering, and one session was devoted to the use of a graphing calculator in a number of problem contexts.

The course was set up to provide students with an engaging introduction to the field, but some faculty suggested that the course could also be used to address mathematical and other deficiencies that they observed in student work. Complex numbers, use of scientific units and prefixes, linear modeling, and manipulation of symbolic equations were identified as areas of concern by faculty teaching electric circuits. While some of these topics were addressed in EE100 as part of the calculator activity, the amount of instruction in this single activity was not sufficient to correct the problems seen in circuit courses. Furthermore, equivalent credit for the course was granted for students with Project Lead the Way (PLTW) or other prior college-level coursework in engineering, so a significant number of students entered the electric circuits sequence without having taken EE100 in residence at MSOE.

In 2015, MSOE as an institution encouraged all programs to restrict the first year course sequence to four 4-credit courses per term. The electrical engineering program took this opportunity to expand the two-credit EE100 course into a four-credit EE1000 course of the same title, Introduction to Electrical Engineering. The new course format would include three hours of lecture, along with a two-hour laboratory period per week. The lecture periods would now

focus on mathematics and problem solving with applications in electrical engineering. The goal of the laboratory activities would remain the same, to cultivate interest in the major, but activities would be redesigned to support the lecture material.

Introduction to Electrical Engineering (EE1000) Course Details

EE1000 is offered in the fall term, and all traditional electrical engineering majors are expected to enroll in the course in their first term at MSOE. Matriculating students with a declared major of electrical engineering and math placement in precalculus or above are registered for the course by entrance advisors. Students who do not place into precalculus will typically take the course in the fall of the second year, concurrent with the first electric circuits course. EE1000 is a required course in the electrical engineering major, but transfer students in some cases receive equivalent credit for introductory courses in other engineering majors.

The course is run in sections of no more than 20 students, each taught by a different instructor. The instructors are chosen from full-time faculty who are also academic advisors. While a student in EE1000 will have one lecture instructor for the duration of the course, the instructors rotate through the laboratory sections, to give students the opportunity to meet multiple EE faculty members in their first term. The course also contains additional major orientation activities, including a "passport" activity introducing the student to important people and places within the department, and a grade tracking and scheduling activity to support the sense of personal responsibility required of the college student.

The lecture material is based primarily on the textbook *Introductory Mathematics for Engineering Applications* by Rattan and Klingbeil [10] which covers mathematics from linear and quadratic functions through differential equations, using engineering application problems as the vehicle for instruction. This book was selected due to its unique approach and its accessibility for first year students. The mathematical content aligns closely with the areas identified by circuits faculty as needing reinforcement, and the application-oriented nature of the material aligns with our original objective of introducing the first year students to the field of electrical engineering. Many previous studies [2-9] and [11-14] have demonstrated that this specific curriculum has a measurable, positive effect on various performance measures, including performance in a first circuits course [7].

The topics covered include linear models, quadratic models, trigonometry, complex numbers, sinusoids, and simultaneous linear equations. These topics are directly applicable to the circuits sequence, and the text has a wide selection of electrical engineering application problems. In addition to the technical concepts, students learn the expectations associated with college level work in engineering, including the correct use of units and prefixes, creation of high quality graphs, and use of the graphing calculator.

Delivery does not follow the traditional lecture format. Instead, instructors typically follow a weekly cycle, in which the first meeting may be close to a traditional format with some breaks for self-assessment, the second meeting consists of think-pair-share exercises covering the material from the previous meeting, and the third meeting is student-led presentation of homework solutions and associated Q&A. Exams are common across sections and the faculty

follow the course schedule strictly, so that students from different sections can form study partnerships that will continue to benefit them as they progress through the rest of the electrical engineering curriculum. Student response to the course has been positive, with course evaluation responses exceeding the average score for first year courses in the MSOE EECS department.

Study

In order to measure the effectiveness of the introduction of engineering mathematical content into the introductory electrical engineering course, we will be collecting data for three different groups. A student who took one or both of the introductory circuits courses EE2050 (Linear Circuits I, primarily DC) and EE2060 (Linear Circuits II, primarily AC) in the last five academic years will be included in the study. The student will be placed into a group as follows:

> Group A: The student was enrolled in EE100 during academic years 2013 to 2015, prior to enrolling in EE2060.
>
> Group B: The student was enrolled in EE1000 during academic years 2016 to present, prior to enrolling in EE2060.
>
> Group C: The student was not enrolled in either EE100 or EE1000 prior to enrolling in EE2060.

Student performance in the circuits courses EE2050 and EE2060 is the primary focus of our study, as the engineering math that is introduced in EE1000 is focused on improving students' performance in those courses. However, other data will be gathered for each student in the study, including high school GPA, ACT scores, zip codes, and grade information for Calculus I (MA136), Calculus II (MA137), Calculus III (MA231), Introduction to Electrical Engineering (EE100 or EE1000; if taken), Linear Circuits I (EE2050), and Linear Circuits II (EE2060).

Our hypothesis is that the introduction of engineering mathematical content in EE1000 will have measurably improved student performance in the linear circuits courses as compared to those who did not take EE1000 prior to enrolling in the linear circuits courses. To that end, we plan to conduct one-way ANOVA tests for each of the courses for which we have student grade data, focusing particularly on the two linear circuits courses.

Conclusions

At MSOE we have modified our Introduction to Electrical Engineering course to include precalculus content into the lectures. One of the main reasons behind this change was feedback from faculty regarding student performance in the circuits sequence. It was hypothesized that student performance in the circuit sequence would improve with the precalculus as well as polar form and various with sinusoids in Introduction to Electrical Engineering. We plan to collect data for three years prior to and three years after the modifications. The main research question being addressed in the data is if there was improvement in student performance within the circuit sequence with the new course.

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