2-2007

Engineering Mathematics Education at Wright State University: Uncorking the First Year Bottleneck

Nathan W. Klingbeil
Wright State University - Main Campus, nathan.klingbeil@wright.edu

Kuldip S. Rattan
Wright State University - Main Campus, kuldip.rattan@wright.edu

Michael L. Raymer
Wright State University - Main Campus, michael.raymer@wright.edu

David B. Reynolds
Wright State University - Main Campus, david.reynolds@wright.edu

Richard Mercer
Wright State University - Main Campus, richard.mercer@wright.edu

Engineering Mathematics Education at Wright State University

Uncorking the First-Year Bottleneck

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

Investigators

Nathan Klingbeil
Department of Mechanical & Materials Engineering

Kuldip Rattan
Department of Electrical Engineering

Michael Raymer
Department of Computer Science & Engineering

David Reynolds
Department of Biomedical, Industrial & Human Factors Engineering

Richard Mercer
Department of Mathematics & Statistics

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

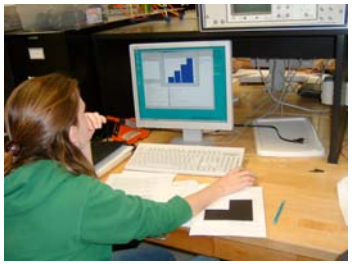
- Taught by College of Engineering & Computer Science faculty
- Course Structure: 5 credit hours
  - 4 hours lecture
  - 1 hour lab (real time = 2 hrs/wk)
  - Recitation (1 hr/wk)
- Prerequisite: Math placement in Trigonometry

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):**

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

- **Restructured First 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
** First course in the revised engineering calculus sequence, with separate sections for engineers.

Revised Math Sequence

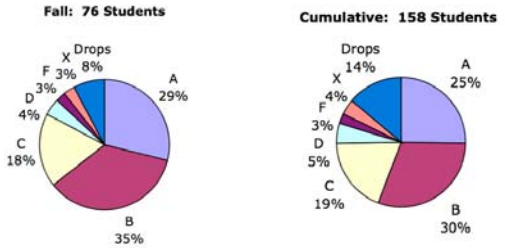
- **EGR 101 (5 hours, freshman year)**
- **Engineering Calculus Sequence (5 hours each)**
  - **Engineering Calc I (freshman year)**
  - **Engineering Calc II (sophomore year)**
  - **Engineering Calc III (sophomore year)**
  - **Engineering Calc IV (junior year)**
- **Differential Equations with Matrix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

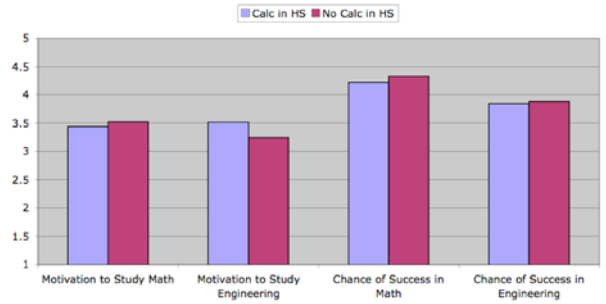
- **Grade distributions, Fall and Cumulative (Fall 04-Spring 05)**



- **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

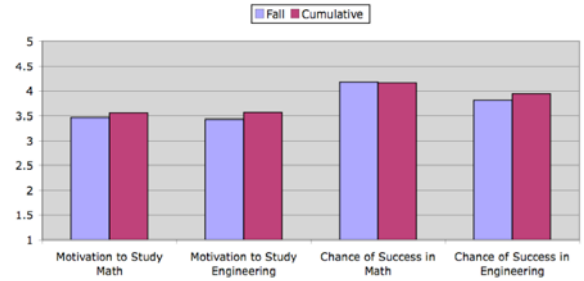
- Student perception of EGR 101 sorted by high school math background:



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

Student Perception
First Year of EGR 101

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



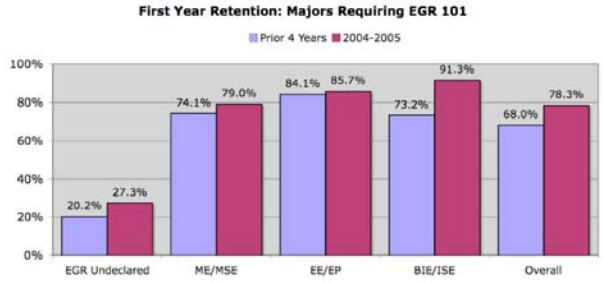
- Student perception of EGR 101 remained strong in subsequent quarters, even though the students were generally *less* prepared to be there!

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."

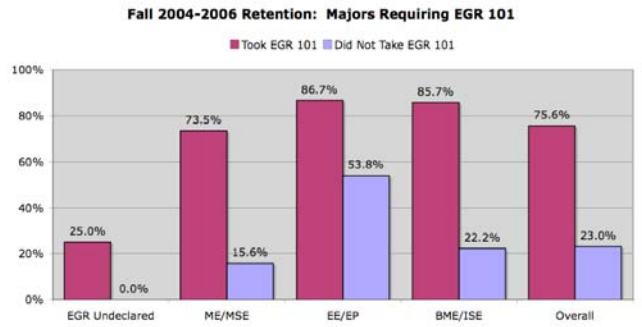
First-Year Retention
(Fall-to-Fall)

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



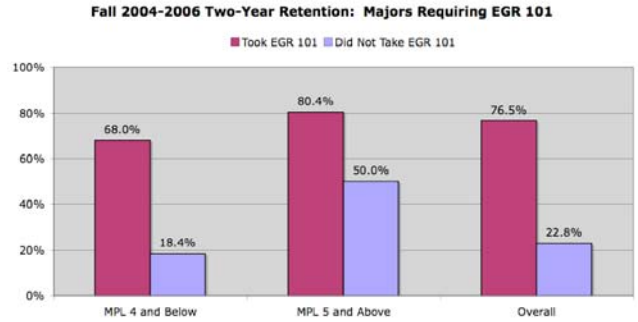
- Overall, first-year retention for majors requiring EGR 101 increased from 68.0% to 78.3%

Two-Year Retention
(Fall 2004-Fall 2006)



- 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%)

Two-Year Retention
(Fall 2004-Fall 2006)



- 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

?