Uncorking Curricular Bottlenecks to Student Success in STEM

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National Science Foundation
Grant Numbers
EEC-0343214, DUE-0618571, DUE-0622466, DUE-0817332, DUE-1356518
http://www.cecs.wright.edu/engmath/
Motivation:

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

- Meanwhile, the global competitiveness of our great nation requires continued increases in the number, caliber and diversity of engineering and other STEM graduates.

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>
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<td>ENG 101</td>
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* Traditional first-year calculus sequence

- Restructured First-Year Curriculum (Mechanical Engineering):

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* New first-year engineering mathematics course
** First course in the revised engineering calculus sequence, with separate sections for engineers.
“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.”
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
Longitudinal Study: Student Performance in Calculus
(Klingbeil and Bourne, 2012-15)

Impact of EGR 101 on Student Performance in Calculus
All DFHS Students Entering Fall 2000-Fall 2006

- 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…
Longitudinal Study: Are the Populations Comparable?

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

<table>
<thead>
<tr>
<th>ACT Math</th>
<th>Took EGR 101 (n=258)</th>
<th>Did Not Take EGR 101 (n=1738)</th>
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*p<.10, **p<.05, ***p<.01, ****p<.001

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**
Even for the *Switchers*…

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

- Took EGR 101 (n=258)
- Did Not Take EGR 101 (n=1738)
- Rest of WSU (n=11533)

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<.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.
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 women than of men.

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.
“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, 08/01/08-07/31/16

Total Funding: $2,400,000 – Including 2013 TUES Type 3 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
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!
Implementation: Uncorking Your Bottleneck

1. Obtain the support of upper administration. Focus on the business model. Tuition revenues from increased student retention and success can 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 universities, community colleges and area high schools for seamless articulation across institutions.
Resources

Program Website:

- Links to All Course Materials
- Lecture Videos/Virtual Labs
- TEDx Dayton Talk
- EGR 101 Textbook

http://www.cecs.wright.edu/engmath/

Contact and Faculty Mentor:

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Director of Engineering Mathematics  
280 Joshi Research Center  
Wright State University  
Ph: (937) 775-3775  
E-mail: craig.baudendistel@wright.edu
Questions