Engineering Mathematics Education at Wright State University

Uncorking the First-Year Bottleneck

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

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Motivation

- Historically, only about 42% of students who wish to pursue an engineering or computer science degree at WSU ever advance 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, math-related attrition plagues engineering programs across the country.
- We submit that even at universities with open admissions, the retention rate could (and should) be much higher.

Goal

To increase student
- Retention
- Motivation
- Success
through
- Application-Driven
- Just-in-Time

Engineering Math instruction.
The WSU Model

- Develop a first-year engineering mathematics course (EGR 101) addressing only the salient math topics actually used in core engineering courses (physics, engineering mechanics, electric circuits, computer programming, etc.)
- Restructure the engineering curriculum, with EGR 101 as the only math prerequisite for the above core courses
- Develop a revised engineering mathematics sequence, to be taught by the math department later in the curriculum, in concert with College and ABET requirements

EGR 101: Introductory Mathematics for Engineering Applications

- Taught by College of Engineering & Computer Science faculty
- Course Structure: 5 credit hours
  - 4 hours lecture
  - 1 hour lab (real time = 2 hrs/wk)
  - Recitation (1 hr/wk)
- Prerequisite: Math placement in Trigonometry

EGR 101: Introductory Mathematics for Engineering Applications

- Course Topics
  - Linear & Quadratic Equations (1.0 weeks)
  - Trigonometry (1.0 weeks)
  - Vectors and Complex Numbers (1.0 weeks)
  - Sinusoids and Harmonic Signals (0.5 weeks)
  - Systems of Equations and Matrices (0.5 weeks)
  - Basics of Differentiation (2.0 weeks)
  - Basics of Integration (2.0 weeks)
  - Differential Eqs. w/Constant Coeffs. (2.0 weeks)
- All topics driven by engineering applications taken directly from core engineering courses
- Lectures motivated by hands-on laboratory exercises, including a thorough integration with MATLAB

EGR 101 Laboratory Excerpts

- While typical engineering labs are designed to illustrate engineering physics, EGR 101 labs are designed to illustrate engineering mathematics
- Indeed, physical measurement of the derivative as the velocity in freefall - or of the integral as the area under the force-deflection curve - provides a much greater conceptual understanding of the material than typically achieved in a traditional first-year calculus course
Restructured Curriculum
(Effective Fall, 2004)

Traditional First Year (Mechanical Engineering):

<table>
<thead>
<tr>
<th>Fall Quarter</th>
<th>Winter Quarter</th>
<th>Spring Quarter</th>
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<tbody>
<tr>
<td>ENG 101</td>
<td>ENG 102</td>
<td>ME 199</td>
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<tr>
<td>EGR 190</td>
<td>EGR 153/CEG 220</td>
<td>PHY 240</td>
</tr>
<tr>
<td>CHM 121</td>
<td>GE</td>
<td>ME 202</td>
</tr>
<tr>
<td>MTH 229 Calc 1</td>
<td>MTH 220 Calc II</td>
<td>MTH 220 Calc III</td>
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* Traditional freshman calculus sequence

Restructured First Year (Mechanical Engineering):

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* New freshman engineering mathematics course

Revised Math Sequence

- **EGR 101** (5 hours, freshman year)
- Engineering Calculus Sequence (5 hours each)
  - Engineering Calc I (freshman year)
  - Engineering Calc II (sophomore year)
  - Engineering Calc III (sophomore year)
  - Engineering Calc IV (junior year)
- Differential Equations with Matrix Algebra (5 hours, sophomore year)

Assessment

- WSU has obtained multi-year NSF support to provide a rigorous evaluation of the program, and to enable a widespread dissemination of results
- Quantitative data readily available on student
  - Retention in engineering
  - Success in future math and engineering courses
  - Ultimate graduation rates
- Qualitative feedback will also be obtained from faculty and student surveys at each level of the program

Student Performance
First Year of EGR 101

- Grade distributions, Fall and Cumulative (Fall 04-Spring 05)

- Cumulative performance surpassed expectations, with 74% of students completing EGR 101 with a “C” or better
- Suggests the potential for a dramatic improvement in student retention and success in engineering
Student Perception
EGR 101 First-Run, Fall 2004

- Student perception of EGR 101 sorted by high school math background:

- EGR 101 increased student motivation and perceived chance of success in future math and engineering courses

Student Comments on EGR 101

- “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.”

Student Perception
First Year of EGR 101

- Student surveys, Fall and Cumulative (Fall 04-Spring 05)

- Student perception of EGR 101 remained strong in subsequent quarters, even though the students were generally less prepared to be there!

First-Year Retention
(Fall-to-Fall)

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

- Overall, first-year retention for majors requiring EGR 101 increased from 68.0% to 78.3%
Students who took EGR 101 had a much greater chance of success through their first two years (75.6%), as compared to those who did not (23.0%).

Students at all initial math placement levels (MPL) gained a significant advantage from EGR 101.

**NSF CCLI Phase 2 Program**

“A National Model for Engineering Mathematics Education”
Grant Number DUE-0618571, 08/15/06-07/31/09.
Total Funding: $500,000

PI: N. Klingbeil
Co-PI’s: K. Rattan, D. Reynolds, M. Raymer, R. Mercer

1. Multiyear assessment at WSU (student retention, motivation and success, including effect on student learning in subsequent math and engineering courses)
2. Pilot adoption and assessment at collaborating institutions (University of Cincinnati, University of Toledo)
3. Widespread dissemination of results: Development of an EGR 101 textbook; publication and presentation in STEM venues; workshops for faculty from across the country (build team for Phase 3 in 2009)

**NSF STEP Program**

“Gateway into First-Year STEM Curricula: A Community College/University Collaboration Promoting Retention and Articulation”
Grant Number DUE-0622466, 10/01/06-09/30/10.
Total Funding: $1,786,559 (additional $211,061 expected in FY 2010)

PI: M. Wheatly
Co-PI’s: N. Klingbeil, B. Jang, G. Sehi, R. Jones

1. Adoption of EGR 101 and associated engineering math reforms at Sinclair Community College (SCC)
2. Development of companion SM 101/ASE 101 “Scientific Thought and Method,” offered to all first-year science majors at WSU and SCC
3. Training of faculty, graduate students and senior undergraduates, who will participate in the development and implementation of the unified first-year STEM experience at WSU and SCC
4. Expected Outcomes: 10% increase in first-year STEM retention at WSU; 10% increase in articulation of STEM majors from SCC to WSU; 50 additional WSU STEM graduates per year by close of project
Summary

- We propose an application-driven, just-in-time approach to engineering mathematics, with the goal of increasing student retention, motivation and success in engineering.
- The approach is designed to be readily adopted by any institution employing a traditional engineering curriculum.
- Student performance, perception and retention in the initial implementation the program has surpassed our expectations, and verified the feasibility of the approach.
- We believe the WSU model has the potential for an extremely broad impact, including significant increases in retention and graduation rates at universities across the country.

Questions