The Wright State Model for Engineering Mathematics Education:

Uncorking the Bottleneck to Student Success

Support:
National Science Foundation
Grant Numbers EEC-0343214, DUE-0618571, DUE-0622466, DUE-0817332

http://www.cecs.wright.edu/engmath/
Motivation and Objective

Motivation:

- The inability of incoming students to advance past the traditional freshman calculus sequence remains a primary cause of attrition in engineering programs across the country.

- Meanwhile, our nation’s leaders are calling for 10,000 more engineers per year. We can far exceed this number by simply addressing curricular barriers and graduating more of the students we already have.

Objective:

To increase student retention, motivation and success in engineering through *application-driven, just-in-time, engineering* math instruction.
EGR 101: Introductory Mathematics for Engineering Applications

- Course Topics
  - Linear & Quadratic Equations
  - Trigonometry
  - Vectors and Complex Numbers
  - Sinusoids and Harmonic Signals
  - Systems of Equations and Matrices
  - Basics of Differentiation
  - Basics of Integration

- All topics driven by engineering applications taken directly from core engineering courses
- Lectures reinforced by hands-on laboratory and recitation components including a thorough integration with MATLAB
- Replaces traditional math prerequisites for core sophomore-level engineering courses – effectively uncorking the calculus bottleneck
Restructured Curriculum
(Effective Fall, 2004)

Traditional First-Year Curriculum (Mechanical Engineering):

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<th>Fall Quarter</th>
<th>Winter Quarter</th>
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<td>ENG 101</td>
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<td>EGR 190</td>
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<td>CHM 121</td>
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<td>MTH 229 Calc I*</td>
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* Traditional freshman calculus sequence

Restructured First-Year Curriculum (Mechanical Engineering):

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* New freshman engineering mathematics course
** First course in the revised engineering calculus sequence, with separate sections for engineers.
Revised Math Sequence

- EGR 101 (5 quarter hours, freshman year)

- Required Calculus Sequence (5 quarter hours each)
  - Calc I (freshman year)
  - Calc II (sophomore year)
  - Calc III (sophomore year)
  - Calc IV (junior year)

- Differential Equations with Matrix Algebra
  (5 quarter hours, sophomore year)
“This course has really helped me. I was thinking of dropping engineering, but because of this course I am sticking with it…”

“Being able to put calculus to actual engineering problems helps a lot for me. I didn’t understand it in high school, but being able to imagine or see it in an actual problem helped greatly.”

“I enjoyed the class because it focused more on application to real world problems rather than just numbers. The lectures based on example problems followed up by recitation created a very good learning environment for me.”
Initial Impact: First-Year Retention

- Every department requiring EGR 101 saw an increase in first-year (Fall-to-Fall) retention in 2004-2005:

First Year Retention: Majors Requiring EGR 101

![Bar chart showing first-year retention rates for different majors requiring EGR 101.

- Overall, first-year retention for majors requiring EGR 101 increased from 68.0% to 78.3%]
Of the students ultimately enrolled in Calc I, 89% of those who took EGR 101 earned a “C” or better, compared to only 60% of those who did not
Students who took EGR 101 had a significantly higher chance of graduating from Wright State University, whether from engineering or some other degree program.
Students who took EGR 101 had a statistically significant advantage in their first two calculus courses.
Students who took EGR 101 had a statistically significant advantage in Dynamics, Strength of Materials and Electric Circuits. No significant difference in Physics I or Statics.
Students who took EGR 101 earned CECS degrees at more than *double* the rate of those who did not. For underrepresented students, the difference was nearly a factor of *three*…
On average, students who took EGR 101 were in fact somewhat more prepared, since many initially underprepared students dropped out before ever getting there.

Still, a number of initially underprepared students did ultimately take the course.
And This Was the Result...

Impact of EGR 101 on CECS Graduation Rates
All DFHS Students Entering Fall 2000-Fall 2006 Earning CECS Degree

- Took EGR 101 (n=258)
- Did Not Take EGR 101 (n=1738)

* p<.10, ** p<.05, *** p<.01, **** p<.001

ACT Math

Bottom 15%  The Future of U.S. Global Competitiveness  Top 15%

EGR 101 has successfully mitigated the impact of incoming math preparation over the entire range of incoming ACT math scores
Of students who took EGR 101, 70% earned Wright State degrees, compared to 51% of those who did not. Rest of WSU: 46%
What About the Caliber of Our Engineering Graduates?

Despite graduating a higher proportion of initially underprepared students, EGR 101 has increased both the number and caliber of our engineering graduates.

For underrepresented students, taking EGR 101 was the difference between graduating with a 2.9 GPA and graduating with a 3.0 – the interview cutoff for many prospective employers.
Longitudinal Study: Student Motivation and Self-Efficacy

Average EGR 101 Post-Course Student Survey Responses

- Q1 Motivation to Study Engineering
- Q2 Chance of Success in Engineering
- Q3 Motivation to Study Math
- Q4 Chance of Success in Math

* p<.10, ** p<.05, *** p<.01, **** p<.001

EGR 101 had a stronger impact on the motivation and self-efficacy of students who ultimately graduated in engineering, as compared to those who did not.
EGR 101 had a positive impact on the motivation and self-efficacy of students having either above or below average ACT math scores, with no significant difference between groups.
Impact on Motivation and Self-Efficacy Sorted by High School GPA

EGR 101 had a stronger impact on the self-efficacy of students with above average high school GPA’s (i.e., the hard workers), as compared to that of students with below average GPA’s.
EGR 101 had a stronger impact on the self-efficacy of females as compared to males.

About 90% of the female population had above average high school GPA’s (i.e., they were hard workers). EGR 101 helped them *believe* they could do it.
In the context of the Academic Performance Commitment Matrix (APCM), EGR 101 had the greatest impact on the motivation of Support & Purpose Seekers, regardless of whether or not they ultimately graduated.

For both the Purpose Seekers and Achievers (high ACT students), there was a statistically significant difference between those that did and did not graduate.
Impact on Self-Efficacy Sorted by APCM Group

Average Response to Question Q2 - This course has increased my chances of success in engineering - by APCM Group

- Graduated EGR
- Did Not Graduate EGR

With the exception of Achievers who ultimately graduated, EGR 101 had the greatest impact on the self-efficacy of Support Seekers, regardless of whether or not they ultimately graduated.

For both the Purpose Seekers and Achievers (high ACT students), there was a statistically significant difference between those that did and did not graduate.
So What About the *Rest of the Students*?

- Despite the success of EGR 101, our curriculum was still not immediately accessible to our *average* incoming student, who has a math placement level (MPL) of around 4.3 (EGR 101 requires MPL 5 or ACT Math 25 plus Trig).

- As a result, EGR 100 “Preparatory Mathematics for Engineering and Computer Science” was introduced as a precursor to EGR 101, with an initial enrollment of 111 MPL 3 and 4 students in Fall, 2007 (under temporary course number EGR 199).

  - EGR 100/199 covers only pre-calculus topics, from algebra through trigonometry, with all topics motivated by their actual application in core engineering and computer science courses.

  - EGR 100/199 serves as an alternative prerequisite to EGR 101, and provides an opportunity for incoming students (including CS/CEG majors) to raise their MPL scores and avoid as many as three remedial math courses before advancing in their chosen degree programs.
The majority of EGR 199 students increased their MPL score by at least one level, and some by as many as three (avoiding an entire year of remedial math courses).
The introduction 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.
The introduction of EGR 100/199 has increased the number of first-year students enrolled in EGR 101 by roughly 50%.
Despite a significant increase in the number of initially underprepared students enrolled in the course, first-year retention for students who took EGR 101 reached an all-time high of 86%.
Pre-College Implementations of EGR 101 Materials

- Dual-Enrollment of EGR 101: Bellbrook High School, the Dayton Regional STEM School, Carroll High School (Fall 2014). Other Dayton area schools under consideration.

- Dayton Regional Summer STEM Academy: Three week summer program for rising juniors and seniors

- 36 week high school engineering mathematics curriculum at Chantilly High School Academy (Fairfax County, VA)

- Offerings at DC area high schools (Friendship Collegiate Academy, Oxon Hill High School) with University of Maryland credit

- Multiple school districts under consideration across the country
NSF STEP Type 1 Program

“Gateway into First-Year STEM Curricula: A Community College/University Collaboration Promoting Retention and Articulation”

Grant Number DUE-0622466, 10/01/06-09/30/13.
Total Funding: $1,997,620

1. Adoption of EGR 101 and associated engineering math reforms at Sinclair Community College (SCC)

2. Development of EGR 100/199 as a pre-cursor to EGR 101 for initially underprepared students

3. Development of companion SM 101/ASE 101 “Scientific Thought and Method,” offered to all first-year science majors at WSU and SCC

4. Key Outcomes: 43% increase in undergraduate STEM degrees awarded (339 to 484 overall; 168 to 290 for CECS); 46% increase in STEM degrees awarded to women (114 to 166 overall; 26 to 42 for CECS); 209% increase in STEM degrees awarded to underrepresented minorities (21 to 65 overall; 8 to 34 for CECS).
NSF CCLI Phase 3 Program

“A National Model for Engineering Mathematics Education”
Grant Number DUE-0817332, 08/01/08-07/31/15

Total Funding: $2,400,000 – Including 2013 HBCU Supplement

18 Collaborating Institutions:

California Baptist University, California State University-Long Beach, Chantilly Academy (Fairfax County Public Schools, VA), Howard University, Morgan State University, Oklahoma Christian University, Oklahoma State University, San Antonio College, Texas A&M University - Kingsville, University of Cincinnati, University of Maryland Eastern Shore, University of San Diego, University of Texas at El Paso, University of Texas at San Antonio, University of Toledo, University of Tulsa, Washington State University, Western Michigan University

External Evaluator:

University of Maryland - College Park
Potential for National Impact
10,000 More Engineers… Times Seven

NSF Funded Collaborators
Unfunded Collaborators
National Engineering Math Consortium Participants
Implementation

1. Obtain the support of upper administration. Focus on business model. Tuition revenues from increased student retention and success exceed implementation costs by an order of magnitude.

2. Get faculty buy-in. Identify (and compensate) one faculty champion to shepherd the course and associated prerequisite changes through the curricular approval process.

3. Resource the course appropriately, including only top teaching faculty and undergraduate student TA support.

4. Work collaboratively among 2-year and 4-year colleges for seamless articulation across institutions.
Recommended Math Pathways for Engineering Students

1. Students who are calculus ready (or above) should enroll in EGR 101 in Fall and continue with calculus in Spring.

2. Students placing in pre-calculus (one course behind Calc I) should be enrolled in both pre-calculus and EGR 101 in Fall.

3. Students placing more than one course behind Calc I should be enrolled in a discipline-specific intervention in Fall designed to increase math placement levels. These students should have the opportunity to be calculus ready within a single semester.

*Do not enroll students in an entire sequence of prerequisite math courses which do not count toward their intended degrees!*
Questions
(And Shameless Plug)

http://www.wiley.com/college/rattan