Effects of a Limited Implementation of the Wright State Model for Engineering Mathematics Education focused on Pre-Calculus Students

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Abstract

This is a complete evidence-based paper, which presents the implementation of a new course to mitigate the effects of student math preparation on student performance. At Grand Valley State University, a first-year engineering course has been developed based on the Wright State Model for Engineering Mathematics Education. At GVSU, the student population has been found to be similar to the population at WSU based on incoming ACT math scores and preparation; however, the curriculum does not have room to add an additional required course as was done at WSU. Since the research to date shows that the majority of the impact of the course is on students that are not calculus ready, the course developed at GVSU focuses on those students. Consequently, this course is optional and marketed toward students who are not in calculus, enrolled in either a pre-calculus math course or trigonometry.

The course was first offered in Fall of 2016. Much of the course is based on the course materials and text developed as part of the Wright State Model; however, due to constraints, the lab portion was limited to in-class demonstrations and group activities. In addition, a new module for the course was created to address student unfamiliarity with logarithmic and exponential functions.

This paper presents the new course along with data to assess the effect it has had on students' performance. Each year qualitative data was collected regarding student impressions of the course and feedback. Additionally, quantitative data was collected in the form of student course grades and GPA. This performance is measured based on retention in the engineering program and final grades in courses that have a strong correlation to graduation rates (calculus, physics, and select 2nd year engineering courses). Data collected on students who took the new course is compared with data on students with the same preparation and courses, who did not take the course. In addition to quantitative performance data, qualitative data is also presented with some lessons learned.

Trends in Graduation Rates and Math Start

Engineering students at Grand Valley State University follow the traditional mathematics curriculum path, with most engineering courses beginning after calculus. Many of the students that begin in Calculus I (MTH201) were found to have a 6 year graduation rate of 43% compared with the next highest rate of 16% for those that start in College Algebra (MTH122) as shown in Figure 1. It is also noteworthy that there was a trend in the graduation rate relative to the starting mathematics course. As can be seen in Figure 2, earlier cohorts had a much similar graduation rate 21-27% whether they were starting in College Algebra (MTH122), Trigonometry (MTH123), or Calculus (MTH201). It is clear that the program has been changing to cater to those that start in calculus and is not serving those that are not in calculus well. The general consensus is that the graduation rate among those who are calculus ready is on the rise while it is falling for those who are not.

Figure 1: Six-Year graduation rate vs starting math course for a cohort in 2009. The titles of the courses listed are MTH 097 Elementary Algebra, MTH 110 Algebra, MTH 122 College Algebra, MTH 123 Trigonometry, MTH 201 Calculus I

Figure 2: Six-Year graduation rate vs. starting math course for cohorts starting 2006-2009. The titles of the courses listed are MTH 097 Elementary Algebra, MTH 110 Algebra, MTH 122 College Algebra, MTH 123 Trigonometry, MTH 201 Calculus I

While the significant improvement in graduation rates for calculus ready students is good news, the decline among the non-calculus ready students is of concern. Trends in the starting mathematics course for incoming FTIAC students is shown in Figure 3. While calculus ready students have increased to roughly half of the incoming population, this has plateaued around 55%. The more significant trend is the decrease in those requiring a remedial math course (MTH110) and the increase of students starting in either college algebra or trigonometry. This led to an effort to find a solution to improve outcomes for students starting in college algebra and trigonometry.

Figure 3: Yearly Percentage of Total FTIAC's Starting in Indicated Math Course

The Wright State Model for Engineering Mathematics

The Wright State Model calls for two significant changes [1]. The first is the creation of an engineering mathematics course, which focusses on the mathematics that are used in 2nd year engineering courses. The second change is to make the new course the prerequisite to begin courses in the 2nd year. Rather than waiting to complete the calculus sequence.

The reported improvement in retention and graduation rates at WSU were significant and made this solution attractive. Prior to piloting a new course similar to the one at WSU, a comparison was made between the student population at both institutions. Figure 4 and Figure 5 show the distribution of ACT math scores for intending engineering students at both WSU and GVSU respectively. The distributions are similar, but the average ACT score is 27.3 at GVSU compared to 23.9 at WSU, which is a significant difference.

Given that the graduation rate among calculus-ready students is comparable to the report rate among students at WSU who took their new math sequence, we made the decision to not make a curriculum change that would affect all students. Rather, we chose to provide additional tutoring resources and develop an optional course for incoming students that would be marketed as a tool to improve their success.

Figure 4: Student ACT distribution for students that did and did not take EGR101 at WSU [2].

Figure 5: Student ACT distribution for students who intend to study engineering at Grand Valley State University

The course is similar to the freshman course developed at Wright State University [3] and covers the application of math to solving engineering problems. The course begins with applications of algebra to engineering problems, which is followed by an exploration of the use of trigonometry. While it is assumed that students have not been taught calculus, students are introduced to the basic concepts of calculus and how it is applied to basic engineering problems.

This course differs from the Wright State model in sequence and content. When covering algebra, additional teaching materials were developed and introduced regarding the use of logarithms and exponential functions in engineering, and all algebra topics are taught prior to starting trigonometry. The resequencing of topics was done to mirror the content delivery of the pre-calculus math course at Grand Valley State University. A sample topic schedule with the new sequencing is shown in the Appendix. Many of the *Class Activities* in the schedule are in-class demonstrations and activities based on the lab assignments done in the WSU course.

Grade Effect

The goal of introducing this course was to improve outcomes and retention for students whose starting math courses were either college algebra or trigonometry. Starting in 2016 the new course was offered in the Fall semester. In the Fall 2016 semester, only one section with 30 seats was offered. There was doubt as to whether or not the class would fill given that the course was not required nor a prerequisite to other engineering courses as was done at WSU. It was a surprise when the course filled within the 1st few weeks of registration. Subsequent offerings were for two sections, but there remains unmet demand for the course.

While the course has not been offered long enough to determine if there is an effect on graduation rates, there is data available regarding student performance in key courses. Many students that transfer out of engineering struggle the most in both physics and the initial engineering courses EGR106 and EGR107, which teach programming, graphical communication, and design. As seen in Figure 6, there is a significant improvement to the average GPA for students that took the new course, and the difference in course GPA for EGR106, EGR107, and PHY230 are statistically significant at the 0.05 level. The most exciting is the improvements in course grades for EGR106 and PHY230, both of which see the highest drop rates of courses in the beginning two years of the curriculum.

Figure 6: Average course GPA for key courses. EGR106 (Intro. to Engineering Design I), EGR107 (Intro. to Engineering Design II), MTH201 (Calculus I), MTH 202 (Calculus II), and PHY230 (Physics I)

Since it is a concern that the population that took the course may be significantly different than the one that did not, the ACT math score distribution for the two populations was compared in Figure 7 and Figure 8, which show that the populations are close with mean ACT scores of 23.3 (did NOT take EGR180) vs 23.8 (Took EGR180).

Figure 7: ACT Math Score distribution for students that took EGR180

Figure 8: ACT Math Score distribution for students that did not take EGR180

Student Perceptions

Students in each class were asked a set of survey questions. The survey included six statements, and students were asked to rate them with a Likert scale from strongly agree to strongly disagree. The statements are listed below:

- The course has increased my motivation to study engineering.
- The course has increased my chances of success in engineering.
- The course has increased my motivation to study math.
- The course has increased my chances of success in future math courses.
- I was challenged by this course.
- I was overwhelmed by this course.

The results of the survey are summarized in Figures 9-14. In Figures 9 & 10, it is clear that a majority of students either agreed or strongly agreed that the course increased their motivation to study engineering (61.8%) and their chances of success in engineering (73.5%). The majority of students that did not agree were neutral and only a few disagreed. Given that these were two of the main goals for the course, it is a positive sign the student perception of the course matches the

designed intent of the course. This is backed up by student comments when asked what they liked about the course, which included:

- “Actually applying mathematics to real-world engineering situations”
- “The best part about this course was mostly just learning the Calculus and engineering skills, confirming to me that this is what I want to do with my life and I want to become an engineering.”
- “Covering electronic circuits because I learned about them in AP physics in Highschool and I plan to be an electrical engineering “
- “The chance to explore different fields of engineering seeing what all aspects are like”

This course has increased my motivation to study engineering.

Figure 9: Pie chart summarizing the responses of 103 students to the statement, "This course has increased my motivation to study engineering."

This course has increased my chances of success in engineering.

Figure 10: Pie chart summarizing the responses of 103 students to the statement, "This course has increased my chances of success in engineering."

Figures 11 & 12 explored the students' perception of the course in regard to its goal of improving their math skills. As seen in Figure 11, a majority of students (59.8%) agreed or strongly agreed that the course increased their motivation to study math. Additionally, Figure 12 Shows that an even larger majority (88.2%) agreed or strongly agreed that the course increased their chances of success in math courses. This confirms that the majority of students have a positive perception of the course in terms of its positive impact on their performance in math courses.

This course has increased my motivation to study math.

Figure 11: Pie chart summarizing the responses of 103 students to the statement, "This course has increased my motivation to study math."

This course has increased my chances of success in future math courses.

Figure 12: Pie chart summarizing the responses of 103 students to the statement, "This course has increased my chances of success in future math courses."

I was challenged by this course.

Figure 13: Pie chart summarizing the responses of 103 students to the statement, "I was challenged by this course."

I was overwhelmed by this course.

Figure 14: Pie chart summarizing the responses of 103 students to the statement, "I was overwhelmed by this course."

Given that the course covers more advanced topics than are typically seen by students with only a pre-calculus background, the students were asked how challenged they felt and whether they were overwhelmed. Figure 13 summarizes the students' responses to the statement "I was challenged by this course". An overwhelming majority of 95.1% of students agreed or strongly agreed that they were challenged by the course. While challenging students is viewed as a positive, it is possible to overwhelm them. The results of student responses to the statement, "I was

overwhelmed by this course” are summarized in Figure 14. Unfortunately, a majority (53%) of students agreed or strongly agreed with this statement. This sense of being challenged to the point of being overwhelmed is backed up by student comments as well, which include:

- “I believe some topics needed to be taken slower and gone into more detail.
- “The content can be difficult to understand at times, and since the course does not require calculus knowledge to be on it, I feel there should be more time to focus on the basics of integrals, as well as differential equations.
- “I wish it was a little less challenging but at the same time I understand that's how engineering goes.”

When initially piloting the new course, there was a significant MATLAB component, where students were introduced to the software and used it to solve engineering problems. After finding that everyone in the course was overwhelmed, it was decided to remove the MATLAB component and focus on calculations using other tools and hand calculations. This somewhat alleviated the issue by allowing for topics to be covered more slowly and in more detail; however, it remains that a third of the enrollment for the course is still stressed by it.

Conclusions

Despite the fact that the course is not required nor a prerequisite for any courses, the new course has had full enrollment for every offering. This is due to evidence-based marketing, where students are told of the intended goals for the course along with evidence of its effectiveness, which has been published by many instructors at many institutions [4, 5, 6, 7, 8]. While the Wright State Model has been found to be effective in many schools, it is not always possible to implement it completely as a one-size fits-all solution. At Grand Valley State University, the course championed by the WSU model was piloted and molded to best fit the population it served.

Unlike the WSU course, the students taking it were not a combination of students both in trigonometry and calculus, rather they were only students taking both college algebra and trigonometry. The result is a group of students that can be easily overwhelmed by the material. It is suspected that having calculus ready students enrolled in the course may help support those that are not; this may be an area of interest for future study. However, given that this course is limited in its scope to aid precalculus students, it was essential to cut back on material (MATLAB), rearrange topics, and slow down delivery. The result is a course that many students rave about as they are taking calculus and physics, and best yet, their average course GPA shows a half-to-full letter grade improvement, which bodes well for retention.

References

- [1] N. Klingbeil, K. High, M. Keller, I. White, B. Brummel, J. Daily, R. Cheville and J. Wolk, "The Wright State Model for Engineering Mathematics Education: Highlights from a CCLI Phase 3 Initiative," in *2012 ASEE Annual Conference & Exposition*, San Antonio, TX, 2012.
- [2] N. Klingbeil, "The Wright State Model for Engineering Mathematics Education," [Online]. Available: <https://engineering-computer-science.wright.edu/research/the-wright-state-model-for-engineering-mathematics-education>. [Accessed 2016].
- [3] N. Klingbeil, R. Mercer, K. Rattan, M. Raymer and D. Reynolds, "The WSU Model for Engineering Mathematics Education," in *2005 Annual ASEE Conference*, Portland, OR, 2005.
- [4] L. Albers, "Implementing the Wright State Model First-Year Engineering Mathematics Course in a Startup School of Engineering," in *2018 ASEE Annual Conference & Exposition*, Salt Lake City, Utah, 2018.
- [5] S. Das, "Implementing the Wright State Model for Engineering Mathematics at University of Detroit Mercy," in *2019 ASEE Zone I Conference & Workshop*, Niagara Falls, NY, 2019.
- [6] N. Klingbeil, B. Newberry, A. Donaldson and J. Ozdogan, "The Wright State Model For Engineering Mathematics Education: Highlights From A Ccli Phase 3 Initiative," in *2010 Annual Conference & Exposition*, Louisville, Kentucky, 2010.
- [7] L. Long and C. Morello, "Using More Frequent and Formative Assessment When Replicating the Wright State Model for Engineering Mathematics Education," in *2019 ASEE Annual Conference & Exposition*, Tampa, Florida, 2019.
- [8] B. Newberry, R. Miller and R. Stevenson, "Engineering Enrollment Retention Improvement by Application of the Wright State Mathematics Education Model," in *2011 ASEE Annual Conference & Exposition*, Vancouver, British Columbia, 2011.

Appendix

Table 1: Sample Course Schedule

DATE	TOPIC
26-Aug	Course Introduction / Application to Algebra in Engineering - Linear Equations
28-Aug	Application of Algebra in Engineering - Quadratic Equations
2-Sep	Labor Day -- UNIVERSITY CLOSED
4-Sep	Systems of Equations and Matrices in Engineering
9-Sep	Logarithms and Exponentials in Engineering
11-Sep	Class Activity
16-Sep	Trigonometry - One and Two-Link Planar Robot
18-Sep	2-D Vectors in Engineering
23-Sep	Complex Numbers in Engineering
25-Sep	Class Activity
30-Sep	Sinusoids and Harmonic Signals in Engineering
2-Oct	Sinusoids and Harmonic Signals in Engineering
7-Oct	EXAM #1
9-Oct	Introduction of Derivatives in Engineering
14-Oct	Application of Derivatives - Position, Velocity and Acceleration
16-Oct	Application of Derivatives - Electronic Circuits
21-Oct	Fall Break -- UNIVERSITY CLOSED
23-Oct	Application of Derivatives - Deflection of Beams
28-Oct	Introduction of Integrals in Engineering
30-Oct	Application of Integrals in Statics
4-Nov	Class Activity
6-Nov	EXAM #2
11-Nov	Application of Integrals in Dynamics
13-Nov	Application of integrals in Electronic Circuits
18-Nov	Class Activity
20-Nov	Introduction to Differential Equations - The Leaking Bucket
25-Nov	Application of Differential Equations - Mechanical Systems
27-Nov	Thanksgiving Break -- UNIVERSITY CLOSED
2-Dec	Application of Differential Equations - Electrical Systems
4-Dec	Class Activity
	Final Exam