AC 2010-1708: THE WRIGHT STATE MODEL FOR ENGINEERING MATHEMATICS EDUCATION: HIGHLIGHTS FROM A CCLI PHASE 3 INITIATIVE

Nathan 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 WSU'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.

Byron Newberry, Oklahoma Christian University of Science and Arts

Byron Newberry is Professor and Chair of Mechanical Engineering at Oklahoma Christian University. He also serves as Director of the Master of Science in Engineering at OC. He is the lead PI for OC's implementation of Wright State's National Model for Engineering Mathematics Education. His interests include engineering education, stress analysis, dynamic systems, and engineering design.

Anthony Donaldson, California Baptist University

Anthony Donaldson is the founding dean of the School of Engineering at California Baptist University. One of the four focus areas he established for the school is having an outstanding undergraduate engineering curriculum. In addition to this NSF effort in mathematics, he has promoted the development of inquiry based physics, and an introduction to chemistry for engineers. He is developing and teaching a pilot introduction to the major course at CBU and an introduction to engineering design course. He previously directed the engineering programs at Seattle Pacific University where he led a successful accreditation effort and was responsible for numerous innovations in curriculum and facilities.

Joan Ozdogan, Chantilly High School Academy

Joan Ozdogan is a Career Experience Specialist in Career and Technical Education at Chantilly High School Academy, Fairfax County Public Schools in Fairfax, Virginia. Ms. Ozdogan has been responsible for pre-collegiate engineering new program development resulting in Engineering Math (upper level math elective); Girls Exploring Engineering - GE² (an all-girls engineering class); and Independent Research – Engineering (senior capstone research internships). She recently served as a STEM Expert at the Race to the Top Briefing in Baltimore, Maryland.

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

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 WSU 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 WSU model are now under pilot adoption and assessment at a total of 15 institutions across the country. This paper will provide a brief overview of the WSU model for engineering mathematics education, followed by year one highlights from a subset of these collaborating institutions.

Introduction - The WSU 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 WSU 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 WSU 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 WSU 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 WSU model was first implemented in Fall of 2004, and its effect on student retention, motivation and success in engineering has since been widely reported[6-22]. 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.[6] 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.

Highlights from a CCLI Phase 3 Initiative

A nationwide adoption and assessment 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. This section includes year one highlights from a small subset of these institutions, including Oklahoma Christian University, California Baptist University, and Chantilly High School Academy.

Oklahoma Christian University:

In the fall of 2008 the faculty of the Oklahoma Christian University School of Engineering joined the NSF CCLI Phase 3 team to implement a version of the Wright State University model for engineering mathematics education. Oklahoma Christian University is a private, faith-based institution located in northeast Oklahoma City offering ABET accredited undergraduate programs in computer, electrical, and mechanical engineering, as well as a Master of Science in engineering. Currently OC enrolls approximately 220 engineering undergraduates with the freshman class representing 32% of that group. There are 12 engineering faculty.
OC was motivated to join the NSF team due to its interest in improving the retention of engineering students. In 2008, OC participated in the NSF sponsored Academic Pathways of People Learning Engineering Survey (APPLES) led by Stanford University. Over 1/3 of our engineering students leave the program within one year and the graduation rate is under 50%. Based on the early success of the Wright State model and similarities that we saw in our retention numbers, we wanted to try a full implementation of the engineering mathematics freshmen model across all our engineering programs. We had the unanimous support of all faculty members.

The course entitled ENGR-1113 Foundations of Engineering Math was jointly designed by the OC Department of Electrical and Computer Engineering and the OC Department of Mechanical Engineering. The course consists of two 1-hour lectures and a single 3-hour lab each week. Consistent with the Wright State goals of increased retention and student engagement, the class was placed in the curriculum of all three undergraduate engineering programs as a required first semester course taught by engineering faculty; shifting the remaining mathematics courses one semester later in the sequence. It was agreed by the faculty that no eligible students would be exempt from taking the new ENGR-1113 regardless of entering mathematics placement scores. Furthermore, recognizing that time would not allow coverage of material at the depth of traditional mathematics courses, it was decided that a minimum entering ACT Math score of 23 be required for the ENGR-1113 course.

Figure OC1 presents the design of the OC ENGR-1113 course. The class establishes a "tollgate" to the Calculus sequence (as well as progression in the engineering curriculum). After 6 weeks of intense coverage of algebra and trigonometry fundamentals, the students are required to take an internal calculus readiness exam written by the Oklahoma Christian mathematics faculty. Students passing the exam, while still required to successfully complete the ENGR-1113 course, are allowed to enroll for Calculus 1 for the subsequent semester. Students failing to pass the readiness exam have the option of completing computer-based training to strengthen their foundational math skills (in addition to completing the remaining ENGR-1113 content). The computer-based training is offered using the ALEKS system (www.aleks.com). This system allows the instructor complete control of the content within a self-paced, interactive instruction system. Students successfully completing the ALEKS training are allowed to proceed with the students that passed the calculus readiness exam. Students failing to complete the ALEKS

training are required to take additional courses in College Algebra and/or Trigonometry, depending on their readiness exam score, before proceeding to Calculus 1.

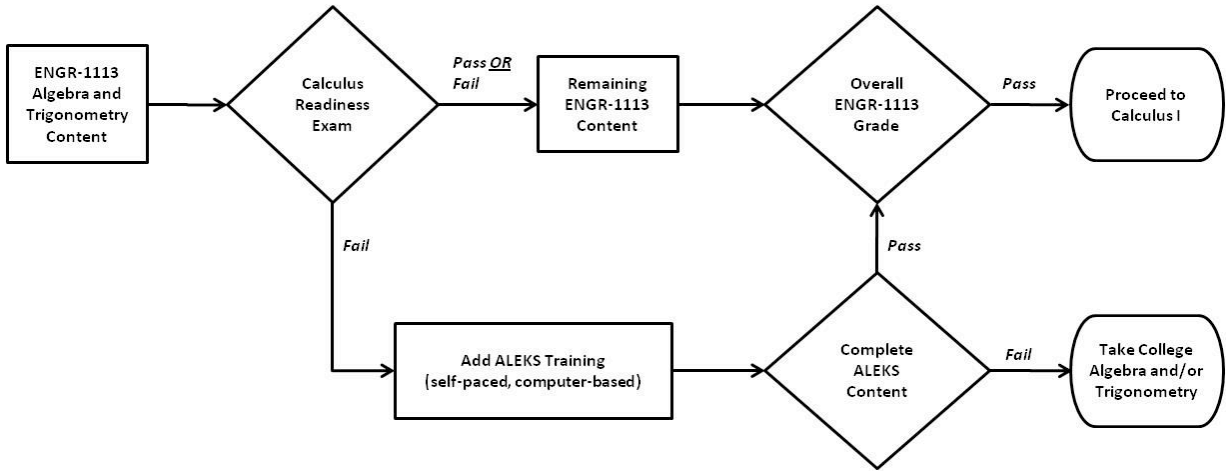

Figure OC1: Oklahoma Christian ENGR-1113 course design (remediation path shown for students needing strengthening of essential math skills for Calculus 1)

Based on this design, the Oklahoma Christian University Academic Affairs committee approved the ENGR-1113 Foundations of Engineering Math course in the spring of 2009 for all three undergraduate engineering programs beginning in the 2009-10 academic catalog.

Details of the Initial Offering of ENGR-1113

ENGR-1113 Foundations of Engineering Math was first offered in the fall of 2009. The initial offering consisted of a single lecture section for all computer, electrical, and mechanical engineering freshmen. Four lab sections were offered, each being limited to a maximum of 20 students. This approach provided a more personal laboratory experience and opportunity for the professors (one from electrical engineering and one from mechanical engineering) to become better acquainted with the incoming engineering class. Table OC1 presents a summary of the course content. Only the salient math topics that are most critical to success in the core freshman and sophomore-level engineering courses have been included.

Table OC2 briefly describes the laboratory assignments used in the ENGR-1113 course. As will be seen from student feedback, the laboratory activities were well received and qualitatively enhanced the education experience. A concerted effort was made to balance the use of electrical and mechanical examples within the class to demonstrate the universal nature of the mathematics within engineering and to effectively motivate the mixed audience of engineering students. A mixture of data collection techniques was used within the laboratory assignments. The students were exposed to a variety of instrumentation including multimeters, function generators, oscilloscopes, thermocouples, thermistors, and acoustic distance transducers. Computer data acquisition was implemented in a small subset of the labs. In every lab, the students were required to critically compare physical data with analysis (by hand and/or using MATLAB).

Table OC1: Oklahoma Christian ENGR-1113 Lecture Content Overview

Algebra Fundamentals (linear equations, quadratic equations, higher-order polynomials, basic conic sections, roots, exponents, and logarithms)	6 Lectures
Trigonometry Fundamentals (trigonometric functions, inverse trigonometric functions, Law of Sines and Cosines, vector basics, complex number basics)	5 Lectures
Matrix Method Fundamentals (matrix notation, Cramer's Rule, determinants, matrix inversion)	2 Lectures
Calculus Fundamentals (definition of the derivative, derivatives of polynomials and exponents, derivatives in min/max problems, definition of the integral, integration of polynomials and exponents, application of integrals to area and centroid problems)	6 Lectures
Differential Equation Fundamentals (introduction to 1st and 2nd order, constant coefficient, linear differential equations, application to common electrical and mechanical engineering systems)	5 Lectures

Table OC2: Oklahoma Christian ENGR-1113 Laboratory Content Overview

Algebra Fundamentals Labs Simple Resistor Circuit, Resistors in Series and Parallel	2 Labs
Trigonometry Fundamentals Labs Direct Measurements on an Articulated 2D Arm, Phase Shift in an RC Circuit	2 Labs
Matrix Method Fundamentals Labs Multiple Loop Circuit	1 Lab
Calculus Fundamentals Labs Derivatives: Freefall Experiment* Integration: Energy stored in a Spring*	2 Labs
Differential Equation Fundamentals Labs 1st order equations: RC Circuit Response, Newtonian Cooling 2nd order equations: Oscillation of a Spring-Mass System	3 Labs

Note: * implies the laboratory experiment utilized computer data acquisition.

Preliminary Student Feedback

A survey was administered in the last week of the ENGR-1113 course to collect self-reported feedback from all students in the class. The primary questions on the survey are listed below. Additionally, free form comments were solicited, as was general information about the student's mathematics training prior to this course. A detailed correlation of the feedback results to the student's math history is planned in 2010.

- Question Q1: The course has increased my motivation to study engineering
- Question Q2: The course has increased my chances of success in engineering
- Question Q3: The course has increased my motivation to study math
- Question Q4: The course has increased my chances of success in future math courses
- Question Q5: The lab section aided my understanding of the lecture material
- Question Q6: Application of MATLAB was a valuable component of the course

Table OC3 indicates that the students on average perceived value in the course; with 71% neutral or positive when asked if the course would increase their chance of success in engineering and 77% neutral or positive when asked if it would increase their change of success in future math courses. It was noted, however, that students with very strong incoming mathematics skills resented being asked to take the course; perceiving it as remedial. Many of the negative responses to questions Q1 – Q4 were received from the highest scoring students in the ENGR-1113 course. Additionally, students with weaker incoming mathematics skills consistently reported that the course content was covered too rapidly to allow full understanding of the material. Finally, students also questioned including differential equations as part of the course content as they perceived this to be a more advanced topic (admittedly not used until the end of the sophomore year).

Table OC3: Oklahoma Christian ENGR-1113 Student Survey Results Summary

	Number of Student Responses					
	Q1	Q2	Q3	Q4	Q5	Q6
Stongly Agree - 5	11	9	10	8	18	15
Agree - 4	19	21	18	24	30	16
Neutral - 3	20	16	25	18	10	15
Disagree - 2	13	14	8	13	5	10
Stongly Disagree - 1	2	5	4	2	2	9

	Response Statistics					
	Q1	Q2	Q3	Q4	Q5	Q6
Average Student Score	3.4	3.2	3.3	3.4	3.9	3.3
Standard Deviation of Score	1.1	1.2	1.1	1.0	1.0	1.4

Preliminary Course Results and Conclusions

As part of the NSF CCLI Phase 3 study, multiple pre and post exams were administered to all students in the ENGR-1113 course. These exam results will be correlated to the success rate of the students as they progress in the Calculus sequence. This quantitative analysis will not be complete until summer 2010; the results being published in 2011.

Preliminary qualitative results, however, indicate the course to be a positive experience. The following two items are specifically noted as early value-added outcomes of the ENGR-1113 course.

1. Students receive a greater understanding of the nature of engineering mathematics and the engineering analysis process than afforded them by a traditional calculus course. This is especially valuable during the first semester to allow students to make a more informed decision regarding continuation in the engineering curriculum.

2. Students motivated to pursue engineering but lacking the analytical foundation required are provided a rich opportunity to strengthen their math training PRIOR to the calculus sequence.

Considering the 2009 OC freshman class, had the ENGR-1113 class not been available, 58% of the students would have been allowed to begin in Calculus I (the remaining needing to take College Algebra and/or Trigonometry). Based on the results of the fall 2009 offering, 73% of the students in the course completed all requirements to advance to Calculus I.

California Baptist University:

California Baptist University, aka "CBU", is a private liberal arts university with 140 full time faculty and over 4000 students located in Riverside, California about an hour east of Los Angeles, in what is known as the "Inland Empire". It offers 45 bachelors and 13 masters degrees in a semester based curriculum. The current president, Dr. Ron Ellis, who started at CBU in 1994 with 808 students, embarked on a vision for continual growth to achieve 8080 students by the year 2020. The planned growth is so that the school can better serve and relevantly engage the community and the world through its graduates. Hence, the School of Engineering was started in the summer of 2006 and was opened for classes in the Fall of 2007 with 53 freshman students in 4 degree programs (BSCE, BSECE, BSE, and BSME). Currently in its third year there are 8 full time faculty and over 150 students (freshman through juniors) with roughly 20% women and 32% minorities from 10 countries. In addition, we have 26 Rwandan students on presidential scholarship studying Civil and Electrical and Computer Engineering. These students are some of the top academically from their country.

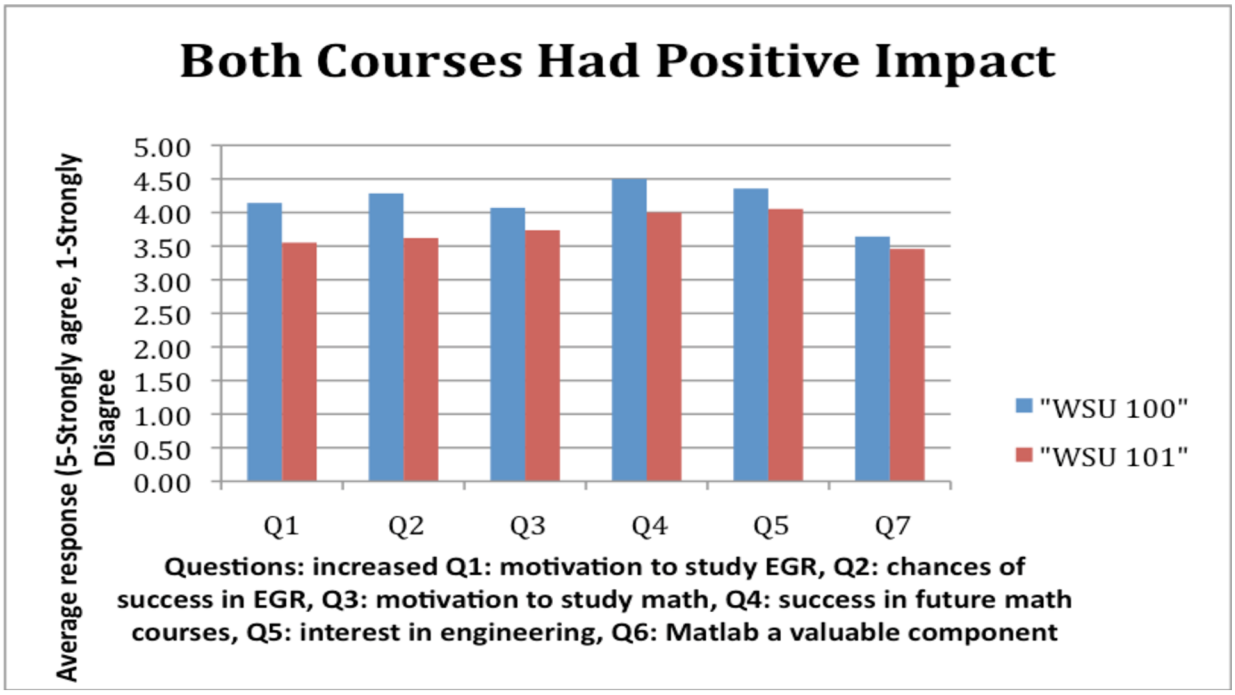

Figure CBU 1: Results of Student Survey at California Baptist

Establishing outstanding undergraduate curriculum, especially in math and science, has been one of the four focus areas of the school from the start. For example, an "inquiry based" Physics curriculum was developed and implemented for the engineering school from the start by Dr.

Alex Chediak. An introduction for the major course under development and taught by the dean was a pilot for the whole University and integrates and incorporates hands on design opportunities, a Christian worldview and utilizes Dr. Ray Landis' outstanding text "Studying Engineering: A Roadmap to Success". In addition there is a service learning requirement and an additional engineering design course the first year. In all of these classes there is a heavy emphasis on oral and written communication.

Table CBU 1. Impact of Student Performance on Responses to Student Survey at CBU

CBU EGR '181' "WSU 100" Fall 2009 14 students — Average GPA in the course for students giving the response for each question. (Note question numbers were from WSU original) Number of responders are in ( ).

Response	Q1		Q2		Q3		Q4		Q5		Q7	
Strongly Agree	2.94	(5)	2.95	(6)	2.86	(7)	2.93	(9)	2.76	(8)	3.50	(2)
Agree	2.57	(6)	2.57	(6)	1.00	(1)	2.23	(3)	2.93	(4)	2.67	(7)
Neutral	2.23	(3)	1.85	(2)	2.63	(6)	1.85	(2)	3.00	(1)	2.47	(3)
Disagree									0	(1)	1.85	(2)
Strongly Disagree												

CBU EGR '182' "WSU 101" Fall 2009 52 students* — Average GPA in the course for students giving the response for each question. Note question numbers were from WSU original. Number of responders are in ( ).

	Q1		Q2		Q3		Q4		Q5		Q7	
Strongly Agree	3.687	(15)	3.67	(17)	3.28	(21)	3.45	(20)	3.42	(25)	3.74	(18)
Agree	3.053	(19)	3.42	(19)	3.35	(14)	2.87	(24)	2.92	(17)	2.92	(16)
Neutral	2.631	(13)	2.01	(10)	2.50	(11)	3.02	(5)	2.87	(7)	2.68	(8)
Disagree	2.7	(3)	3.2	(2)	3.02	(6)			2.20	(2)	2.80	(8)
Strongly Disagree	1.7	(1)	2.2	(2)			3.20	(2)	1.70	(1)	1.70	(2)

Through a serendipitous meeting with Dr. Jeff Froyd from Texas A&M at the 2007 ASEE meeting in Hawaii, the founding dean, Dr. Anthony Donaldson was encouraged to contact Dr. Klingbeil at Wright State University 'WSU'. Two months later, the CBU's school of engineering started the equivalent of WSU's 101 class as one of two math tracks the students could follow. In 2008, Dr. Elizabeth Morris (PhD in Math Education) implemented a non lab version of WSU 100. In 2009 we made our version of WSU 101 with lab required for all entering students deemed ready for pre-calculus or calculus prior to taking the calculus sequence.

In addition our version of WSU 100 with lab, taught by Dr. Helen Jung, with feedback from Dr. Morris was required for all students placed into college algebra. Currently both '100' and '101' consist of 3 hours of lecture and 1.5 hours of lab each week and are taught by our engineering faculty (Dr. Jung, Dr. Xu and Dr. Zhou). Dr. Xuping Xu has just finished writing and typesetting an initial draft of a textbook for the course starting with the notes initially provided from WSU. Several engineering faculty are currently involved in the ongoing development of labs for the course. We emphasize vertical integration of our curriculum in that this engineering math course serves to introduce the students to not only the math they will see in their sophomore and junior engineering classes but also some of the lab equipment and key concepts as well. In essence we are attempting to make relevant and thus motivate and preload their learning of this material. This approach also allows additional time for the concepts to sink in. The material presented below represents our initial efforts at systematically assessing the courses starting in the fall of 2009.

Two sections of 101 with a total of 52 freshman students and one section of 100 with 14 freshman students were asked a series of questions at the end of the semester, but before the students knew their grade in the course. The responses to the 6 questions provided by WSU are shown in Figure CBU1. The role of how well the students actually were doing in the course is probably the most dominant factor as indicated in Table CBU1. For each question the average GPA of the students giving each level of response is shown. In almost all cases the higher the response to a question the higher the average GPA of the responders.

Chantilly High School Academy:

Fairfax County Public Schools (FCPS) located in Fairfax County, Virginia administers six high school Career and Technical Education Academies, centers within existing high schools, which offer advanced technical and specialized courses that successfully integrate career and academic preparation. Chantilly High School Academy i**s** the largest of the six academies and is an embedded part-day magnet academy for student enrollment from multiple schools in the FCPS division.

As a dynamic learning environment, Chantilly Academy's mission is to offer specialized career-oriented electives, in two concentration areas: Engineering & Scientific Technology and Health & Human Services. Students gain professional experience, verified credit, professional licensure, industry certifications, and earn college credits. For Academy admission, students submit a formal application and a cumulative school transcript. Additional requirements include the submission of recommended course prerequisites and a personal statement from the student validating interest in the program.

Of a total school population of approximately 2,850, Chantilly High School is 50 percent male and 50 percent female. Student demographics include (Self-reported data; parent responses at student registration with FCPS) – 62 percent White, 6 percent African-American, 8 percent Hispanic, 17 percent Asian American/Pacific Islander, 1 percent American Indian and the remaining 6 percent identified as Multiracial. About 11.5 percent of the student body is eligible for the free/reduced lunch program. Chantilly High School Academy has a program capacity of 1,200 students; currently one-third of its students come from Chantilly High School, and two-

thirds from 19 other FCPS high schools. The Academy's population is 47 percent females and 53 percent males: 11.02 percent Black/African American, 21.7 percent Asian/Pacific Islander, 14 percent Hispanic, 50 percent White/Non-Hispanic, 3 percent other race/ethnic groups, 22 percent Special Education and 22 percent ESOL.

Pre-Collegiate Engineering Education

CA has nearly ten years of experience delivering engineering education, and currently offers *Engineering Systems I, Engineering Systems II, Engineering Physics, "Girls Exploring Engineering - GE²"* an all-girls section of Engineering Systems I. The GE² Program Advisory Board includes representatives from all Engineering Schools in the Commonwealth of Virginia, George Washington University and the University of Maryland, and corporate representation from Northrop Grumman, Noblis, ExxonMobil, Lockheed Martin, and Micron Technology.

As a senior capstone course, Independent Research – Engineering offers a work-based learning experience through mentorship in corporate, government and higher education organizations. In SY 2008-2009, seniors enrolled in *Independent Research - Engineering completed* mentorship experiences at Northrop Grumman, and the Center for Space Technologies at the U.S. Naval Research Laboratory.

Currently, *Engineering Systems I* articulates to Introduction to Systems Engineering 101 at George Mason University (articulation was established in January 2005). Engineering student organizations include: FIRST Robotics, Aerospace Club, Federation of Galaxy Explorers, and the Institute of Electrical and Electronics Engineers, Inc (IEEE). Chantilly engineering students currently serve as mentors in robotics to area middle schools, and at the National Air and Space Museum at the Udvar Hazy Center, Dulles, Virginia.

Chantilly Academy's motivation for collaboration on the NSF CCLI Phase 3 grant is to advance its commitment to the effective preparation of high school students for the rigors of undergraduate engineering education; with this special emphasis on the application of mathematics in engineering. The resulting new course Engineering Mathematics has been approved by Fairfax County Public Schools as an upper level mathematics elective, one credit course offered to students at Chantilly High School and accessible to students from 19 additional high schools in the school division through the Chantilly Academy.

Engineering Math Implementation

Engineering Mathematics was launched as an upper level mathematics course in the current 2009-2010 academic year with a registration of eighteen students. (Course flyer attached) The course instructor is an electrical engineer by education and original profession and a career switcher to public education after a distinguished history of service in the United States Air Force. Working with high school mathematics faculty and regional university mathematics/engineering faculty during the summer of 2009, the course was modified from the original ten week college course to a thirty-six week high school course and is based on the original curriculum design provided by WSU. The course format includes both lecture and lab sessions that enable direct application of mathematics in engineering problem solving. MatLab

is fully integrated into the course; all labs and assessments have a MatLab component. The prerequisite for Engineering Mathematics is Algebra 2, and the co-requisite is Precalculus with Trigonometry or the completion of Precalculus with Trigonometry. The role of engineering mathematics in Chantilly's engineering pathway is shown in Figure CA1.

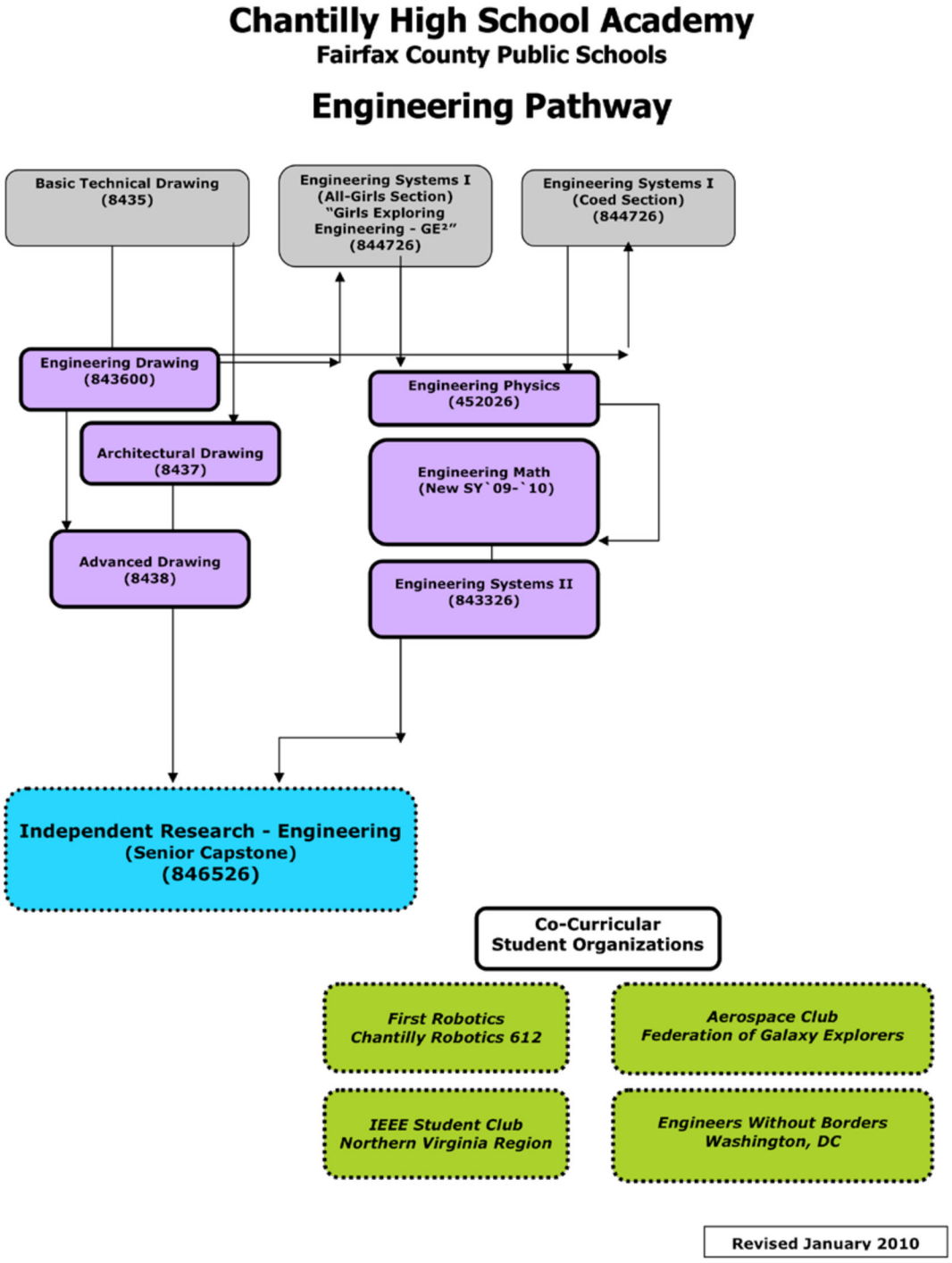

Figure CA 1. Role of WSU's Engineering Mathematics in Chantilly High School Academy Engineering Pathway

All students enrolled in Engineering Mathematics are self-reported to be seeking admission to colleges and universities for undergraduate engineering degree programs. As the course is in its first year, modifications to the curriculum design are ongoing to meet the diverse needs of the students with varying backgrounds in mathematics; Algebra 2 to Multivariable Calculus and Matrix Algebra. To date, an additional on Vectors lab session has been designed and integrated into the course (Figure CA2). While student surveys have been administered, they were not processed in time for the draft paper, and results will be included in the final version.

Figure CA 2. Chantilly Academy Students Engaged in Vector Lab

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 introduction EGR 100/199 as a precursor to EGR 101 for initially underprepared 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. This paper has included highlights from three of these institutions, whose results to date seem to support the widespread transferability of the approach.

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/

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., 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.

7. 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.

8. 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.

9. 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.

10. 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.

11. 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.

12. 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.

13. 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.

14. 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.

15. 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.

16. 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.

17. 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.

18. 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.

19. 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.

20. 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.

21. 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.

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," *Ohio Council of Teachers of Mathematics Conference*, Dayton, OH, October 2005.