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Using Active Learning and the Wright State Model for Engineering Mathematics Education to Cultivate Academic Success among First-Year Engineering Students

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Abstract

A mid-sized private university in the Southeast has created an experimental first-year engineering course based on the Wright State Model for Engineering Mathematics Education. The course aims to increase student retention, motivation, and success in engineering through an application-oriented, hands-on introduction to engineering mathematics. Therefore, active learning techniques were used throughout the course. Students provided preliminary qualitative data via end-of-course evaluations. Preliminary quantitative data included student course grades, cumulative GPAs (CGPAs), and retention rates. Thus far, students taking the experimental first-year engineering course believe they gain confidence and skills such as problem-solving, time management, study habits, computer programming, as well as real-world applications of math and physics. Thus far, over 80% of students have earned a grade of C or better in the experimental first-year engineering course along with their pre-calculus or calculus class. More than 80% of students have also maintained a CGPA above a 2.0.

Keywords: engineering mathematics, retention, academic success

Introduction

Many undergraduate engineering students encounter obstacles or bottlenecks to their degree completion including required first and second year mathematics courses. [1,2] Introductory courses in mathematics, physics and engineering often serve as pre-requisites for second and third-year engineering courses. For example, countless engineering departments require students to successfully complete a sequence of calculus and physics courses before taking engineering courses involving statics, dynamics, solid mechanics, thermodynamics, circuits, etc. Calculus I is listed as an expected first-year and first-term course for engineering students at a lot of four-year colleges and universities in the US. Therefore, first-year students are expected to receive minimum placement scores or already have college credit for courses such as Calculus I and Physics I. Students who are unable to begin or receive credit for Calculus I during their first collegiate term are often placed in remedial math courses that can increase student costs and time to degree.

To help more undergraduate engineering students overcome the aforementioned obstacles and bottlenecks to their degree completion, engineering professors developed The Wright State Model for Engineering Mathematics Education. The Wright State Model provides first-year engineering students with immediate exposure to math topics from essential engineering courses which allows students to meet necessary math prerequisite requirements.[3] The Wright State

Model has several unique components when compared to traditional undergraduate mathematics courses. One, it presents all math concepts within an engineering context while solely using math topics and examples from core engineering classes. Two, the course consists of a combination of lecture, laboratory, and recitation sessions. Finally, the Wright State Model involves having engineering faculty teach first-year students the math that is required for their majors. Engineering students who have experienced the Wright State Model for Engineering Mathematics Education have had increased GPAs and graduation rates, with the greatest impact on underrepresented groups.[4]

This study summarizes an experimental first-year engineering course that was created by faculty at a mid-sized private university in the Southeast and is based on the Wright State Model for Engineering Mathematics Education. Faculty used Wright State's sample lecture presentations and notes that encourage students to "learn by doing" or solving problems in class with the lecturer. However, the style of the new EGR_Math course relied on faculty using additional evidence-based active learning techniques to engage students. The additional active learning techniques are described in a subsequent section of this paper.

Faculty created the experimental course to increase engineering student retention, motivation and success. Students who received a math placement level at or above pre-calculus were eligible to enroll in the experimental course. Successful completion of the experimental course provides students with an opportunity to register for a sophomore-level statics course. The statics course serves as a prerequisite for many junior and senior-level engineering courses so it enables many students to advance through their degree programs in a timely manner.

At the respective mid-sized private institution, engineering students traditionally have to be enrolled in their final calculus course before they can enroll in a statics course. Historically, engineering students have dropped, failed or withdrawn from the university's calculus courses and they have done so at high rates (i.e., between 20-40%). Students who are delayed in their ability to begin or complete all required calculus courses are subsequently delayed from taking most sophomore, junior and senior-level engineering courses that require successful completion of statics.

Course Creation

In 2016, at a mid-sized private university in the Southeast, faculty created an experimental mathematics for engineering course using publicly available material from the Wright State Model for Engineering Mathematics Education.[5] Faculty developed the experimental mathematics course through funding from the university's teaching and learning center and support from the university's first-year engineering department. While the course was being created, faculty also solicited support and feedback from the university's mathematics, physics, and civil engineering instructors. Faculty and staff on the university's retention committee, especially those with knowledge about the university's math placement exam, provided further guidance. Engineering faculty members at Wright State University also provided sample exams and periodically answered questions about their model.

The university's first-year engineering department first offered the experimental mathematics course during the fall of 2017 and the department offered it a second time during the fall of 2018.

Faculty created and reviewed numerous course components for the new course offering. The available material from Wright State University included a sample syllabus and schedule, lecture videos and notes for each class topic, handouts for various class topics, supplemental videos and procedures for lab, simulations for each lab as well as sample exams. Ultimately, faculty created a new course syllabus and schedule along with a new lab manual and sample executive summary, new lab presentations, new class presentations, grading rubrics and even a frequently asked questions document for course topics. For the purpose of this paper, the new experimental mathematics course will be referred to as EGR_Math.

Course Style

Sample lecture presentations and notes are publicly available from the Wright State Model for Engineering Mathematics Education that encourage students to "learn by doing" or solving problems in class with the lecturer.[6] However, the style of the new EGR_Math course relied on faculty using additional active learning techniques to engage students such as (a) in-class teams, (b) think-pair-share, (c) minute papers, and (d) cooperative note-taking pairs.[7,8, 9,10] When faculty introduced new topics in class or lab, the instructor would also use short PowerPoint Presentations to convey the new learning objective(s), visually show images of selected real-world applications and to summarize any necessary math terms or equations. The instructor made all course resources including PowerPoint slides, lecture notes, handouts, and lab manuals available to students via the course management site.

For in-class teams, the instructor provided students with given or background information on the overhead and then asked students to find unknown variables or values while working in groups of four to eight members. Student groups ultimately competed to quickly and accurately work out a team solution of the problem on one of the three classroom whiteboards. To increase participation among all students within a group, the instructor walked around to see what each student was contributing and to answer any individual questions.[7] The instructor has also required that different students take turns writing on the whiteboard. Furthermore, to encourage full participation, the instructor has required that each student have the correct answer written on their own individual paper before the team can get credit for having the correct solution to the problem written on the whiteboard first.

When using think-pair-share, the instructor would begin a problem on the overhead and then ask students to individually think through and solve the rest of the problem. After students reached a solution, the instructor asked them to compare their answer with a classmate and then the entire class discussed the overall process for solving the problem.[8] The instructor made minute papers available to students each day via the course management site as an in-class participation assignment so students could reflect on their learning. Students answered questions such as *what was the most important point of the class, what was the most surprising idea or concept, what question remains unanswered in your mind, what topic is currently the least clear or most difficult to understand* and *what question from this class might appear on the next quiz/test?*[9] Lastly, the instructor had students use cooperative note-taking pairs during review sessions for exams so students could compare and discuss the information they planned to include on their exam "crib" sheets (i.e., handwritten resource sheets).[10]

Preliminary Results

During the fall of 2017, a total of 28 first-degree-seeking, first-year engineering students completed the EGR_Math course. For the two sections of the EGR_Math course, the university's first-year engineering department assigned the same faculty member and a different undergraduate teaching assistant to each section. The 28 students accounted for roughly five percent of all first-degree-seeking, first-year engineering students. Of the 28 students who completed the EGR_Math course, about 36% were women and 4% had an international country of origin. Also, approximately 7% were of an unknown race/ethnicity, 11% were Black, 11% were Hispanic, and roughly 67% were White. As of Fall 2017, undergraduate students from the Southeastern campus were 22% female and 13% international students. In addition, 7% were multi-racial, 5% Black, 5% Asian, 7% Hispanic, and 56% White. See below for Figures 1-2.

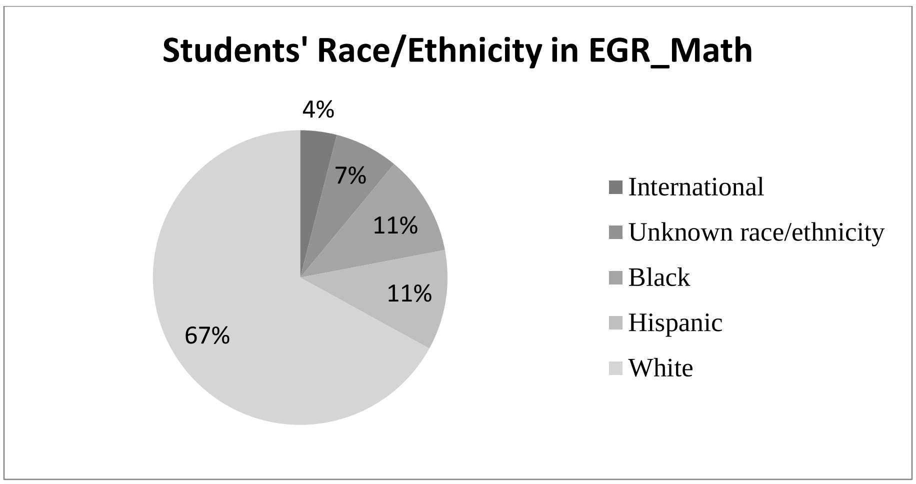

Figure 1: Race/Ethnicity of EGR_Math Students

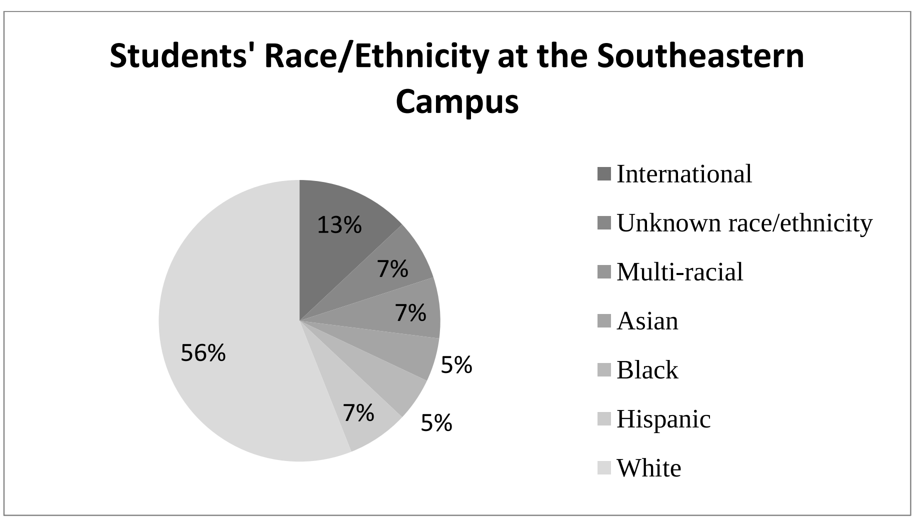

Figure 2: Race/Ethnicity of the Institution's Students

The instructor collected preliminary qualitative data through open-ended student answers to an end-of-course survey. One question asked students to describe "*what elements of the course most helped … [them] learn the course content.*" In the fall of 2017, one student commented that "the elements that most helped were the examples given and how they were worked out as a class" while another student said "completing example problems in class most helped me learn the content." Several other students also mentioned the instructor's "examples."

When asked to describe what they "gained from the course," students taking the experimental first-year engineering course believe they gain confidence and skills such as problem-solving, time management, study habits, computer programming, as well as real-world applications of math and physics. One student stated, "I gained extreme time management and how to deal with stress. I also learned how [to] work with others to achieve excellence. The final thing I learned was how to keep motivated, even when it felt like I failed." Another student said, ""I learned how to apply math to real world applications. In the process, I also learned fundamental self-discipline in how to study." Finally, a student mentioned,

> [The instructor's] motivation and his belief that we could all do as well as we want to encouraged me to stop aiming for a 70 or an 80 on an exam and to aim to understand the topic well. This increased my knowledge and capability as well as my grades! This class was a great class for me, it not only challenged me, it taught me how to rise to the challenge.

Based on quantitative data from the university's institutional research office, students who took the EGR_Math course during the fall of 2017 experienced higher mean term GPAs of 2.98 (SD = 0.935) when compared to students who did not take the EGR_Math course and earned mean term GPAs of 2.67 (SD = 0.922). Since most students were first-term first-year engineering students, cumulative and term GPAs were nearly identical. Table 1 below summarizes term and cumulative GPAs for students who did and did not take the EGR_Math course.

Table 1: Term and Cumulative GPA Comparison for EGR_Math and non- EGR_Math Students

Population		CumGPA	TermGPA
EGR_Math Students	Mean	2.90	2.89
	N	28	28
	Std. Deviation	.937	.934716
Non EGR_Math Students	Mean	2.71	2.67
	N	509	509
	Std. Deviation	.890	.922
Total	Mean	2.72	2.68
	N	537	537
	Std. Deviation	.893	.923

First-time, full-time engineering students who took the EGR_Math course during fall of 2017 had a higher first-year retention rate of 85.2% when compared to a retention rate of 83.6% for students who did not take the course. Table 2 below contains the first-year retention rates of engineering students who did and did not take the course.

Table 2: First-Year Retention Rates for EGR_Math and non- EGR_Math Students

	Initial Headcount		Returned		Attrited	
	#	%	#	%	#	%
Took EGR_Math	27	100%	23	85.2%	4	14.8%
Did not take EGR_Math	489	100%	409	83.6%	80	16.4%

Additional data shows over 80% of students who took EGR_Math have earned a grade of C or better in the experimental first-year engineering course along with their pre-calculus or calculus class. More than 80% of students have also maintained a CGPA above a 2.0. Data from students who took the EGR_Math course during the fall of 2018 is still being gathered.

Discussion and Conclusion

A mid-sized private university in the Southeast has created an experimental first-year engineering course based on the Wright State Model for Engineering Mathematics Education. The course aims to increase student retention, motivation, and success in engineering through an application-oriented, hands-on introduction to engineering mathematics. Therefore, active learning techniques were used throughout the course. Students provided preliminary qualitative data via end-of-course evaluations.

Preliminary quantitative data included student course grades, cumulative GPAs (CGPAs), and retention rates. Thus far, students taking the experimental first-year engineering course believe they gain confidence and skills such as problem-solving, time management, study habits, computer programming, as well as real-world applications of math and physics. Thus far, over 80% of students have earned a grade of C or better in the experimental first-year engineering course along with their pre-calculus or calculus class. More than 80% of students have also maintained a CGPA above a 2.0.

As previously mentioned in the results section, many students who took the EGR_Math course in the fall of 2017 commented that working on example problems in class and with others was beneficial. Example problems were completed in class using active learning techniques such as in-class teams and think-pair-share. The instructor tried to avoid working out examples while students just passively copied what they saw on the projector screen.

Similar to previous findings, first-time, full-time engineering students who took the EGR_Math course experienced higher first-year retention rates than their peers who did not take the course.[3] Students who took the EGR_Math course also did well in their pre-calculus and calculus classes. The students experienced higher term grades than their peers who did not take the course, which is similar to findings from previous studies about the academic benefits of using active learning techniques.[7,11,12,13]

Acknowledgements

Some quantitative data from this paper was compiled by the respective university's institutional research office.

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