AC 2011-1558: THE WRIGHT STATE MODEL FOR ENGINEERING MATHEMATICS EDUCATION: HIGHLIGHTS FROM A CCLI PHASE 3 INITIATIVE, VOLUME 2

Nathan W. Klingbeil, Wright State University

Nathan Klingbeil is a Professor of Mechanical Engineering and Associate Dean for Academic Affairs in the College of Engineering and Computer Science at Wright State University. He is the lead PI for Wright State's National Model for Engineering Mathematics Education. He has been the recipient of numerous awards for his work in engineering education, including the ASEE North Central Section Outstanding Teacher Award (2004) and the CASE Ohio Professor of the Year Award (2005). He also held the university title of Robert J. Kegerreis Distinguished Professor of Teaching from 2005-2008.

Scott C. Molitor, Ph.D., University of Toledo

Scott C. Molitor received his Ph.D. in Biomedical Engineering from the Johns Hopkins University School of Medicine in 1997 and has been a faculty member in Bioengineering at the University of Toledo Department of Bioengineering since 2000. His research is in computational neuroscience, auditory neuroscience and traumatic brain injury. He has also served as the Bioengineering undergraduate program director since 2001.

Brian W. Randolph, University of Toledo

Brian W. Randolph is the Associate Dean of Undergraduate Studies and Professor of Civil Engineering at the University of Toledo. He is the lead investigator for the UT adoption of WSU's National Model for Engineering Mathematics Education. He has received numerous awards for his teaching and professional activities, including the ASEE North Central Dow Outstanding Young Faculty Award, repeated department and college teaching awards and was named Toledo Engineer of the Year in 2005.

Shane A. Brown, Washington State University

Shane Brown is an assistant professor in the Department of Civil and Environmental Engineering at Washington State University. His research focuses on conceptual understanding of engineering students and practitioners and conceptual change processes that lead to differences in understanding.

Robert G. Olsen, Washington State University

Robert G. Olsen is Associate Dean of the College of Engineering and Architecture for Undergraduate Programs and Student Services and the Boeing Distinguished Professor of Electrical Engineering at Washington State University, Pullman, WA, USA. He received the BS degree in electrical engineering from Rutgers University, New Brunswick, NJ in 1968 and the MS and Ph.D. degrees in electrical engineering from the University of Colorado, Boulder, CO in 1970 and 1974 respectively. He is a Fellow of the IEEE, an Honorary Life member of the IEEE Electromagnetic Compatibility Society. He is past Associate Editor of the IEEE Transactions on Electromagnetic Compatibility and Radio Science. As the Associate Dean for Undergraduate Programs and Student Services he is responsible for oversight of the accreditation process, recruitment and retention of students, community college visitation, management of the scholarship program and services to university and state committees.

Dr. C. Richard Cassady, University of Arkansas

Richard Cassady is Director of the Freshman Engineering Program and Professor of Industrial Engineering at the University of Arkansas. As Director of Freshman Engineering, he is responsible for overseeing the development and operation of both the academic and student services components of this first-year experience program for College of Engineering students. This program was introduced during the 2007-2008 academic year. Dr. Cassady is an elected member of the University of Arkansas Teaching Academy, and he has received numerous teaching awards including the Charles and Nadine Baum Faculty Teaching Award from the University of Arkansas (2006) and the inaugural Imhoff Outstanding Teacher Award from the College of Engineering (2005). Dr. Cassady is a Fellow of SRE, a Senior Member of IIE, and a member of ASEE, Tau Beta Pi, and Alpha Pi Mu. Dr. Cassady received his B.S., M.S. and Ph.D., all in Industrial and Systems Engineering, from Virginia Tech.

The Wright State Model for Engineering Mathematics Education: Highlights from a CCLI Phase 3 Initiative, Volume 2

Abstract

The inability of incoming students to advance past the traditional first-year calculus sequence is a primary cause of attrition in engineering programs across the country. As a result, this paper will describe an NSF funded initiative at Wright State University to redefine the way engineering mathematics is taught, with the goal of increasing student retention, motivation and success in engineering. Since its inception in Fall of 2004, the Wright State model has had an overwhelming impact on the retention and success of engineering students at Wright State University. As part of a 2008 NSF CCLI Phase 3 initiative, various aspects of the Wright State model are now under pilot adoption and assessment at a total of 15 institutions across the country. Last year's paper highlighted progress at a subset of the Phase 3 institutions, including the details of their diverse implementations and a preliminary assessment of their results. This year's paper (Volume 2) will highlight progress at three additional institutions, including one flagship institution not even funded under the CCLI Phase 3 award.

Introduction - The Wright State Model for Engineering Mathematics Education

The traditional engineering curriculum requires at least one full year of calculus as a prerequisite to core sophomore-level engineering courses. However, only about 42% of incoming students who wish to pursue an engineering or computer science degree at Wright State University have traditionally advanced past the required first-year 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 past the traditional first-year calculus sequence plagues engineering programs across the country. As such, there is a drastic need for a proven model which eliminates the first-year mathematics bottleneck in the traditional engineering curriculum, yet can be readily adopted by engineering programs across the country. A nationwide expansion and assessment of precisely one such model is the focus of this work.

The Wright State model for engineering mathematics education involves three primary components:

1) The development of EGR 101 "Introductory Mathematics for Engineering Applications," a novel freshman-level engineering mathematics course.
2) A large-scale restructuring of the early engineering curriculum, where students can advance in the program without first completing the traditional freshman calculus sequence.
3) A more just-in-time structuring of the required math sequence.

The Wright State model begins with the development of EGR 101, a novel freshman engineering mathematics course. Taught by *engineering* faculty, the EGR 101 course includes lecture, laboratory and recitation components. Using an application-oriented, hands-on approach, EGR 101 addresses only the salient math topics *actually used* in the core sophomore-level engineering courses. These include the traditional physics, engineering mechanics, electric circuits and computer programming sequences. *More importantly, the EGR 101 course replaces traditional* *math prerequisite requirements for the above core courses, so that students can advance in the engineering curriculum without first completing the required calculus sequence.*

Over the course of a single 10 week quarter, the mathematical content of EGR 101 includes linear and quadratic equations, trigonometry, 2D vectors, complex numbers, sinusoids and harmonic signals, systems of equations and matrices, basics of differentiation, basics of integration, and linear differential equations with constant coefficients. All mathematical topics are 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 EGR 101 lecture sections are completely driven by problem-based learning, while the laboratory and recitation sections offer extensive collaborative learning among the students. As such, the course is strongly supported by the literature on how students learn[1-5].

The primary goal of EGR 101 is to facilitate a large-scale restructuring of the early engineering curriculum, where students can advance in the program without first completing the traditional freshman calculus sequence. As such, the introduction of EGR 101 in the Fall quarter was accompanied by a delay of Calc I until the Winter quarter, and a complete removal of Calc II and Calc III from the first-year curriculum. In addition, revised math prerequisite requirements for the core sophomore-level engineering courses (physics, engineering mechanics, circuits and computer programming) were submitted and approved by the University. In all cases, the words "or EGR 101" were appended to the traditional math prerequisite requirements. This automatically accounts for transfer and continuing students, who can advance in the program with either the traditional math sequence or the completion of EGR 101.

The Wright State model concludes with a more just-in-time structuring of the required math sequence, where students can satisfy traditional math requirements largely at their own pace. While the entire calculus sequence (Calc I-IV) is still required, it can be completed up to a full year later than in the traditional engineering curriculum. For example, students in Mechanical Engineering do not complete Calc IV until the first quarter of their junior year, which is much closer to the time when those topics are actually used in their upper level engineering courses. *The result is a substantially more flexible and accessible engineering curriculum for all students - and one that received the full 6-year ABET accreditation in 2006.*

The Wright State model was first implemented in Fall of 2004, and its effect on student retention, motivation and success in engineering has since been widely reported[6-23]. The recent introduction of EGR 100/199 for initially underprepared students has further strengthened the approach, and has made the core engineering curriculum immediately accessible to roughly 80% of incoming engineering students at Wright State University.[7] For a typical incoming class of 300 students, is estimated that introduction of EGR 101 and EGR 100/199 has resulted in the retention of at least 30 additional sophomores per year in the Wright State engineering programs.

It should be noted that the initial gains in first-year retention at Wright State University have now proven sustainable through graduation. For the incoming classes of Fall 2004, 2005 and 2006, the 4-year graduation rates for students who took EGR 101 averaged 23%, compared to less than 8% for those who did not take the course. And although only about 1/3 of the population ultimately enrolled in the course, the college-wide 4-year graduation rate increased by more than 4 percentage points - from an average of 10% over the prior 4 years to 14% for the 2004-2006 cohorts. This amounts to a 40% increase in the 4-year graduation rate. With the Fall 2007 implementation of EGR 100/199 for underprepared students, the proportion of the incoming class ultimately enrolled in EGR 101 has now reached a steady-state value of roughly 50% (the vast majority of the remaining population are CS/CEG majors, for which EGR 101 is not a required course). And while this increased enrollment in EGR 101 has consisted largely of initially underprepared students, the college-wide first-year retention rate reached a decade-high 70% in 2008-2009. It is expected that this will translate to further (if not proportional) increases in the college-wide graduation rate.

Highlights from a CCLI Phase 3 Initiative

A nationwide adoption and assessment of the Wright State model is now underway as part of a 2008 NSF CCLI Phase 3 award. The nationwide team includes 15 diverse institutions (primarily university but also at the high school and community college levels) representing strategic pockets of interest in some of our nation's most STEM critical regions. In addition to Ohio, these include Michigan, Texas, Oklahoma, California, Washington and Virginia. The dissemination component of the project has resulted in the addition of several unfunded collaborating instructions. All told, a total of 22 institutions spanning 8 different states have piloted aspects of the Wright State model for adoption at their own institutions, including 16 universities, 3 community colleges and 3 high schools. This section includes highlights from a small subset of these institutions, including two funded institutions (University of Toledo and Washington State University) as well as one unfunded institution (University of Arkansas).

University of Toledo:

Background: The University of Toledo (UT) College of Engineering provides six ABET-accredited undergraduate engineering science degree programs in Bioengineering, Chemical Engineering, Civil Engineering, Computer Science and Engineering, Electrical Engineering and Mechanical Engineering; and four ABET accredited Engineering Technology programs in Construction, Computer, Electrical and Mechanical Engineering Technology. All engineering science programs have a mandatory co-operative education component that requires a minimum of 3 semesters of co-operative work experience prior to graduation.

Over the past three years (Fall 2007 - Fall 2009), the average credentials of incoming engineering science students at UT include a composite ACT score of 25.8, an ACT mathematics score of 27.2, and a high school GPA of 3.66. Direct from high school (DHS) students must successfully complete a minimum of four years of high school mathematics (with coverage of trigonometry or precalculus) and high school chemistry for admission to an engineering science program. This population is typically successful in engineering science programs at UT: 75% of these students place directly into Calculus I (MATH 1850) or higher; first to second year retention for DHS students is 76% remaining in an engineering science degree program; and first to second year retention for DHS students is 89% remaining at UT.

Mathematics placement at UT is based on a combination of scores from the ACT mathematics section, plus institutional college algebra placement testing and trigonometry placement testing. DHS students with an ACT mathematics test score < 27 are required to take college algebra and trigonometry placement tests; DHS students with an ACT mathematics score ≥ 27 are only required to take the trigonometry placement test. Final placement into MATH 1850 is based on scores students are able to achieve on the college algebra and/or trigonometry placement tests. If not placed into MATH 1850, engineering science students are typically placed into MATH 1320 College Algebra, MATH 1330 Trigonometry or MATH 1340 College Algebra and Trigonometry based on the results of their placement test scores. Students with Advanced Placement (AP), International Baccalaureate (IB) or post-secondary credit for MATH 1850 can enroll directly into Calculus II (MATH 1860) regardless of placement testing results, if they choose to do so.

Given the success of typical students in engineering science programs, effort was focused on the 25% of the DHS population that does not qualify for direct entry in MATH 1850. This group typically has a lower average GPA in subsequent mathematics, physical sciences and core engineering coursework, and experiences a lower retention rate in engineering science degree programs. Furthermore, the mandatory co-op program adds a time constraint to the first and second year student schedules. In order to pursue their first co-op experience at the end of their second year, engineering science students must complete their mathematics, basic science and engineering core courses within their first four semesters. A typical sequence of these courses that adheres to prerequisite rules would include Calculus I → one or two semesters of Physics → Statics or Electric Circuits. Therefore students that do not place into MATH 1850 during their first semester will delay this course sequence and are unable to obtain co-op positions in the semesters for which it is scheduled.

To address the needs of those DHS students at UT that do not qualify for direct entry into MATH 1850, the Engineering Applications of Mathematics course was adapted from the EGR 101 course originally developed at Wright State University. The UT version of this course has four goals to address the needs of DHS students that are not placed directly into MATH 1850: 1) to improve their performance in their concurrent college algebra and trigonometry courses; 2) to improve their performance in subsequent calculus coursework; 3) to improve the retention of this group in engineering science degree programs; and 4) to insure these students are able to complete their degree programs on schedule.

Implementation: A modified version of the EGR 101 course has been offered at UT for four years (Fall 2007 - Fall 2010) to improve the performance of engineering science students in their first Calculus courses. This course is known as CIVE 2990 Engineering Applications of Mathematics at UT. The CIVE 2990 course consists of 3 hours of lecture with a 1 ¼ hour lab each week. The CIVE 2990 lecture content follows EGR 101, with lecture topics that introduce various applications of linear and quadratic equations, trigonometry, 2-D vectors, complex numbers, sinusoids, matrices, derivatives, integrals and ordinary differential equations.

The laboratory supports lecture materials with hands-on exercises including thermometer calibration for linear equations, two-link robot for trigonometry, sinusoid filtering, resistor networks for matrices, freefall for derivatives, center of mass for integrals, the leaking bucket for first order differential equations and the period of a pendulum for second order differential equations. Since most first year engineering students at UT are taking courses that introduce MATLAB, other engineering software packages including Excel, MathCAD and PSpice are introduced in CIVE 2990 instead.

This course is offered as an elective to improve the mathematics skills of engineering science students that do not place into MATH 1850 Calculus I. Because the CIVE 2990 course is not required for these students, two incentives have been offered to encourage enrollment. The first incentive is that any extra tuition incurred by taking this course is paid for from NSF grant funds. The second incentive is a waiver provided by the Physics department that allows students to enroll in PHYS 2130 Engineering Physics I concurrently with MATH 1850 if they successfully complete CIVE 2990. This was not only offered as an incentive, but it also helps achieve the goal of keeping students on schedule to complete basic science and core engineering coursework before they are scheduled to complete their first semester of co-op.

Preliminary Results and Discussion: Despite these incentives, approximately 10% of the students in the target audience have enrolled in CIVE 2990 over the past four years. A major reason for this low enrollment is that students and their advisors are hesitant to add extra coursework to students during their first semester in college, representing the second or third Math course in the same term. Another reason is the alternative of supplemental instruction offered by the Mathematics department. For students who do not place directly into MATH 1850, the Mathematics department offers a two-week long summer mathematics camp that provides students with the opportunity to retake MATH 1850 placement tests after they successfully complete this program. Approximately 20 – 30% of engineering science students that do not initially qualify for MATH 1850 choose to enroll in the summer mathematics camp.

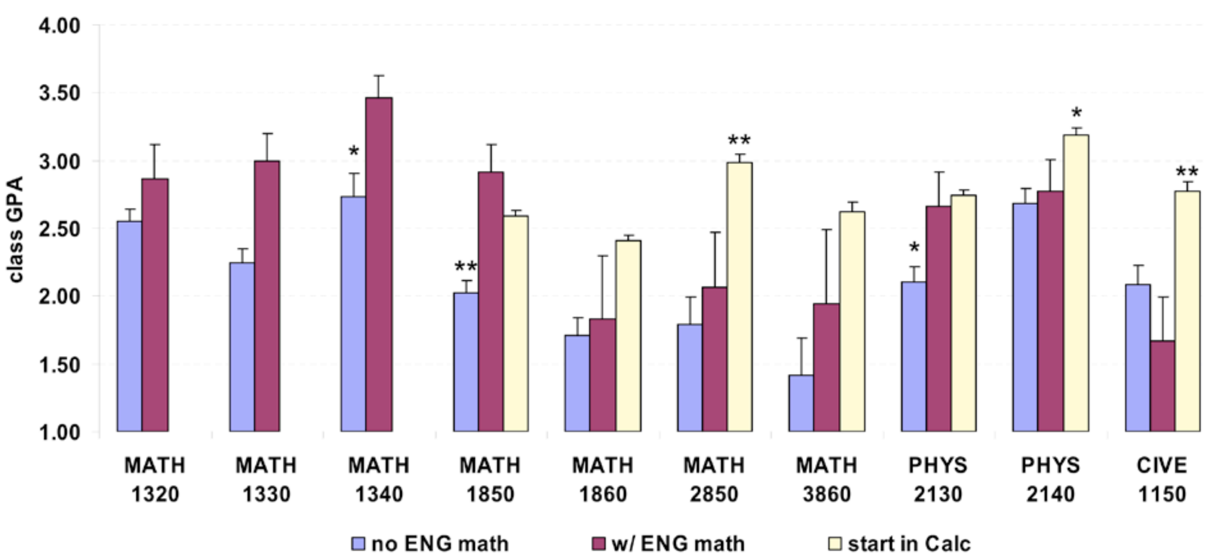

Figure UT-1: Student Performance in Subsequent Math and Engineering Coursework
(* $p < 0.05$, ** $p < 0.01$)

Despite the low enrollment, results suggest that the CIVE 2990 course does improve performance during concurrent and subsequent mathematics coursework. In particular, students enrolled in CIVE 2990 perform better in their concurrent pre-calculus coursework that may include MATH 1320 and/or MATH 1330; the improvement is significant ($p < 0.05$) for CIVE 2990 students enrolled in MATH 1340 (Figure UT-1). Furthermore, students who complete CIVE 2990 fare better in MATH 1850 than their counterparts that choose not to take CIVE 2990, performing as well as students that place directly into MATH 1850 and significantly better ($p < 0.01$) than their counterparts that choose not to take CIVE 2990. Results also showed CIVE 2990 students performed well in PHYS 2130 without taking MATH 1850 as a pre-requisite. CIVE 2990 students performed as well in PHYS 2130 as students that placed directly into MATH 1850 and significantly better ($p < 0.05$) than students that did not place into MATH 1850, did not take CIVE 2990 and could only take PHYS 2130 after completing MATH 1850.

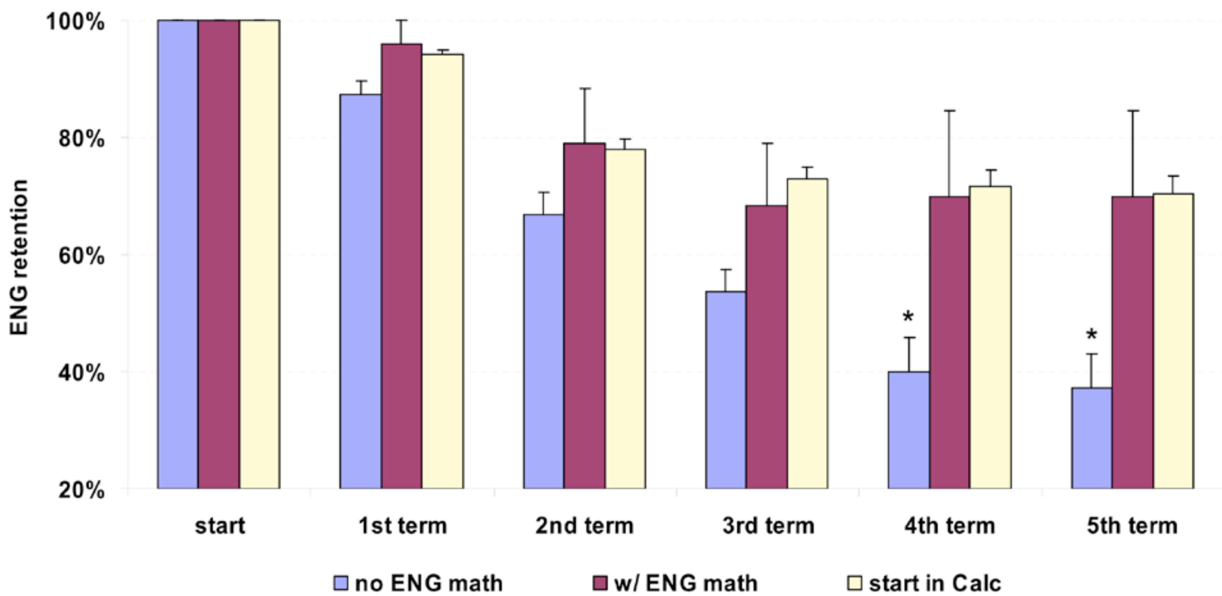

Figure UT-2: Impact of Engineering Math on Retention of UT Students
(* $p < 0.05$)

However, results also suggest that the boost CIVE 2990 students receive in MATH 1850 and PHYS 2130, both taken during the Spring semester after CIVE 2990 is completed, is not sustained in subsequent coursework taken two or more semesters after CIVE 2990. In particular, the improvement in MATH 1850 performance that is seen by students taking CIVE 2990 over those that choose not to take this course disappears in subsequent mathematics coursework including MATH 1860 Calculus II, MATH 2850 Multivariate Calculus and MATH 3860 Differential Equations (Figure UT-1). Furthermore, the gains in PHYS 2130 that CIVE 2990 students experience disappear in PHYS 2140 Engineering Physics II and CIVE 1150 Statics. Fortunately, this does not translate to poor retention, as CIVE 2990 students maintain retention rates equal to those that place directly into MATH 1850 and better than students that do not place directly into MATH 1850 and choose not to enroll in CIVE 2990 (Figure UT-2).

Results show that the UT implementation of the Wright State EGR 101 course provides short-term benefits for UT engineering science students as they proceed through their first Calculus and Physics courses, and provides long-term benefit for retention in engineering science programs. One concern in the interpretation of these results is that the CIVE 2990 group was self-selected, and any gains in their performance can be attributed to the nature of these students instead of any benefit offered by the CIVE 2990 course. However, the observation that any gains are temporary and their performance reverts back to levels obtained by a similar cohort of students that do not choose to enroll in CIVE 2990 suggests that these self-selected students are still similar to their peers. The temporary nature of these gains also suggests that there is a need for supplemental coursework or other support mechanisms to continue during subsequent semesters.

Efforts are underway to expand the population of students that take the CIVE 2990 course, given the improved MATH 1850 performance and improved retention of students enrolling in CIVE 2990 over the past few years. However, challenges to expanding enrollment in this course exist, given that the majority of UT engineering science students place into MATH 1850, and the Mathematics department has alternative pathways into MATH 1850. Current options include working with the Mathematics department to implement some of the course content into existing pre-calculus coursework, and creating a dual-level implementation of CIVE 2990 for high school seniors and first-year engineering science students.

Washington State University:

Background: Washington State University is a research-based, 4 year institution dedicated to the advancement of professional practice and the education of the next generation of leaders in innovation. In 2009 the university took part in the NSF CCLI Phase 3 initiative to combat the rise in engineering program attrition rates that has been recognized across the country. The engineering department at Washington State University currently employs 99 tenured/tenure track faculty members, educating approximately 2000 undergraduates across a wide array of engineering programs, including civil, environmental, mechanical, electrical, material science, chemical, and biological emphases. Of the undergraduates who begin college with the intention to pursue a degree in engineering, 67 percent regrettably leave the major, with 55 percent leaving within the first two years prior to certification. Whether due to the intimidation the first year rigors of calculus or the development of an improper foundation that makes the development of further understandings extremely difficult, there is a need for an adequate transition to develop a proper base of material knowledge in order to increase retention in the engineering program.

In the summer of 2009, the university slightly modified the material created by Wright State University and integrated some additional material from the textbook "Selected Material from Precalculus, Washington State University" by J. Coburn. Initially, the class (labeled as Engineering 107- Introductory Math for Engineering Application) was offered as a three week summer course which enrolled 8 students. After observing initial success in the course, in which 6 of the 8 students who initially were placed into pre-calculus or a lower math course placed into calculus after ENGR107 through a math placement exam, the course was adapted to the Fall schedule and taught in the Fall of 2010. Eligibility for ENGR 107 is determined based on the university math eligibility requirements for Math 107- Precalculus, from the highest score of student SAT, ACT, and ALEKS math placement scores. Exceptions were made for students that placed higher but who felt more comfortable in taking a "refresher" course before attempting college level calculus, as well as for students who place slightly lower than at the precalculus level. Enrollment was limited to students pursuing engineering, but did not distinguish between specific disciplines within engineering. In all cases, every effort was made by the engineering academic coordinators to correctly place students with adequate preparation into ENGR 107.

Washington State University aimed to also examine the effects of the ENGR107 experience on students' math self efficacy, primarily based on research findings relating the influence of math self efficacy to issues regarding retention. Math self efficacy, or a person's belief in their ability to successfully solve math problems or be successful in math courses, has been effectively tested in strictly math courses, but never an engineering application math course. Both quantitative surveys and qualitative interviews were administered at the beginning and end of ENGR 107 to gain an adequate interpretation of the courses potential effects on students' math self efficacy.

Implementation: The Fall 2010 implementation of ENGR 107 enrolled 27 students and consisted of two 1 hour lecture periods and one 3 hour lab period per week. The first 10 weeks of the 15 week course were dedicated to teaching pre-calculus concepts, including basic algebra operations, exponents, radicals, exponential and logarithmic functions, linear and quadratic equations, graphing functions, trigonometry, 2D vectors, systems of equations, and a brief introduction to sinusoids. At the end of 10 weeks the ALEKS placement test was administered to the students, after which the remainder of the course was focused on introducing students to calculus concepts of derivatives and integrals to provide a smooth transition for students in preparation for calculus the following semester.

Table WS-1: Laboratory Topics at Washington State

Lab 1-Exponential Growth and Decay	Sampling performed to model exponential growth; Basic cell and graphing functions of Excel
Lab 2-Application of Algebra in Engr.	Measuring current, voltage, and resistance in multiple circuits
Lab 3-Application of Trigonometry in Engr.	One-link and two-link robots; Right triangle properties; Law of sines/cosines
Lab 4-Statics	2D vectors; Systems of equations
Lab 5-Freefall Application of the Derivative	Relationship of position, velocity, and acceleration; Theoretical versus measured values
Lab 6-Spring Work Application of the Integral	Concepts of work and energy

The labs were arranged for the students to experience hands on application concurrent with the concepts they were learning in the lecture period of a given week. The labs consisted of six "application labs" (Table WS-1) and three "ALEKS labs." ALEKS is an online learning program that supplies instructors with resources to assign homework, quizzes, tests, and monitor student progress and areas that are in need of improvement and is an intelligent testing system used for math placement at WSU. The "ALEKS labs" were designed to increase students' familiarity with the workings of the program and provide them with practice problems relevant to the course topics covered prior to each lab. The ALEKS test for preparedness for calculus has become a standard for eligibility at Washington State University and was therefore required of ENGR 107 students to determine their math placement for the following semester. Following the placement test, 89 percent (24 out of 27) of the ENGR 107 students tested into calculus. The students who tested lower were given the option to retake the exam the following week. Students failing to test into calculus were required to enroll in a math course based on university enrollment criteria. It is the goal of this course that completion of ENGR 107 with a C grade or better will ultimately serve as the single determinate of placement into calculus, without the current need for retaking the ALEKS placement exam. This will allow for more flexibility in development of the curriculum for engineering preparedness, and less on the skills of precalculus.

Preliminary Results and Discussion: During the final week of the course students were asked to complete a short survey about their experiences of how useful they found the course. They responded to the questions on a scale from 5-strongly agree to 1-strongly disagree, as shown in Table WS-2 below. The average score for each question depicts a high degree of students in "agreement" with each question, with at least 96.3 percent of the students answering "neutral" or above for questions 1-4. Overall students interpreted the course as a good transition into calculus. The engineering application problems were well received, allowing them to see real world application of the math concepts they had learned.

Table WS-2: Results of Student Survey

	Strongly Agree 5	Agree 4	Neutral 3	Disagree 2	Strongly Disagree 1	Avg
1. This course has increased my motivation to study engineering.	5	13	8	1	0	3.8
2. This course has increased my chances of success in engineering.	7	15	5	0	0	4.1
3. This course has increased my motivation to study math.	4	14	8	1	0	3.8
4. This course has increased my chances of success in future math courses.	10	13	3	1	0	4.2
5. The lab sections aided my understanding of the lecture material.	1	15	5	6	0	3.4

Mathematics self-efficacy was also examined using qualitative and quantitative pre and post-ENGR 107 measures. Students were interviewed before and after the course. Preliminary interviews focused on students' math backgrounds and confidence in their math abilities. Post course interviews focused on students' perceived value of the course overall and on their development of beliefs to be successful in college math. Pre and post-surveys were identical and consisted of two scales, one listing 18 math problems relevant to pre-calculus and the second including seven college level math courses. Courses listed include algebra, geometry and calculus. For all questions students were asked to rate their confidence in solving the problem or successfully completing the class on a scale from 1-9. All scales were evaluated for internal reliability and found to be reasonable internally consistent (Alpha coefficient 0.6 to 0.9). Comparisons were made between pre and post results. The average problem solving self-efficacy increased from 7.3 to 7.5 and was not statistically significant. This is not unexpected due to very high initial self-ratings. Additionally, it is believed that students may have had unfounded high levels of confidence to solve these problems. Course self-efficacy increased from 6.1 to 7.0 and was significant at the 0.00 level.

Initial examination of students' qualitative interview responses regarding the effects of the class on their math self efficacy indicated the following convergent findings across the majority of students:

1. Students interpreted their experience with the class as a personal success.
2. The students' math self efficacy increased as a result of ENGR 107
3. ENGR 107 increased students' confidence in their preparedness for calculus

Student descriptions of influential aspects of the course identified the classes benefit to reinforcing mathematic concepts previously learned while simultaneously introducing them within real world engineering applications. One student noted the added benefit over a strictly math course, saying "I feel like Engineering 107 is better than Math 107 because Math 107 will teach you the math you need. But Engineering 107 will teach that math and then apply it to a concept so you can like get a real world application for it." These results corroborate the students' feedback of the immense improvements made as a result of the course. As a result, students strongly recommended ENGR 107 to future students as a well developed "transition" class between math at the high school and college level, noting that "it's a good class to prepare yourself for calculus if you don't feel like you're ready to go straight into it."

<u>University of Arkansas</u>:

Background: The University of Arkansas, Fayetteville, is a land-grant institution and the flagship university for the State of Arkansas. The College of Engineering at the University of Arkansas includes seven academic departments that offer a total of eight undergraduate degrees, as well as a number of graduate degrees (including the Ph.D. in Engineering). Almost all (more than 90%) University of Arkansas new freshmen who enroll in the College of Engineering participate in the Freshman Engineering Program.

The Freshman Engineering Program is a two-semester, thirty-credit-hour program, and 400-600 first-year engineering students participate in this program each year. Since the creation of the Freshman Engineering Program in the Fall Semester of 2007, retention to the second year of first-year engineering students at the University of Arkansas has increased from approximately 60% to approximately 70%. However, students who are not calculus-ready upon entry to the university still struggle to progress into and through the traditional calculus course sequence in a reasonable amount of time.

With the goal of improving the math performance of non-calculus-ready students, the Freshman Engineering Program implemented a new course in the Fall Semester of 2010. The course, GNEG 1513: Engineering Applications of Mathematics, was developed using the materials created by Wright State University in support of EGR 101 and EGR 199 and the materials used by the University of Arkansas Department of Mathematical Sciences in developing the university's series of math placement tests.

Implementation: During 2010 New Student Orientation, new engineering students who qualified for Precalculus Mathematics were given information about and the opportunity to enroll in GNEG 1513 (instead of MATH 1284: Precalculus Mathematics). Ultimately, 51 students (49 of whom were not calculus-ready) elected to enroll in the pilot offering of GNEG 1513. The pilot offering was taught in two sections, with each section including two 80-minute lectures per week (no laboratory). The engineering topics included all the topics covered in EGR 101 at Wright State University except for integration and differential equations. In addition to the engineering topics, approximately 35% of class time was dedicated to a review of the math skills included in the university's math placement tests. Students were assessed using traditional homework assignments and exams; 50 of the 51 students completed the course (one withdrew from all classes due to family issues) with a grade of D or better.

The Department of Mathematical Sciences has not yet decided to accept GNEG 1513 as a prerequisite to the calculus sequence. Therefore, the students in our pilot offering were required to successfully complete the series of math placement tests to enroll in MATH 2554: Calculus I for the Spring Semester of 2011. The university's series of math placement tests is such that the student must pass three tests (PALG: a pre-algebra test, MALG: an algebra test, and PCAL: a precalculus test) to gain entry into MATH 2554. Students who have a ACT Mathematics score of 30 or better (SAT equivalent is 680 or better) or college credit for MATH 1284 are exempted from the math placement test.

Preliminary Results and Discussion: Of the 50 students who completed the pilot offering of GNEG 1513:

- 26 were enrolled in MATH 2554 Calculus I for the Spring Semester of 2011
- 10 were enrolled in MATH 1284 Precalculus Mathematics for the Spring Semester of 2011
- 6 were still majoring in engineering but were not enrolled for any math class in the Spring Semester of 2011
- 7 have changed their major to something that does not require calculus
- 1 is no longer enrolled at the University of Arkansas

The students who completed the pilot offering of GNEG 1513 were also asked to complete a survey about the course. In addition to a set of standard items, the survey gave students the opportunity to critique the course in a free response manner. The only complaint that was repeated multiple times was that the students did not like being required to retake the series of math placement tests. The standard survey items and a summary of the responses to each item can be found in Table UA-1.

Based on our experiences with the pilot offering of GNEG 1513, as well as the comments from the students who participated in the pilot offering, we revised our course materials in preparation for a second offering of GNEG 1513 in the Spring Semester of 2011 (29 students are currently enrolled). We are also closely monitoring the performance of our pilot students who are enrolled in Calculus I this semester with the hope that their performance leads the Department of Mathematical Sciences to consider GNEG 1513 as an acceptable prerequisite for the calculus sequence.

Table UA-1: Results of Student Survey

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
This course has increased my motivation to study engineering.	21%	38%	23%	13%	6%
This course has increased my chances of success in engineering.	29%	33%	23%	10%	4%
This course has increased my motivation to study math.	15%	31%	48%	4%	2%
This course has increased my chances of success in future math courses.	17%	52%	15%	13%	4%

Summary

The Wright State model for engineering mathematics education seeks to increase student retention, motivation and success in engineering by removing the first-year bottleneck associated with the traditional freshman calculus sequence. The approach includes the development of a novel freshman engineering mathematics course EGR 101, along with a substantial restructuring of the early engineering curriculum. This has been further strengthened by the introduction EGR 100/199 as a precursor to EGR 101 for initially underprepared students. The Wright State model is designed to be readily adopted by any university employing a traditional engineering curriculum, and proposes an immediate solution to math-related attrition in engineering. The approach has already had a dramatic impact on student retention, motivation and success in engineering at Wright State University, and is now being piloted by at least 22 institutions across the country. This paper has included highlights from three of these institutions, whose preliminary results seem to support the widespread transferability of the approach. In particular, significant gains in both first-year retention and student performance in the first calculus course have been reported by the University of Toledo, which is in agreement with results first reported by Wright State University. The initial implementation and assessment at Washington State University has further demonstrated measurable gains in student mathematics self-efficacy. Finally, course surveys at all collaborating institutions to date have indicated a positive impact on student perception, including an increased motivation to study both math and engineering, as well as an increased chance of success in future math and engineering courses. This includes the University of Arkansas, which is the first flagship institution to pilot aspects of the program without funding from either Wright State University or NSF.

Acknowledgments

This work has been supported by the NSF Division of Engineering Education and Centers under grant number EEC-0343214 (Department-Level Reform Program), by the NSF Division of Undergraduate Education under grant numbers DUE-0618571 (CCLI Phase 2), DUE-0622466 (STEP Type 1) and DUE-0817332 (CCLI Phase 3), and by a Teaching Enhancement Fund grant at Wright State University. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or Wright State University.

Program Information

More information on the Wright State model for engineering mathematics education (including all course materials for EGR 101) can be found on the program website: http://www.engineering.wright.edu/cecs/engmath/

Bibliography

1. Kerr, A.D., and Pipes, R.B., 1987. "Why We Need Hands-On Engineering Education." *The Journal of Technology Review*, Vol. 90, No. 7, p. 38.

2. Sarasin, L., 1998, "Learning Style Perspectives: Impact in the Classroom." *Madison, WI*: Atwood.

3. Gardner, H., 1999. "Intelligence Reframed: Multiple Intelligences for the 21st Century." *New York: Basic Books.*

4. Joyce, B., and Weil, M., 2000, "Models of Teaching." *Boston*: Allyn and Bacon.

5. Brandford, J.D., *et al*., Eds., "How People Learn: Brain, Mind, Experience and School," Expanded Edition, *National Academy of Sciences*, 2000.

6. Klingbeil, N., Newberry, B., Donaldson, A. and Ozdogan, J., 2010, "The Wright State Model for Engineering Mathematics Education: Highlights from a CCLI Phase 3 Initiative," *Proceedings 2010 ASEE Annual Conference & Exposition*, Louisville, KY, June 2010.

7. Klingbeil, N., Rattan, K., Raymer, M., Reynolds, D. and Mercer, R., 2009, "The Wright State Model for Engineering Mathematics Education: A Nationwide Adoption, Assessment and Evaluation," *Proceedings 2009 ASEE Annual Conference & Exposition,* Austin, TX, June, 2009.

8. Klingbeil, N., Rattan, K., Raymer, M., Reynolds, D., Mercer, R., Kukreti, A. and Randolph, B., 2008, "The WSU Model for Engineering Mathematics Education: A Multiyear Assessment and Expansion to Collaborating Institutions," *Proceedings 2008 ASEE Annual Conference & Exposition,* Pittsburgh, PA, June, 2008.

9. Klingbeil, N., Rattan, K., Raymer, M., Reynolds, D., Mercer, R., Kukreti, A. and Randolph, B., 2007, "A National Model for Engineering Mathematics Education," *Proceedings 2007 ASEE Annual Conference & Exposition,* Honolulu, HI, June, 2007.

10. Wheatly, M., Klingbeil, N., Jang, B, Sehi, G. and Jones, R., "Gateway into First-Year STEM Curricula: A Community College/University Collaboration Promoting Retention and Articulation," *Proceedings 2007 ASEE Annual Conference & Exposition,* Honolulu, HI, June, 2007.

11. Klingbeil, N.W., Mercer, R.E., Rattan, K.S., Raymer M.L. and Reynolds, D.B., 2006, "Redefining Engineering Mathematics Education at Wright State University," *Proceedings 2006 ASEE Annual Conference & Exposition*, Chicago, IL, June 2006.

12. Klingbeil, N.W., Mercer, R.E., Rattan, K.S., Raymer, M.L. and Reynolds, D.B., 2006, "The WSU Model for Engineering Mathematics Education: Student Performance, Perception and Retention in Year One," *Proceedings 2006 ASEE Illinois-Indiana and North Central Conference,* Fort Wayne, IN, April 2006.

13. Klingbeil, N.W., Mercer, R.E., Rattan, K.S., Raymer, M.L. and Reynolds, D.B., 2005, "Work-in-Progress: The WSU Model for Engineering Mathematics Education," *Proceedings 2005 Frontiers in Education Conference,* Indianapolis, IN, October, 2005.

14. Klingbeil, N.W., Mercer, R.E., Rattan, K.S., Raymer, M.L. and Reynolds, D.B., 2005, "The WSU Model for Engineering Mathematics Education," *Proceedings 2005 ASEE Annual Conference & Exposition,* Portland, Oregon, June, 2005.

15. Klingbeil, N.W., Mercer, R.E., Rattan, K.S., Raymer M.L. and Reynolds, D.B., 2005, "Redefining Engineering Mathematics Education at Wright State University, " *Proceedings 2005 ASEE North Central Conference*, Ada, Ohio, April 2005.

16. Klingbeil, N.W., Mercer, R.E., Rattan, K.S., Raymer, M.L. and Reynolds, D.B., 2004, "Rethinking Engineering Mathematics Education: A Model for Increased Retention, Motivation and Success in Engineering." *Proceedings 2004 ASEE Annual Conference & Exposition*, Salt Lake City, Utah, June 2004.

17. Klingbeil, N.W., Mercer, R.E., Rattan, K.S., Raymer M.L. and Reynolds, D.B., "The Wright State Model for Engineering Mathematics Education: Uncorking the First-Year Bottleneck," *A Dialogue on Engineering Education II: The Role of the First Year*, ASEE First Year Engineering Workshop, Notre Dame, IN, July 2007.

18. Klingbeil, N.W., Mercer, R.E., Rattan, K.S., Raymer M.L. and Reynolds, D.B., "A National Model for Engineering Mathematics Education," *ASEE Southeastern Section Conference*, Louisville, KY, April 2007.

19. Wheatly, M., Klingbeil, N., Jang, B., Sehi, G. and Jones, R., "Gateway into First-Year STEM Curricula: A Community College/University Collaboration Promoting Retention and Articulation," *ASEE Southeastern Section Conference*, Louisville, KY, April 2007.

20. Klingbeil, N.W., "The WSU Model for Engineering Mathematics Education: Increasing Student Retention, Motivation and Success in Engineering," Keynote Address, *Texas Engineering and Technical Consortium Best Practices Conference*, University of Texas at Austin, March 2007.

21. Klingbeil, N.W., Mercer, R.E., Rattan, K.S., Raymer M.L. and Reynolds, D.B., "Engineering Mathematics Education at Wright State University: Uncorking the First-Year Bottleneck," *26th Annual Conference on the First-Year Experience*, National Resource Center for the First-Year Experience & Students in Transition, Addison, TX, February 2007.

22. Klingbeil, N.W., Mercer, R.E., Rattan, K.S., Raymer M.L. and Reynolds, D.B., "Redefining Engineering Mathematics Education at Wright State University," *A Dialogue on Engineering Education: The Role of the First Year*, ASEE First Year Engineering Workshop, Notre Dame, IN, July 2006.

23. Klingbeil, N.W., Mercer, R.E., Rattan, K.S., Raymer M.L. and Reynolds, D.B., "Redefining Engineering Mathematics Education at Wright State University," *Ohio Council of Teachers of Mathematics Conference*, Dayton, OH, October 2005.