# AC 2009-1416: THE WRIGHT STATE MODEL FOR ENGINEERING MATHEMATICS EDUCATION: A NATIONWIDE ADOPTION, ASSESSMENT AND EVALUATION

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# The Wright State Model for Engineering Mathematics Education: A Nationwide Adoption, Assessment and Evaluation

**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. This paper will provide a brief overview of the WSU model for engineering mathematics education, including its impact on student retention and success. It will also summarize the scope of a 2008 NSF CCLI Phase 3 award, which includes pilot adoption and assessment of the WSU model by a total of 15 institutions across the country.

## Introduction

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 WSU model for engineering mathematics education involves the introduction of a novel freshman engineering mathematics course EGR 101, along with a substantial restructuring of the early engineering curriculum. 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 entry-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.* The result has shifted the traditional emphasis on math prerequisite requirements to an emphasis on *engineering motivation* for math, with a just-in-time structuring of the required math sequence.

The WSU model was first implemented in 2004, and its effect on student retention, motivation and success has since been widely reported[1-16]. The current paper includes significant updates since the approach was last reported one year ago, including first-year retention results following the recent introduction of EGR 100 as a precursor to EGR 101 for initially underprepared

students. It will also summarize the scope of a recent NSF CCLI Phase 3 award, which includes pilot adoption and assessment of the WSU model by a total of 15 institutions across the country. *The goal of this initiative is to effect a transformative and nationwide change in the way engineering mathematics is taught.*

**The WSU Model**

This section provides an overview of the WSU model for engineering mathematics education, which involves three primary components: 1) The development of EGR 101, a novel freshman-level engineering mathematics course; 2) A large-scale restructuring of the engineering curriculum, where students can advance in the program without having completed a traditional freshman calculus sequence; 3) The development of a revised engineering mathematics sequence, offered later in the curriculum in a more just-in-time fashion.

EGR 101, "Introductory Mathematics for Engineering Applications"

The WSU model begins with the development of EGR 101, a novel freshman-level engineering mathematics course. *The goal of EGR 101 is to address only the salient mathematics topics actually used in the primary core engineering courses, thereby fulfilling math prerequisite requirements within the context of a single course.* This opens the door for students to advance in the engineering curriculum without first completing the traditional calculus sequence. The course content consists of the mathematical prerequisites for the following core engineering courses: PHY 240 (General Physics I), ME 212 (Statics), ME 213 (Dynamics), ME 313 (Strength of Materials), EE 301 (Circuit Analysis I), CEG 220 (C Programming), and EGR 153 (Fortran Programming). In the traditional curriculum, all of these courses require a minimum of Calculus I, while some require Calculus I-III and Differential Equations. However, only a handful of topics from these traditional math courses are actually applied in the above core engineering courses. Moreover, the above core courses also include engineering mathematics concepts not found in the traditional calculus sequence, including basic operations in vectors, complex numbers and matrix algebra.

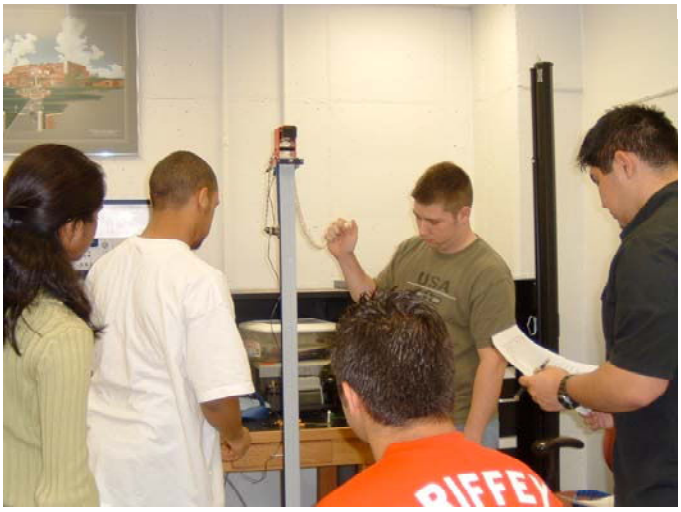

**Figure 1. Derivative Lab**

After consultation with faculty from around the College, the following topics were slated for inclusion in EGR 101: Linear and Quadratic Equations; Trigonometry; 2-D Vectors; Complex Numbers; Sinusoids and Harmonic Signals; Systems of Equations and Matrices; Basics of Differentiation; Basics of Integration; Linear Differential Equations with Constant Coefficients.

The course is taught by engineering faculty, with all mathematical topics motivated by their direct application in the core engineering courses. Moreover, course material is emphasized by *physical* experiments in the classroom and laboratory, and is thoroughly integrated with the engineering analysis software Matlab.

The EGR 101 course structure includes lecture, laboratory and recitation sections. The 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*[17-21].

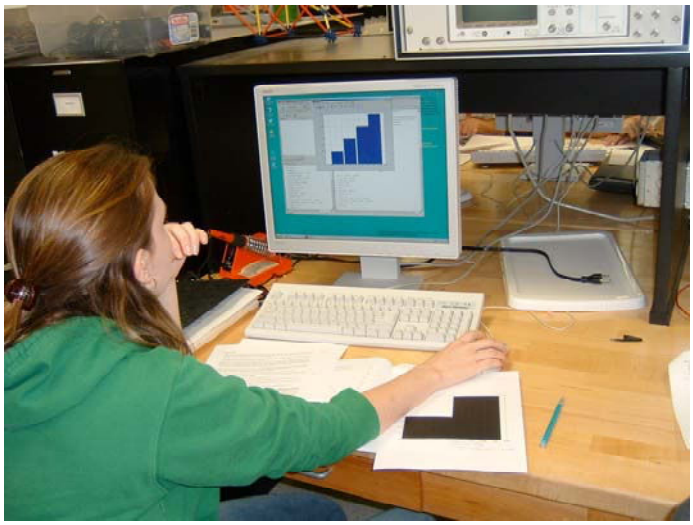

**Figure 2. Integral Lab**

Excerpts from the EGR 101 laboratory are shown in Figs. 1-2. Indeed, physical *measurement* of the derivative as the velocity in free-fall (Fig. 1), or of the integral as the area under the force-deflection curve (Fig. 2), provides a much greater conceptual understanding of the mathematical concepts than classroom lecture alone. The prerequisite requirement for incoming students to register for EGR 101 is a minimum mathematics background in Trigonometry, as indicated by a combination of math placement level (MPL) 5 and high school transcripts, or by the completion of MTH 131 Trigonometry at WSU. *This makes the core engineering curriculum immediately accessible to incoming students who are calculus-ready, as well as to those with a math placement level one course behind Calculus I.*

Restructured Curriculum

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 having completed a traditional freshman calculus sequence. In order to emphasize the need for the proposed curriculum changes, the traditional freshman year curriculum for Mechanical Engineering is shown in Table 1. In order to advance into their sophomore years, students are expected to complete MTH 229 Calc I, MTH 230 Calc II and MTH 231 Calc III during their first three quarters at the University. This is the case for the remainder of engineering majors in the College, and is standard practice in engineering programs across the country. *No wonder students who struggle in calculus end up switching majors!*

The restructured alternative to the traditional freshman year curriculum is shown in Table 2. The EGR 101 course appears immediately in the Fall quarter. However, the course runs every quarter, so that those students who do not immediately qualify for EGR 101 can register as soon as they complete the necessary math background (Trigonometry). In addition, the only traditional calculus course remaining in the freshman year is MTH 229 Calc I, which has been

moved to the Winter quarter (i.e., following the completion of EGR 101). *It should be noted that because EGR 101 is now the only math prerequisite for the core sophomore-level engineering courses, students who are not immediately successful in MTH 229 Calc I can still advance in their intended engineering programs.*

**Table 1. Traditional Freshman Year (Mechanical Engineering)**

| **Fall Quarter** | | **Winter Quarter** | | **Spring Quarter** | |
|---|---|---|---|---|---|
| ENG 101 | 4 | ENG 102 | 4 | ME 199 | 3 |
| EGR 190 | 4 | EGR 153/CEG 220 | 4 | PHY 240 | 5 |
| CHM 121 | 5 | GE | 4 | GE | 4 |
| MTH 229 Calc I* | 5 | MTH 230 Calc II* | 5 | MTH 231 Calc III* | 5 |
| | 18 | | 17 | | 17 |

* Traditional freshman calculus sequence

**Table 2. Restructured Freshman Year (Mechanical Engineering)**

| **Fall Quarter** | | **Winter Quarter** | | **Spring Quarter** | |
|---|---|---|---|---|---|
| ENG 101 | 4 | ENG 102 | 4 | ME 199 | 3 |
| EGR 190 | 4 | EGR 153/CEG 220 | 4 | PHY 240 | 5 |
| CHM 121 | 5 | MTH 229 Calc I ** | 5 | GE | 4 |
| EGR 101* | 5 | ME 220 | 3 | ME 202 | 4 |
| | 18 | | 16 | | 16 |

* New freshman engineering mathematics course

** Only traditional calculus course in the freshman year, with separate sections for engineers

While Tables 1 and 2 are specific to Mechanical Engineering (ME), similar changes have been made for degree programs across the College of Engineering and Computer Science (CECS), including Materials Science and Engineering (MSE), Electrical Engineering (EE), Engineering Physics (EP), Biomedical Engineering (BME), and Industrial and Systems Engineering (ISE). In addition, revised math prerequisite requirements for the core sophomore-level engineering and physics courses previously summarized have been submitted and approved by the University. In all cases, the words "or EGR 101" have been 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 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!*

Revised Math Sequence

While EGR 101 provides an introduction to the salient math topics required to progress in the engineering curriculum, it is not intended to be a replacement for the calculus sequence and other traditional mathematics courses. As previously described, Calc I is part of the freshman curriculum, with the remaining courses delayed until the sophomore and junior years. The exact locations of the remaining courses are specific to each major in the College, as determined at the Department level. In Mechanical Engineering, Calc II and III now occur in the sophomore year, while Calc IV is reserved for the first quarter of junior year. In addition, the traditional

Differential Equations and Matrix Algebra courses have been combined into a single 5-hour course, "MTH 235 Differential Equations with Matrix Algebra," offered during the sophomore year. This has recovered 3 of the 5 additional credit hours associated with the introduction of EGR 101, with the remaining 2 credit hours absorbed by the various degree programs. *Coupled with the restructured program guides previously described, the result of the new math sequence is a more just-in-time, application-oriented approach to engineering mathematics.*

**Impact on Student Retention and Success**

As shown in Fig. 3, the initial implementation of the program in Fall, 2004 had a dramatic effect on first-year retention in engineering at WSU. Every department requiring EGR 101 saw an

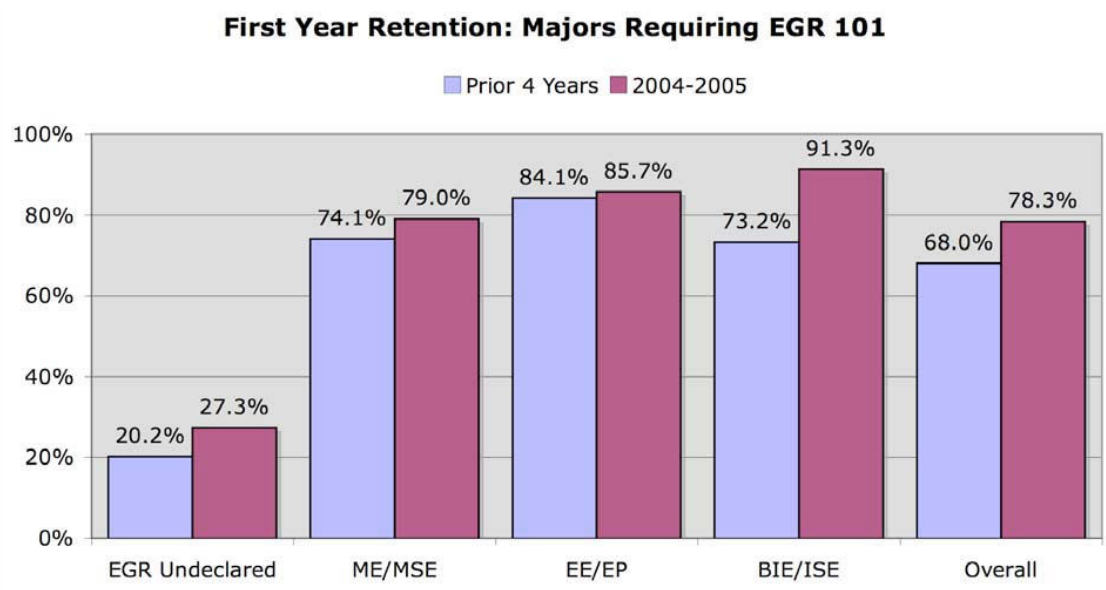


**Figure 3. First-Year Retention for Majors Requiring EGR 101**

increase in first-year retention in 2004-2005, as compared to baseline data averaged over the prior four years. Overall, majors requiring EGR 101 saw first-year retention increase from 68.0% to 78.3%. For this particular incoming class, this corresponds to about 15 additional sophomores in engineering.

In addition to first-year retention, EGR 101 and the associated just-in-time structuring of the required math sequence have had a significant impact on student performance in calculus. Of the students ultimately enrolled in Calc I, 89% of those who had formerly taken EGR 101 earned a "C" or better, compared to only 60% of those who had not.

The above result has undoubtedly contributed to increased student persistence through the first two years of their programs. In particular, Figure 4 shows two-year retention for majors requiring EGR 101, sorted by those who took the course and those who did not. Clearly, students who took EGR 101 at any time during their first two years had an enormous advantage, with a

two-year retention rate of 75.6%, compared to only 23.0% for those who did not. One reason for such a large discrepancy is that many of those students who did not take the course were simply too far behind in math, which substantially decreased their likelihood of success. However, a significant number of initially underprepared students did eventually take the course, and realized a similar advantage[1].

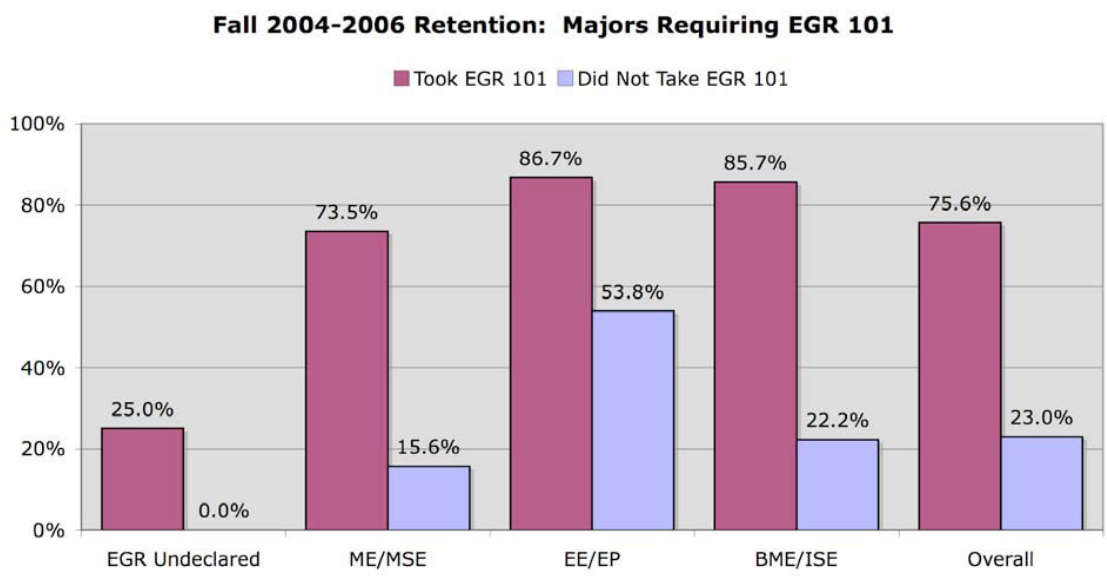


**Figure 4. Two-Year Retention for Majors Requiring EGR 101**

**Introduction of EGR 100 for Initially Underprepared Students**

While the introduction of EGR 101 has had a dramatic effect on student retention and success in engineering, the course is only immediately accessible to incoming students with math placement in trigonometry, which corresponds to a WSU math placement level (MPL) of 5. Since our average incoming student has an MPL of around 4.3, our revised curriculum was still not immediately accessible to our AVERAGE incoming student. Moreover, roughly half of the college's incoming enrollment consists of computer science and engineering (CS/CEG) majors, for whom EGR 101 is not a required course. As a result, a multiyear assessment of the program revealed that only about 1/3 of our incoming students were ever taking EGR 101.

As a result of this finding, we have recently developed EGR 100 "Preparatory Mathematics for Engineering and Computer Science," the inaugural offering of which enrolled over one hundred MPL 3 and 4 students in Fall, 2007 (under temporary course number EGR 199). These students are two or three classes behind Calc I (which requires an MPL 7) and are not immediately eligible for EGR 101. Assessment has shown that MPL 3 and 4 students make up about 1/3 of our college's incoming students, and that only about 30% of them are retained in engineering and computer science through their first two years.

The EGR 100/199 course content consists entirely of high school math, from algebra through trigonometry, but with all topics presented in the context of their application in core engineering and computer science courses. The EGR 100/199 course serves the following two purposes:

1. For majors requiring EGR 101, EGR 100/199 serves as an alternative prerequisite requirement, which allows MPL 3 and 4 students to enroll in EGR 101 and begin advancement in their chosen degree programs as early as their second quarter at WSU.

2. For all CECS majors (including CS/CEG), EGR 100/199 provides a comprehensive review of high school math topics, and culminates in a retest of the math placement exam at the end of the quarter. *This provides an opportunity for initially underprepared students to avoid as many as 3 remedial math department courses before advancing in their chosen degree programs.*

Following the Fall 2007 offering of EGR 100/199, over half of the enrolled students increased their MPL score at the end of the quarter, some by as many as 3 levels. Roughly 30% of the students remained at the same MPL level, while a small number either decreased their MPL score or failed to retake the exam.

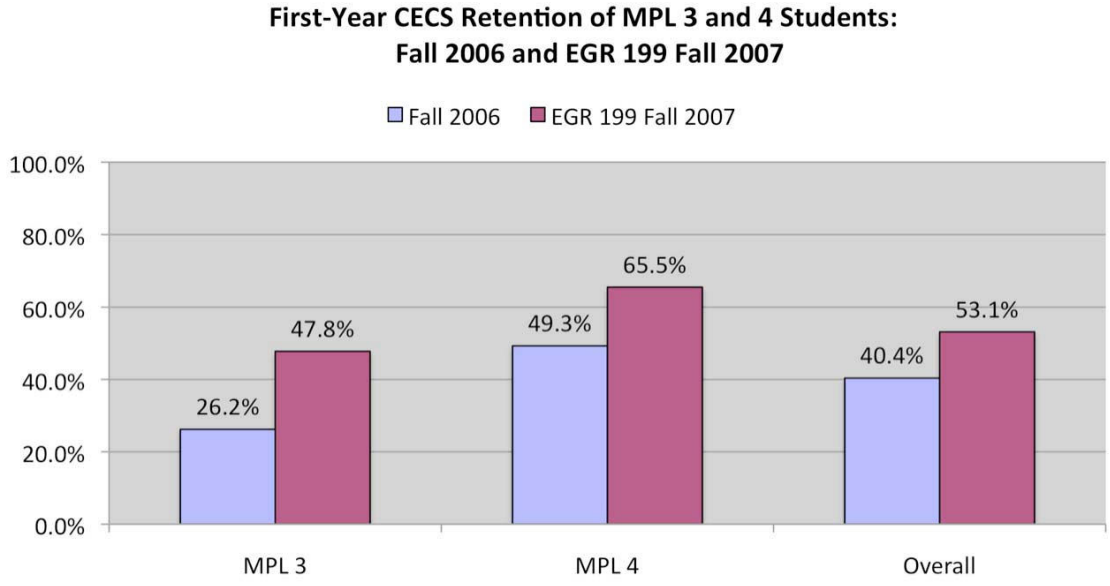


**Figure 5. Effect of EGR 100/199 on First-Year Retention of Underprepared Students**

In the traditional curriculum, students entering at an MPL 3 would have been required to take MTH 126, MTH 130 and MTH 131 before even beginning the required calculus sequence. Assuming they were still around, those same students would not likely be enrolled in EGR 101 until the beginning of their second year. With the introduction of EGR 100/199, students entering at an MPL 3 can enroll in EGR 101 the very next quarter, regardless of whether they improve their MPL score. As a result, the 2007-2008 enrollment in EGR 101 was up by more than 75 students compared to prior years. The majority of these additional students came in at an MPL 3 or 4, and in prior years may have never even made it to EGR 101.

The resulting impact on first-year retention is shown in Figure 5. As compared to the prior year, the Fall 2007 implementation of EGR 100/199 nearly doubled the first-year retention rate of

MPL 3 students, and had a significant impact on MPL 4 students as well. Overall, the first-year retention rate for MPL 3 and 4 students increased from 40.4% to 53.1%.

In conjunction with EGR 101, the introduction of EGR 100/199 has resulted in an engineering curriculum which is now immediately accessible to roughly 80% of the college's intending majors. This is in contrast to the traditional starting point of Calculus I, which is only accessible to roughly 20% of our incoming students. For a typical incoming class of roughly 300 students, it is estimated that the combined implementation of EGR 101 and EGR 100/199 has resulted in at least 30 additional sophomores per year in the WSU engineering programs.

**A Nationwide Adoption, Assessment and Evaluation**

A nationwide expansion of the WSU 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. Using similar methodologies to those employed at $WSU^2$, formative and summative assessment at each institution will include a combination of qualitative and quantitative measures of student retention, motivation and success in engineering. Results from each institution will be consolidated and externally evaluated by a national expert in engineering education. What follows is a brief summary of the specific activities now underway at each institution.

California Baptist University: California Baptist University (CBU) will adapt the WSU model with the following objectives: 1) To develop a semester model with additional lab modules. 2) To compare the results of two simultaneous tracks of students that merge in their sophomore year classes. Namely track one 'T1': students who either completed calculus at other institutions or who took calculus their first year at CBU, and track two 'T2': students who had a beta version of EGR 101. 3) To compare the results of students having refined and improved EGR 101 with the pilot year. 4) To use the above to guide the development of adapting a large portion of the traditional Math sequence into a "plug and play", just in time, teaching of mathematics into specific core engineering courses and physics courses their sophomore year. 5) To develop and teach a version of EGR 101 suitable for summer camps for the large home school and ethnic populations in our area. 6) To begin discussions about the development of an 'Asian context' version of EGR 101 at Yanbian University of Science and Technology or 'YUST'. Quantitative and qualitative assessment will be conducted throughout, following the methods employed at WSU.

California State University- Long Beach: California State University - Long Beach (CSULB) will examine the content of WSU's EGR 101 course and determine the degree to which it addresses their own curricular barriers to student success. While a large portion of the existing course materials are expected to be of interest, the pilot implementation of the course will be structured to address precisely the educational needs of their diverse enrollment. It should be noted that the CSULB Engineering College has a center designated specifically for Recruitment and Retention. In addition, each undergraduate program has at least one dedicated advisor. Data obtained from the pilot offering of the CSULB implementation of EGR 101 will be shared with

this group so that the subsequent success of participating students will be monitored. *With CSULB's designation as a Hispanic Serving Institution, they will also be able reach a large number of underrepresented minorities.* Further, the two highly successful MESA (Mathematics, Engineering, Science, Achievement) program and MEP (Minority Engineering Program) will provide both an ideal pipeline and a suitable test bed for subsequent offering of their course.

Chantilly Academy - Fairfax County Public Schools, VA: The inclusion of Chantilly Academy (CA) is intended to provide a national model for K-12 implementation of WSU's engineering mathematics materials. This is in keeping with other NSF supported efforts to infiltrate early engineering preparation into the high school curriculum and leverages other well established programs such as Project Lead The Way. Chantilly High School Academy is the largest of the Fairfax County Public School (FCPS) academies, with some 1,200 students. *Moreover, it is an embedded part-day magnet program accessible for all FCPS juniors and seniors from multiple division high schools; one-third of its students come from Chantilly High School, while two-thirds come from nineteen other high schools.* In year one, CA will modify WSU's EGR 101 as a thirty-six week engineering mathematics course, which will be offered to all juniors and seniors as a pilot course in year 2. Standard course approval for EGR 101 by the Virginia Department of Education will be requested in year 3. Prerequisites for the CA implementation will include completion or concurrent enrollment in Pre-Calculus or Pre-Calculus Honors. Assessment will include student attitudes into the nature of engineering and understanding of its phenomena through "problem-based" applications of the mathematics behind engineering. Building on WSU's commitment to re-architecting mathematics instruction at the college level, CA will evaluate this instructional model's efficacy through the correlation of student achievement in the Pre-Calculus only population, verses the Pre-Calculus population concurrently enrolled in EGR101.

Oklahoma Christian University: Oklahoma Christian (OC) will implement a pilot version of WSU's EGR 101 to 80-100 students in Fall of 2009. During year 1, the faculty will assess the courses in the current curriculum which would have their prerequisites modified to utilize the new course. The WSU material will be assessed to determine the suitability of the various topics based on their present and planned curriculum. It is likely that additional curriculum modifications will be adopted as part of the new math sequence. Since year 1 will be the last year operating under the old math sequence, OC will use this year to collect control group perceptions of mathematics in engineering and persistence in engineering. Years 2-4 will be used for a full-scale roll out of the new course along with follow up and assessment, using the same instruments as employed at WSU. *OC conducts a summer camp for high school sophomores and juniors aimed at increasing the participation of a diverse group in engineering.* They plan to incorporate the most relevant and exciting components of laboratory experiments developed for this class as a part of these residential weeks spent on campus by potential engineering students.

Oklahoma State University: At Oklahoma State University (OSU), the College of Engineering, Architecture, and Technology (CEAT) will pilot an adapted Wright State Model course (WSM) in a new, three semester-hour freshman engineering course. CEAT's implementation will additionally incorporate elements of engineering design and be linked with an English course to meet local curricular needs. *To meet the needs of diverse students, design projects will draw from the PIs' prior experience teaching design in outreach programs to middle school girls and*

*a Department of Education funded summer academy for first-generation students.* In the first project year OSU will use materials developed at Wright State while developing design-based curricular materials to be offered in the second and third years. Enrollment will include students concurrently enrolled in calculus, students currently enrolled in pre-calculus remedial courses, and students who do not need remedial courses but delay taking calculus. A longitudinal study of student academic performance and retention data will compare these groups' performance on mathematics placement tests to later academic performance and retention. Surveys developed at Wright State, rubric-based evaluation of student work, design projects (years 2 and 3), and a written self-reflection exercise will be used to evaluate student learning both formatively and summatively.

San Antonio College: *San Antonio College (SAC) is the only community college among the collaborating institutions, and will work alongside UT San Antonio to emulate the NSF STEP funded collaboration between Wright State University and Sinclair Community College.* In so doing, SAC will pilot their own version of EGR 101 and make corresponding changes to the math prerequisite requirements for core engineering courses. SAC will establish the laboratory, develop the course materials, and change the curriculum during year one. The SAC implementation of EGR 101 will be developed concomitantly with UTSA, and offered to a group of approximately 25 engineering freshmen in Fall of 2009 on a voluntary basis. *It should be noted that the SAC implementation will leverage the infrastructure developed in an ongoing Department of Education MSEIP grant to increase the success of its minority population of students.* Assessment at SAC will follow the metrics in use at UTSA, and will occur throughout the project duration. Following assessment and any required revision, it is expected that a full implementation will be undertaken; that is, all entering students will follow the new curriculum. The SAC partnership with UTSA will assure credit transferability between the institutions.

Texas A&M University-Kingsville: Texas A&M University-Kingsville (TAMUK) has a 70 year history of producing engineers from a region with challenged K-12 preparation. *Historically Hispanic, TAMUK serves the Rio Grande Valley providing education to many first-generation college students and those to whom English is not the predominant household language.* As a result, retention in the first two years is an area of constant concern. The TAMUK investigators will introduce an Engineering Mathematics course based on the WSU model in Fall, 2008. Students taking Engineering Mathematics will still be required to complete a Calculus-Differential Equations sequence for graduation, although those math classes will cease to be prerequisite barriers to core engineering courses. Assessment of success will be measured by percentage retention into the junior year of students taking Engineering Mathematics. Because of legislative mandated limits on total course hours in a degree plan, Engineering Mathematics will not be immediately listed as a required course; rather, Engineering Mathematics will be promoted as an alternative prerequisite route to physics and engineering coursework through the junior year. As some will choose to follow the traditional math sequence, TAMUK will be able to track two pools of students and compare their retention, motivation and success, using similar instruments to those employed at WSU.

University of Cincinnati: As part of a CCLI Phase 2 initiative, the University of Cincinnati (UC) has already instituted a version of WSU's EGR 101 class for Civil and Environmental Engineering as CEE 100/103. *For Phase 3, the intent is to expand the UC implementation*

*beyond Civil Engineering*. In year 1, the UC team will modify CEE 100/103 by adding subjects which are still germane to Civil Engineering, but are also usable in other engineering disciplines. The topics will draw on materials already developed at WSU, but might also include thermodynamics/heat transfer, general chemistry, general fluid mechanics, and others. The developed material will be assessed and modified as needed. In year 2, the UC team will apply the developed materials by taking over the ENFD 100 (Engineering Fundamentals) course. This course is populated by two groups of students: those who are undecided as to specific discipline; and those who meet the general admission requirements of the College, but do not meet the specific admission requirements for a specific discipline. Since some of the students in this class are admitted under a lower admission requirement, it will be necessary to accurately assess the math ability of the students and modify the lessons appropriately. In year 2, the modified CEE 100/103 will still be taught. At the end of the year, CEE 100/103 and ENFD 100 will be carefully assessed using the methods developed in Phase 2. In year 3, CEE 100/103 and ENFD 100 will be modified based on the year 2 results. Ultimately, the results and lessons will be presented to the College so that other Departments can adopt the model, potentially leading to a College-wide implementation.

University of San Diego: The University of San Diego (USD) has small engineering classes and a high degree of student-faculty interaction. Still, their third year retention is approximately 50%. *As opposed to a direct implementation of the WSU model, USD will investigate how the materials developed for WSU's EGR 101 can be used to supplement existing courses and how they can complement tutoring performed by undergraduate students.* In year one, USD will establish an *Engineering Core Tutoring Center* staffed by top undergraduate students. *A special effort will be made to recruit women and students from underrepresented groups as tutors, who might serve as role models for lower-division students.* The tutors will work with the investigators to identify the most common math errors made by students and the math concepts that cause the most difficulties. Beginning in year 2, the appropriate WSU EGR 101 materials will be offered to freshmen in the form of two, one-unit elective courses which complement existing first-year engineering courses. USD's math placement exams will be used to identify at risk students who will be strongly encouraged to enroll in the classes. Student performance in physics and the engineering core will be tracked along with retention in engineering. The performance of first-year engineering students will be compared to assess the impact of the student tutoring alone, as compared to that combined with the new courses. In addition, skill surveys will be administered in core engineering courses, which will feed both formative and summative evaluation of the program.

University of Texas at El Paso: At the University of Texas at El Paso (UTEP), a pilot adaptation and implementation of WSU's EGR 101 course will be undertaken in the College of Engineering's fundamental sequence of introductory engineering courses. Currently, the College of Engineering has a Basic Engineering sequence of common core classes for students in the Civil, Industrial, Mechanical, and Metallurgical & Materials Engineering programs. The first course in the Basic Engineering program will be reconfigured to utilize the WSU approach and materials, and will serve as the gateway to those majors. The Introduction to Computer Science and the Introduction to Electrical and Computer Engineering courses will also be modified accordingly. These modifications are expected to result in prerequisite changes to core sophomore-level engineering courses throughout the College of Engineering, subject to the

approval of all departments, the College course committee and the UTEP faculty senate. Assessment will be a key component of the UTEP adoption, being formative throughout implementation, and focused on student performance, retention and success measures. *UTEP has considerable experience in undertaking such assessment and evaluation practices, developed over the last decade in the Model Institutions for Excellence (MIE) program.* Based on the expected results, it is anticipated that all UTEP students will proceed through a WSU-modeled course sequence as a gateway to engineering.

University of Texas at San Antonio: The University of Texas at San Antonio (UTSA) will incorporate the ideas from WSU's EGR 101 within their own pilot implementation of the course. In addition, the prerequisite requirements for a number of core engineering courses will change from Calculus I to the UTSA version of EGR 101. *The UTSA implementation will heavily leverage a 2007 award for course redesign from the Texas Higher Education Coordinating Board (THECB).* In year one, UTSA will establish the laboratory, develop the course materials and make the appropriate prerequisite changes to the curriculum. The UTSA version of EGR 101 will be offered to a group of about 100 engineering freshmen in Fall, 2009 on a voluntary basis. The quality (GPA), system reliability (Retention - RET), and time (Progress Toward Degree - PTD) will be tracked for two groups of students (i.e., those electing the program vs. those who do not). In addition, qualitative assessment for both groups of students will be conducted using student surveys and other metrics developed at WSU. Based on the assessment results, is expected that a full implementation will be undertaken, so that all entering students will participate in the new curriculum (as predicated by UTSA faculty committee and ABET process requirements).

University of Toledo: As part of a CCLI Phase 2 initiative, the University of Toledo (UT) version of EGR 101 has already been successfully piloted to mathematically under-prepared students in a semester format. The objectives of the UT expansion in Phase 3 are three-fold: 1) To deliver the WSU model for a majority of first-semester students who are under-prepared to enroll in Calculus without a pre-requisite math course; 2) To modify the WSU model to an EXCEL laboratory basis to complement other first year courses at UT; 3) To further expand the EGR 101 course modules to include more applications in Chemical, Civil and Bioengineering. *The weekly recitation/lab in the course will be devoted to presentation and hands-on application of the WSU EGR 101 lab modules, but modified to an EXCEL basis.* Assessment of student learning will take place throughout each course offering, based on methods and instruments developed during Phase 2. Assessment will continue into required engineering courses in the sophomore year, including the traditional Calculus sequence. Improvements will be developed for subsequent year offerings of EGR 101.

University of Tulsa: The University of Tulsa will adopt aspects of the WSU model within the Mechanical Engineering curriculum. A subset of WSU's EGR 101 course materials will be implemented as part of an existing course: ME1312 Microcomputer Fundamentals for the Mechanical Engineer. This two credit hour course traditionally has incorporated Visual Basic for Applications for teaching the fundamentals of computing. With this experience, the University of Tulsa will augment some of the WSU examples in Matlab with those problems implemented in VBA. *Additionally, incorporation of practical problems from real world applications in traffic crash reconstruction and the oil and gas industry will be introduced to motivate and excite first-*

*year students.* An existing one credit hour course ME1311 will serve as the lab/recitation section for ME1312. The graduate teaching assistants will run the weekly lab course in similar fashion to WSU. The combination of these two courses will effectively represent a three credit hour pilot implementation of EGR101. This pilot implementation will set the precedent for combining two first-year engineering courses into a common engineering sciences course designed to satisfy the mathematics prerequisite for higher level engineering courses. Assessment of the Tulsa implementation will follow the qualitative and quantitative measures used at WSU. After the first year of implementation and assessment, a proposal will be made to the College of Engineering and Natural Sciences to implement aspects of the WSU model in other engineering departments.

Washington State University: Washington State University will develop, implement, and assess a new course focused on the application of mathematical principles to engineering (ENGR 107) that is based largely upon EGR 101 at Wright State University. Existing EGR 101 course materials will be the basis of the new course. The Washington State course will include lab, lecture, and recitation portions. The course will be offered three times in the Summer (2009, 2010, and 2011), as a 3-week course immediately before the start of the Fall semester, and once in Fall, 2010. ENGR 107 will be an alternative course for engineering students to the existing Math 107 (pre-calculus) course, and will be cross-listed as such in the course catalog. The 3-week summer session version of ENGR 107 will be advertised to students who are not eligible to enroll in calculus as a path by which they may "catch up" with their peers. Although it has not been formally implemented at WSU, it is anticipated that ENGR 107 will serve as an alternate math prerequisite to one or more engineering courses, such as statics and electrical fundamentals. *Assessment at Washington State will leverage substantial experience and infrastructure associated with the Engineering Education Research Center.* Formative and summative assessment of the project will include the implementation of the Wright State student perception survey, and tracking student retention and success in subsequent engineering and math courses. Impacts on student learning will be assessed using concept inventory instruments in the statics and mechanics of materials courses. Performance will be compared between students who took ENGR 107 and those who did not. Differences between male and female students and traditional and minority students will be tracked for all assessment measures.

Western Michigan University: Western Michigan University (WMU) will implement a pilot engineering mathematics course modeled after WSU's EGR 101. In the pilot implementation, the course will serve as the anchor class for a learning community for students placed into Pre-Calculus who major in Mechanical or Electrical and Computer Engineering; students in this learning community will also be enrolled in the same section of technical communication, general chemistry and lab, and pre-calculus. *This engineering mathematics project will be an integral part of the First-Year Engineering Experience, which is funded by an NSF STEP grant to increase retention and graduation rates.* WMU researchers will review and select curriculum materials created at WSU and create additional modules and laboratory exercises to support the engineering mathematics course, and they will collaborate with a mathematics professor to ensure the engineering mathematics course will support student success in Calculus I. As part of the FYEE program, a data-collection system for tracking student success has been in place since Fall, 2005. This system will be used to determine, track, and compare student performance (successful course completion in sophomore-level, gate-keeper engineering science courses, and

retention rates). WMU will use the perception survey developed by WSU to measure the effectiveness of the engineering mathematics course, and use the results for course revision. It is expected that the engineering mathematics course will be expanded after pilot implementation to include other engineering and engineering technology majors.

## Summary

The WSU 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 recent introduction of EGR 100 as a precursor to EGR 101 for initially underprepared students, which has made WSU's core engineering curriculum immediately accessible to roughly 80% of its first-year students. The WSU 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 15 diverse institutions across the country. These institutions (primarily university but also at the community college and K-12 levels) represent strategic pockets of interest in some of our nation's most STEM critical regions, including Ohio, Michigan, Texas, Oklahoma, California, Washington and Virginia. The results of this nationwide adoption and assessment will be widely reported in the months and years to come.

## Acknowledgments

This work has been supported by the NSF Division of Engineering Education and Centers under grant number EEC-0343214, by the NSF Division of Undergraduate Education under grant numbers DUE-0618571, DUE-0622466 and DUE-0817332, 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 WSU 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/

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