WRIGHT STATE UNIVERSITY

A National Model for Engineering Mathematics Education

Support:

National Science Foundation

Grant Numbers EEC-0343214, DUE-0618571, DUE-0622466, DUE-0817332

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

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 and Objective

Motivation:

- Historically, only about 40% of students who wish to pursue an engineering or computer science degree at Wright State University ever advance past the traditional freshman calculus sequence
- The remaining 60% 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

Objective:

To increase student retention, motivation and success in engineering through *transformative and nationwide change* in engineering mathematics education

The Wright State Model

1. Develop a first-year engineering math course (EGR 101) addressing only the salient math topics *actually used* in core engineering courses (physics, engineering mechanics, electric circuits, computer programming)

2. Restructure the early engineering curriculum, with EGR 101 as the *only* math prerequisite for the above core courses

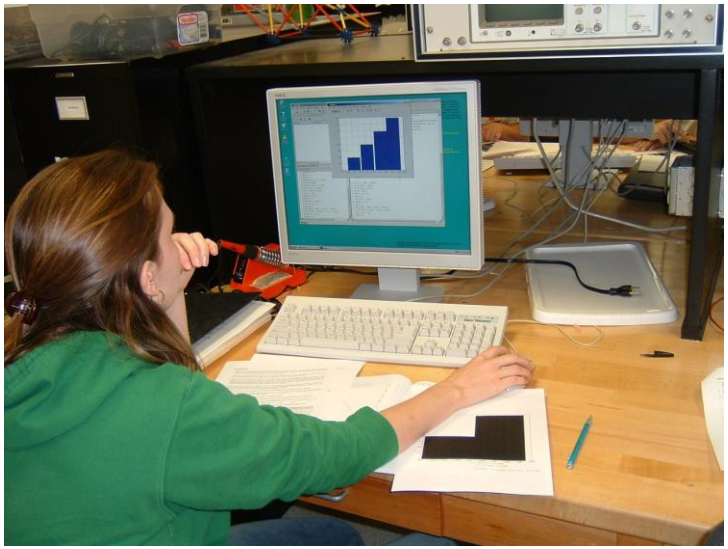
1. Develop a revised engineering math sequence, taught by the math department later in the curriculum, in concert with College and ABET requirements

EGR 101: Introductory Mathematics for Engineering Applications

- Taught by *engineering* faculty
- Course Structure: 5 credit hours (quarter system)
  - 4 hours lecture
  - 1 hour lab (real time = 2 hrs/wk)
  - Recitation (1 hr/wk)
- Prerequisite: Math placement in Trigonometry (MPL 5)

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
  - Differential Eqns. W/Const. Coeffs.





- 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

Restructured Curriculum
(Effective Fall, 2004)

- Traditional First-Year Curriculum (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 Curriculum (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

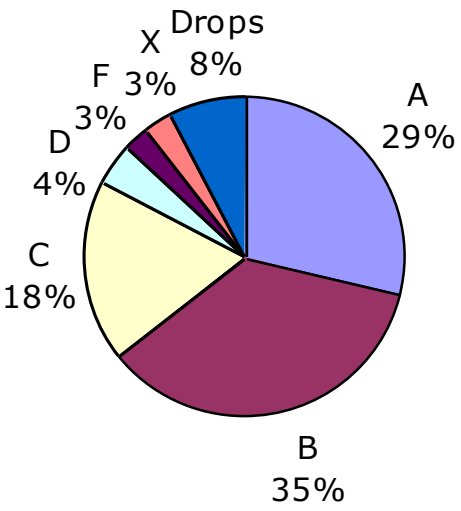
- EGR 101 (5 hours, freshman year)
- Engineering Calculus Sequence (5 hours each)
  - Engineering Calc I (freshman year)
  - Engineering Calc II (sophomore year)
  - Engineering Calc III (sophomore year)
  - Engineering Calc IV (junior year)
- Differential Equations with Matrix Algebra (5 hours, sophomore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

Student Performance

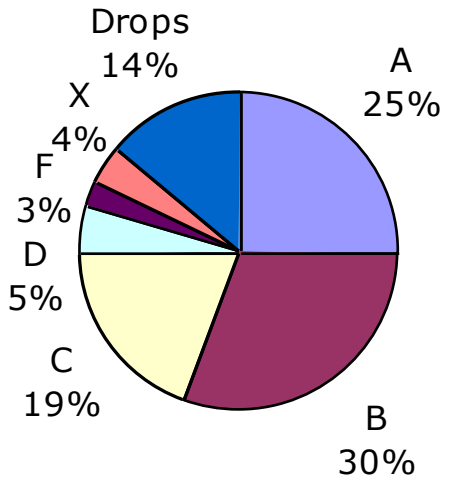
First Year of EGR 101

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

Fall: 76 Students



Cumulative: 158 Students

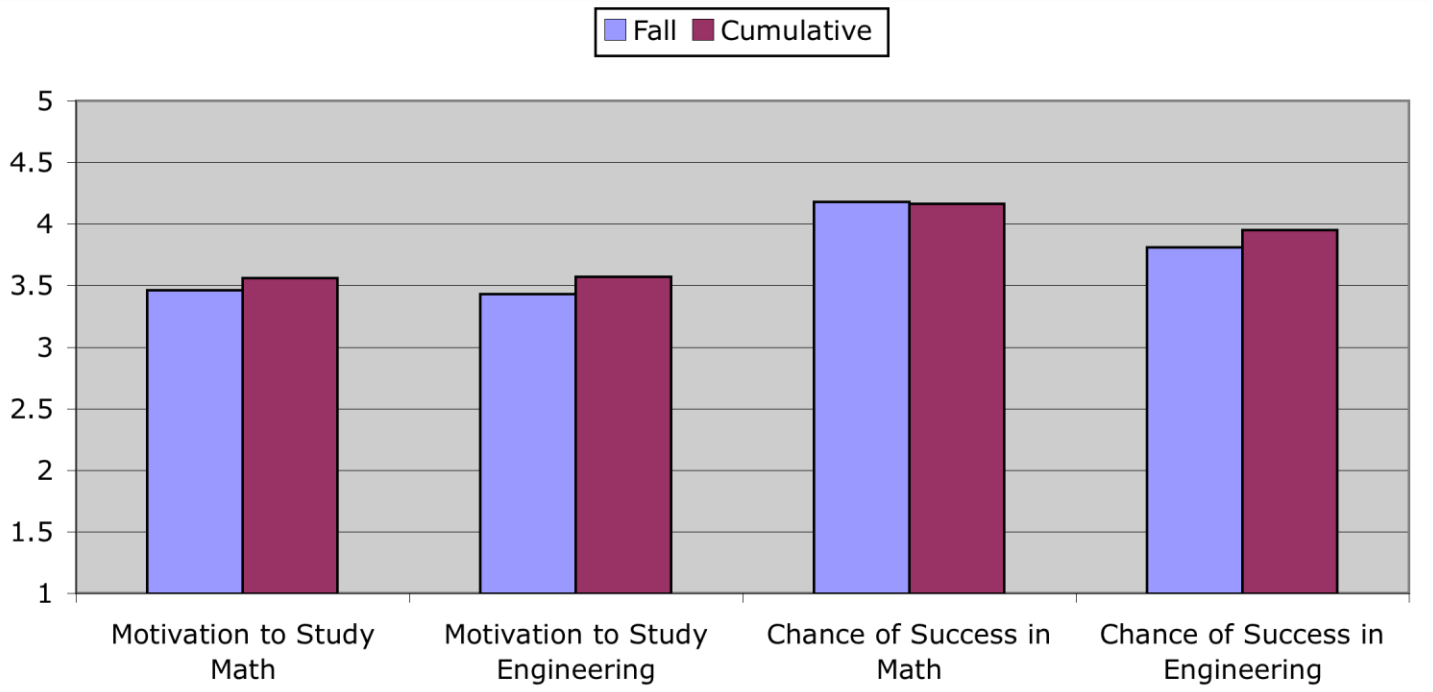


- Cumulative performance surpassed expectations, with 74% of students completing EGR 101 with a “C” or better
- Suggests the potential for a dramatic improvement in student retention and success in engineering

Student Perception

First Year of EGR 101

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

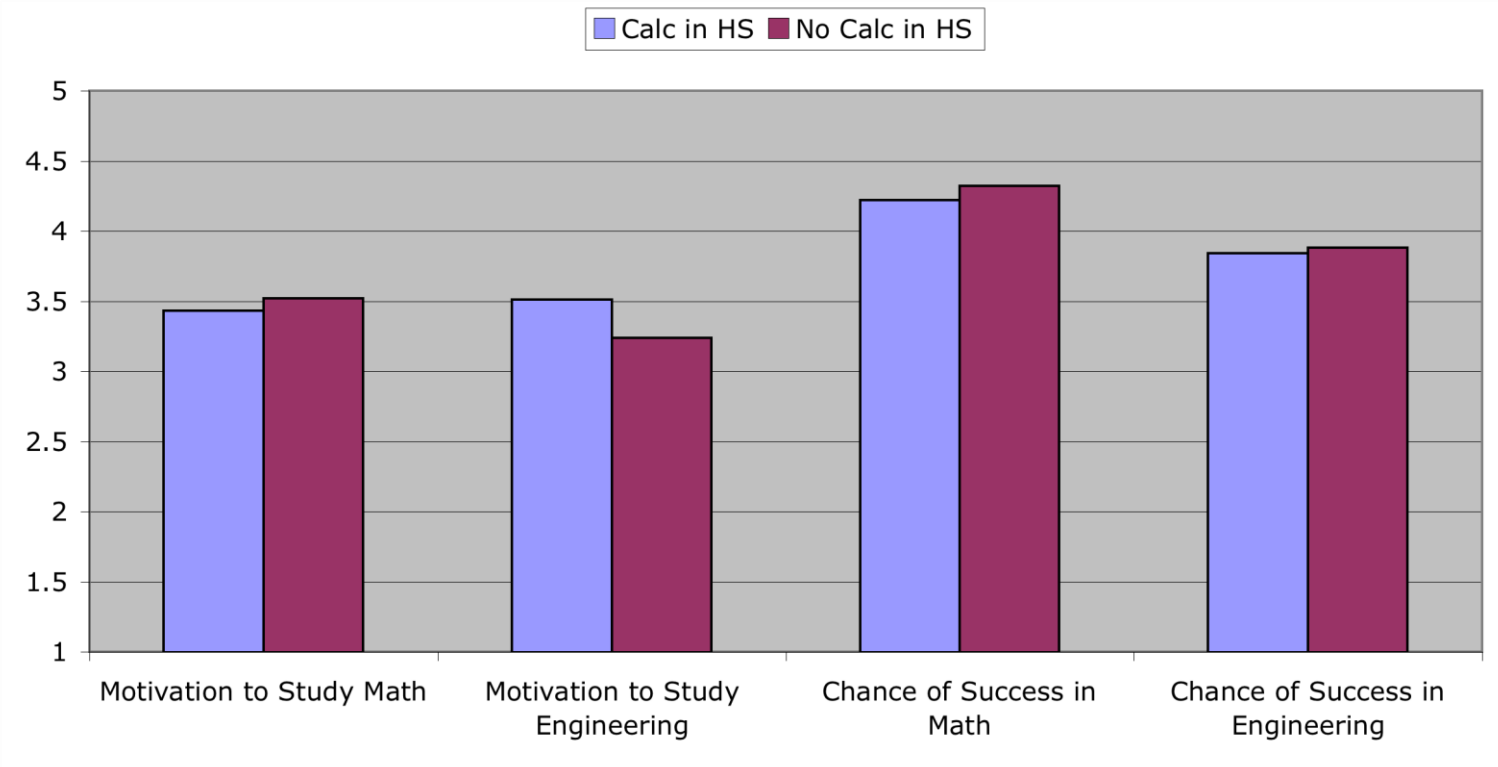


- Student perception of EGR 101 remained strong in subsequent quarters, even though the students were generally *less* prepared to be there!

Student Perception

EGR 101 First-Run, Fall 2004

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



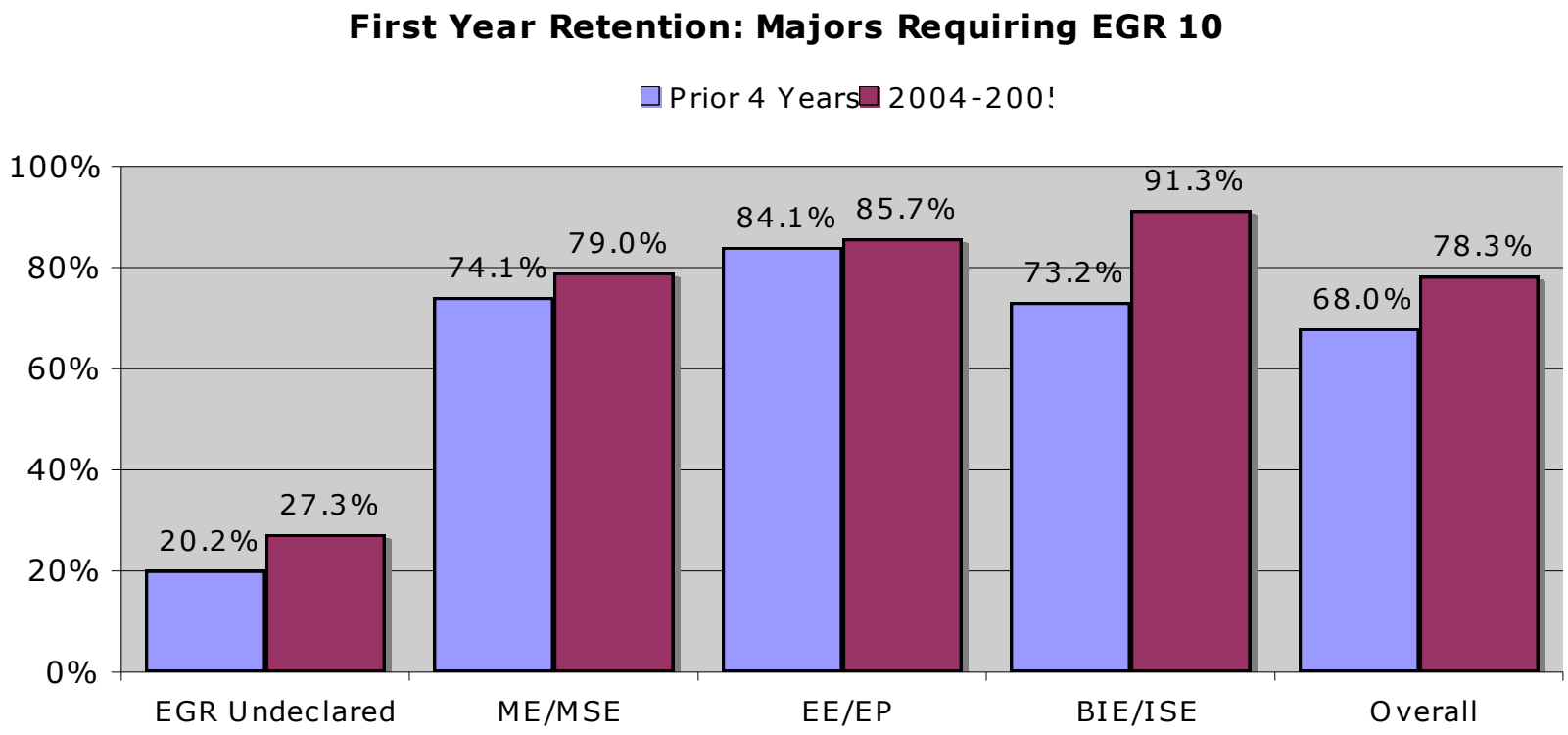
- EGR 101 increased student motivation and perceived chance of success in future math and engineering courses

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."

First-Year Retention

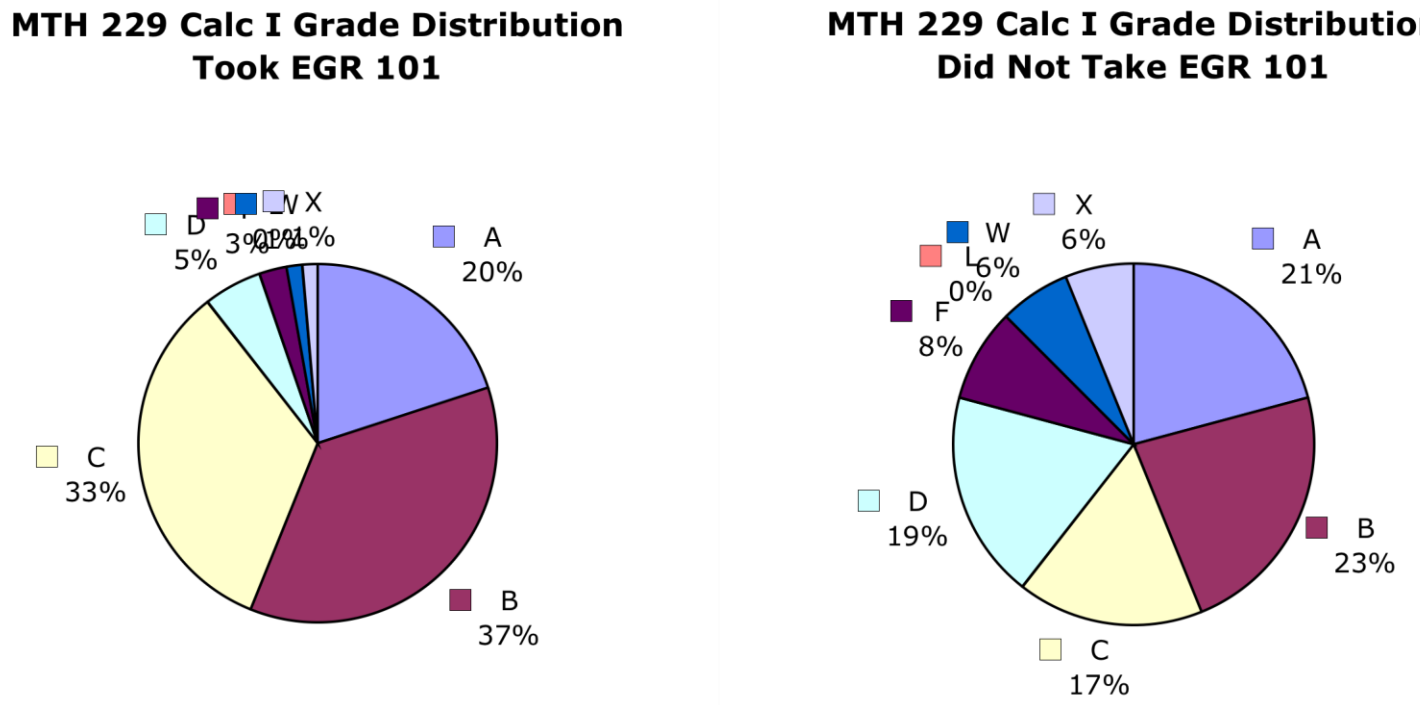
- Every department requiring EGR 101 saw an increase in first-year (Fall-to-Fall) retention in 2004-2005:



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

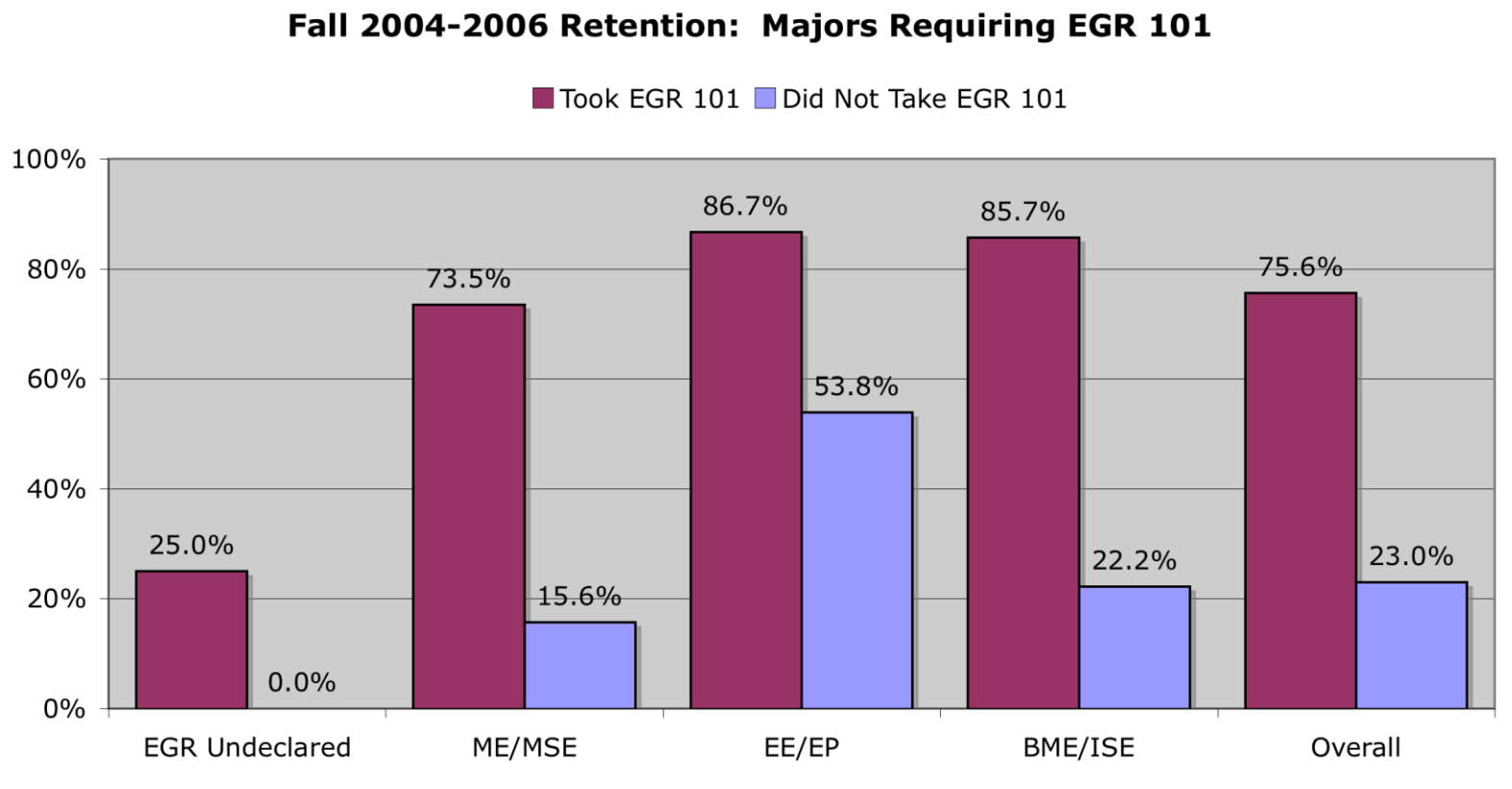
Student Performance in Calculus

(Fall 2004 Cohort)



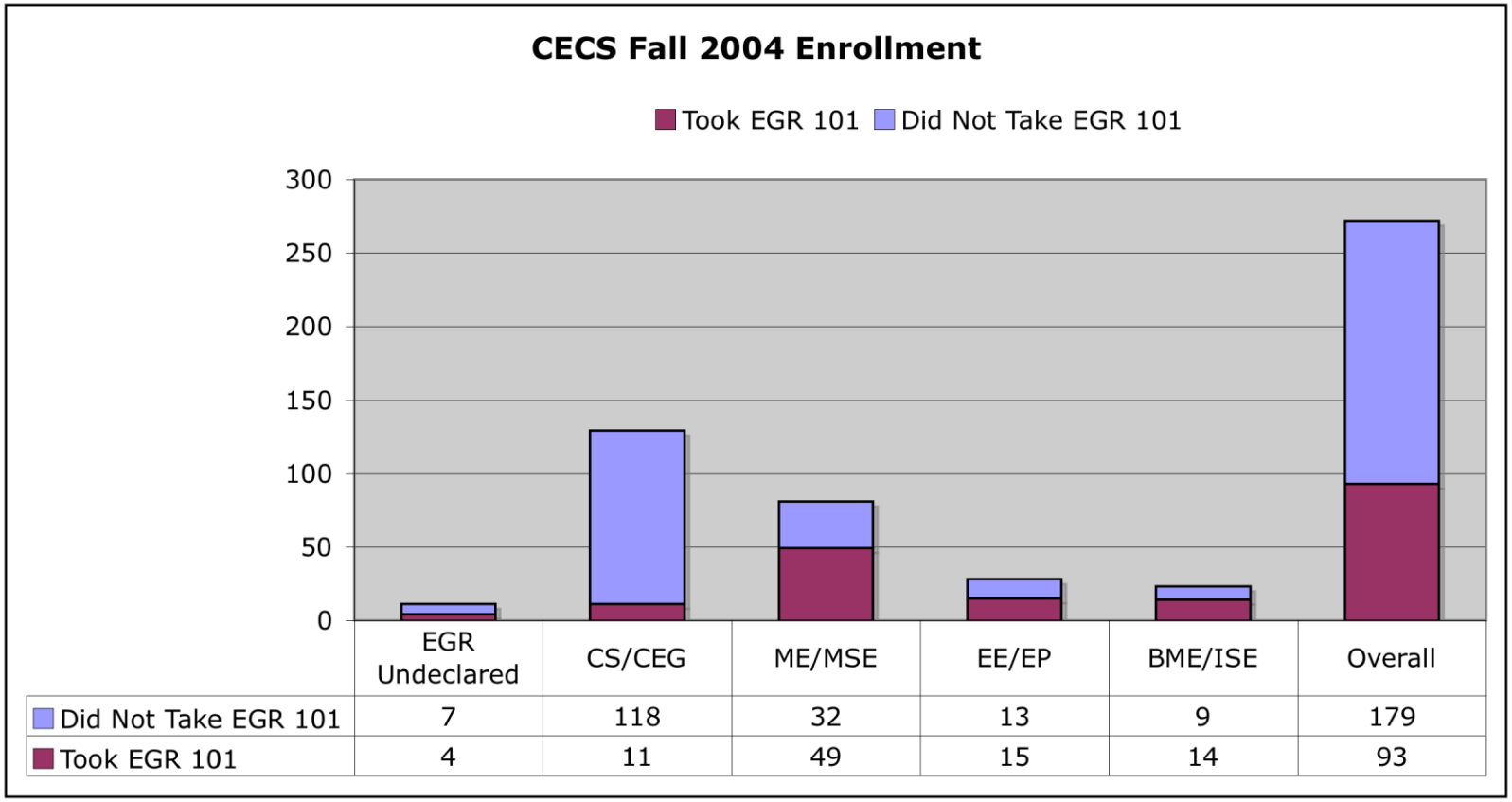
- Of the students ultimately enrolled in Calc I, 89% of those who took EGR 101 earned a “C” or better, compared to only 60% of those who did not

Two-Year Retention
(Majors Requiring EGR 101)



- 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%)

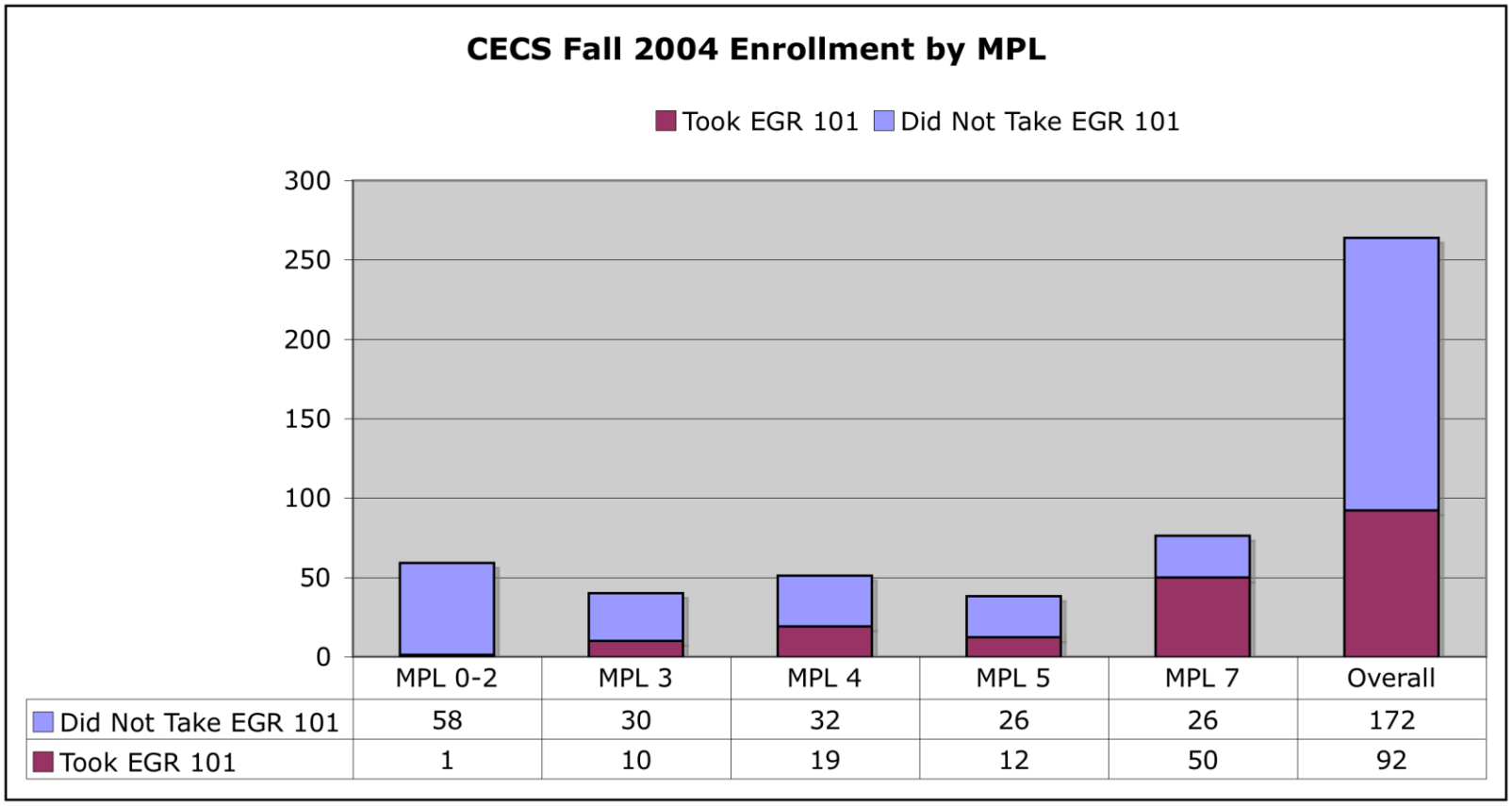
So Who Actually Took EGR 101?



	EGR Undeclared	CS/CEG	ME/MSE	EE/EP	BME/ISE	Overall
Did Not Take EGR 101	7	118	32	13	9	179
Took EGR 101	4	11	49	15	14	93

- Only about 1/3 of our total enrollment. The remaining 2/3 were either CS/CEG majors (do not require EGR 101), did not follow advising guidelines, or were just too far behind.

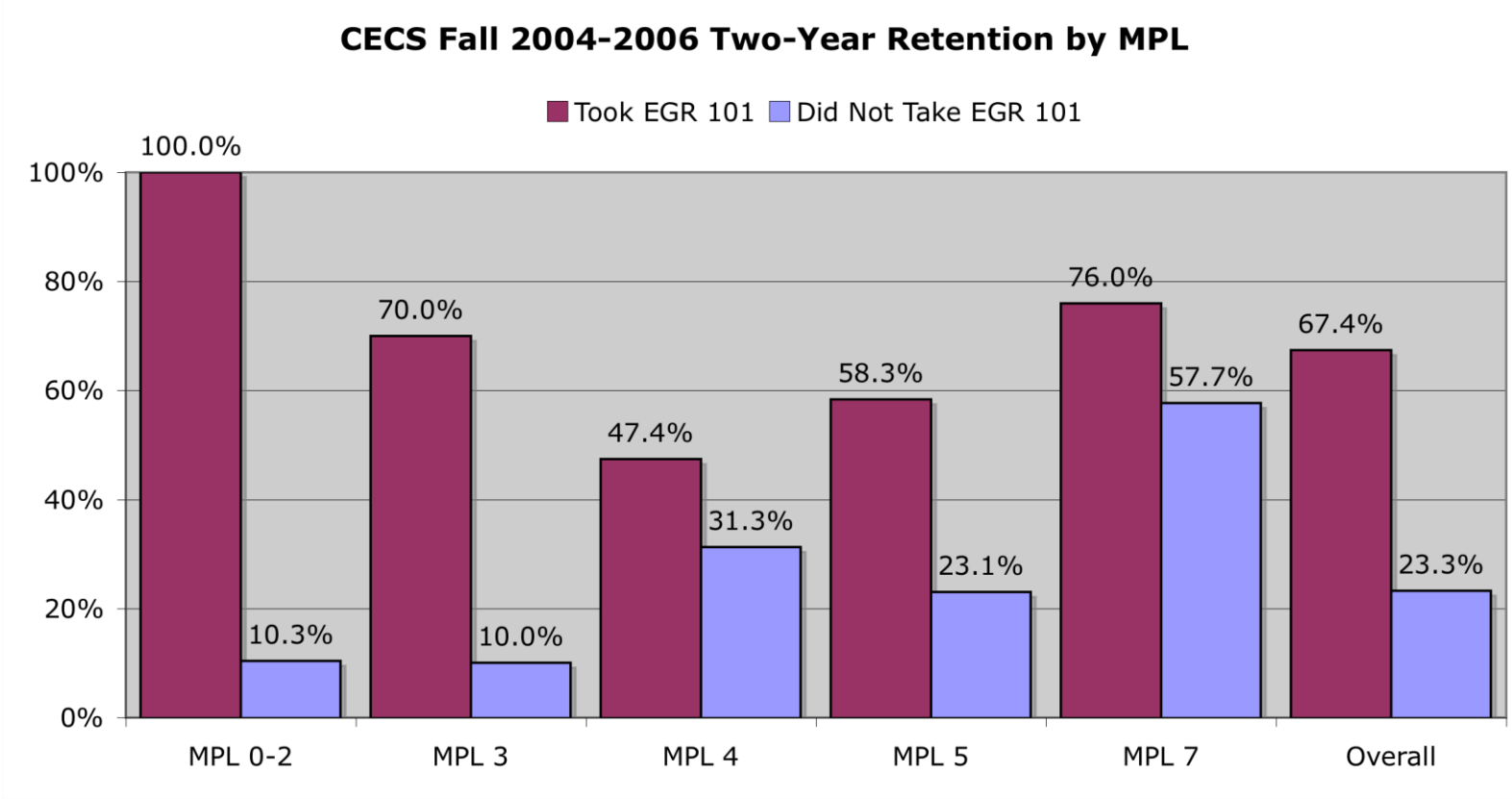
Did Only Our Best Students Ever Take EGR 101?



	MPL 0-2	MPL 3	MPL 4	MPL 5	MPL 7	Overall
Did Not Take EGR 101	58	30	32	26	26	172
Took EGR 101	1	10	19	12	50	92

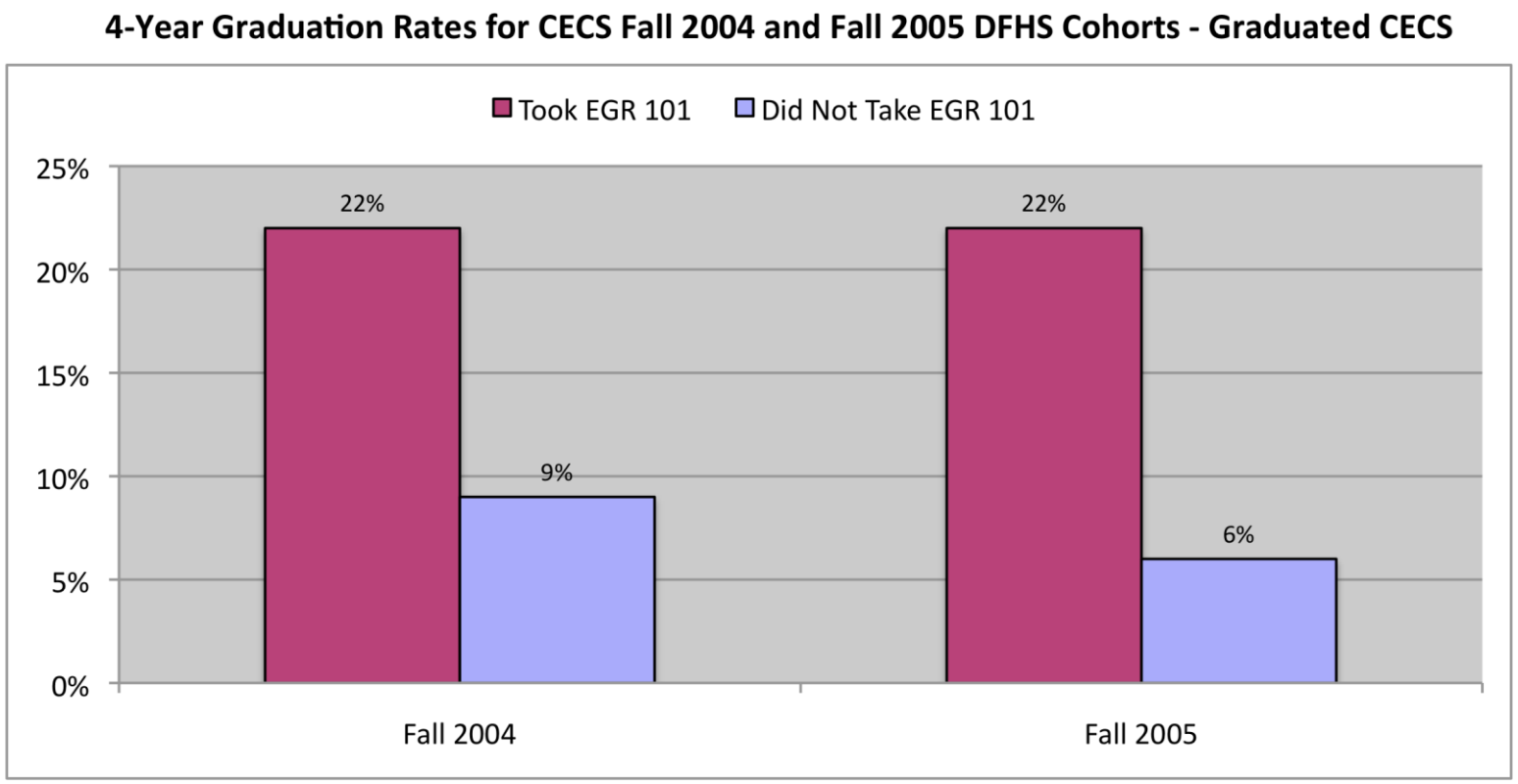
- Absolutely not! While the majority of our top students did take EGR 101, so did a significant number of initially underprepared students (MPL 4 and below).

And Apparently They Reaped What They Sowed…



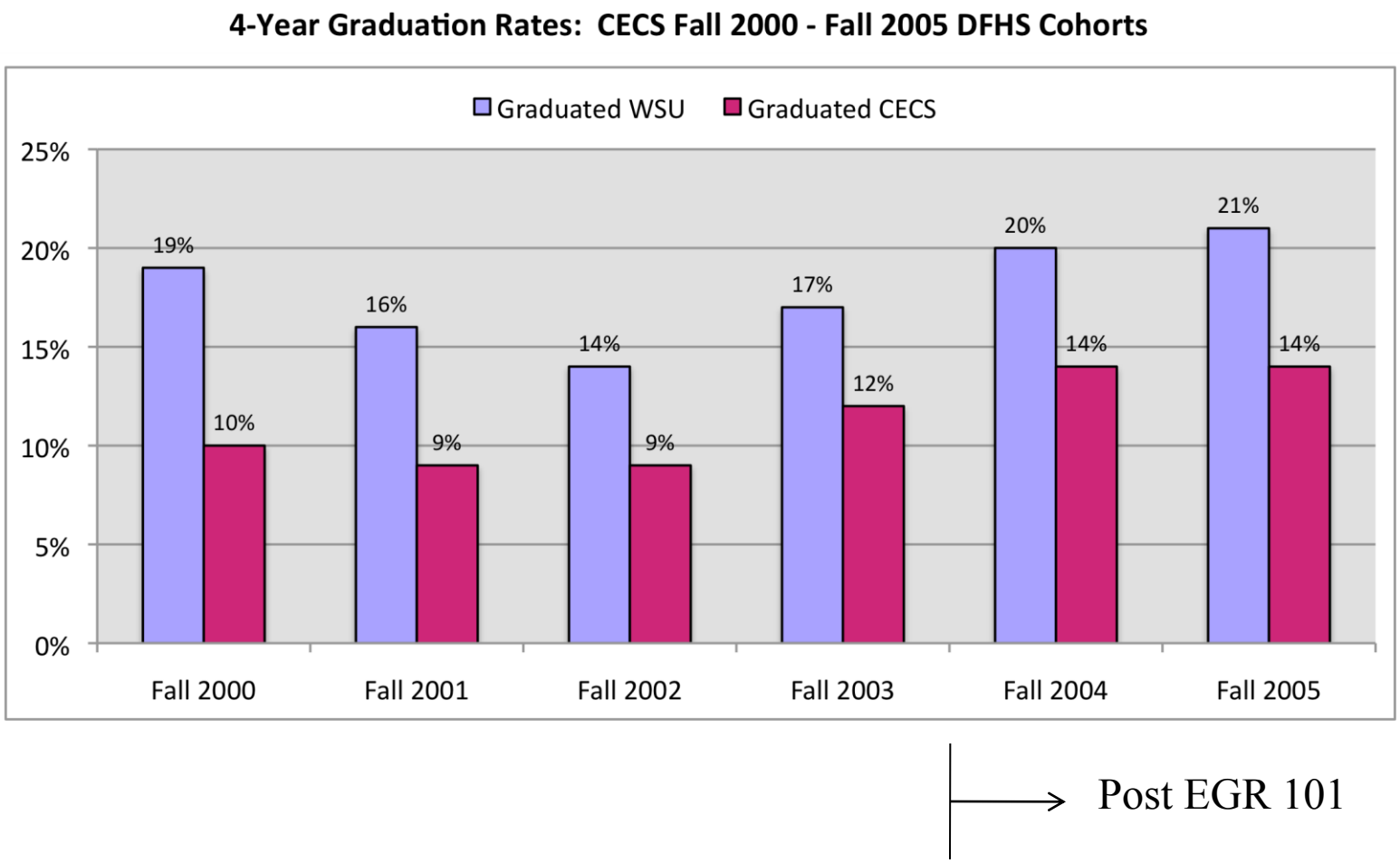
- EGR 101 and the associated curriculum reforms have had an overwhelming impact on the success of incoming students at *all* MPL levels.

All The Way Through Graduation!



- On average, students who took EGR 101 had 4-year graduation rates that were roughly 3 times greater than those of students who did not take the course.

Impact of EGR 101 on 4-Year Graduation Rates



- Even with only 1/3 of the population ever taking the course, EGR 101 had a measurable impact on College-wide graduation rates

So What About the *Rest* of the Students?

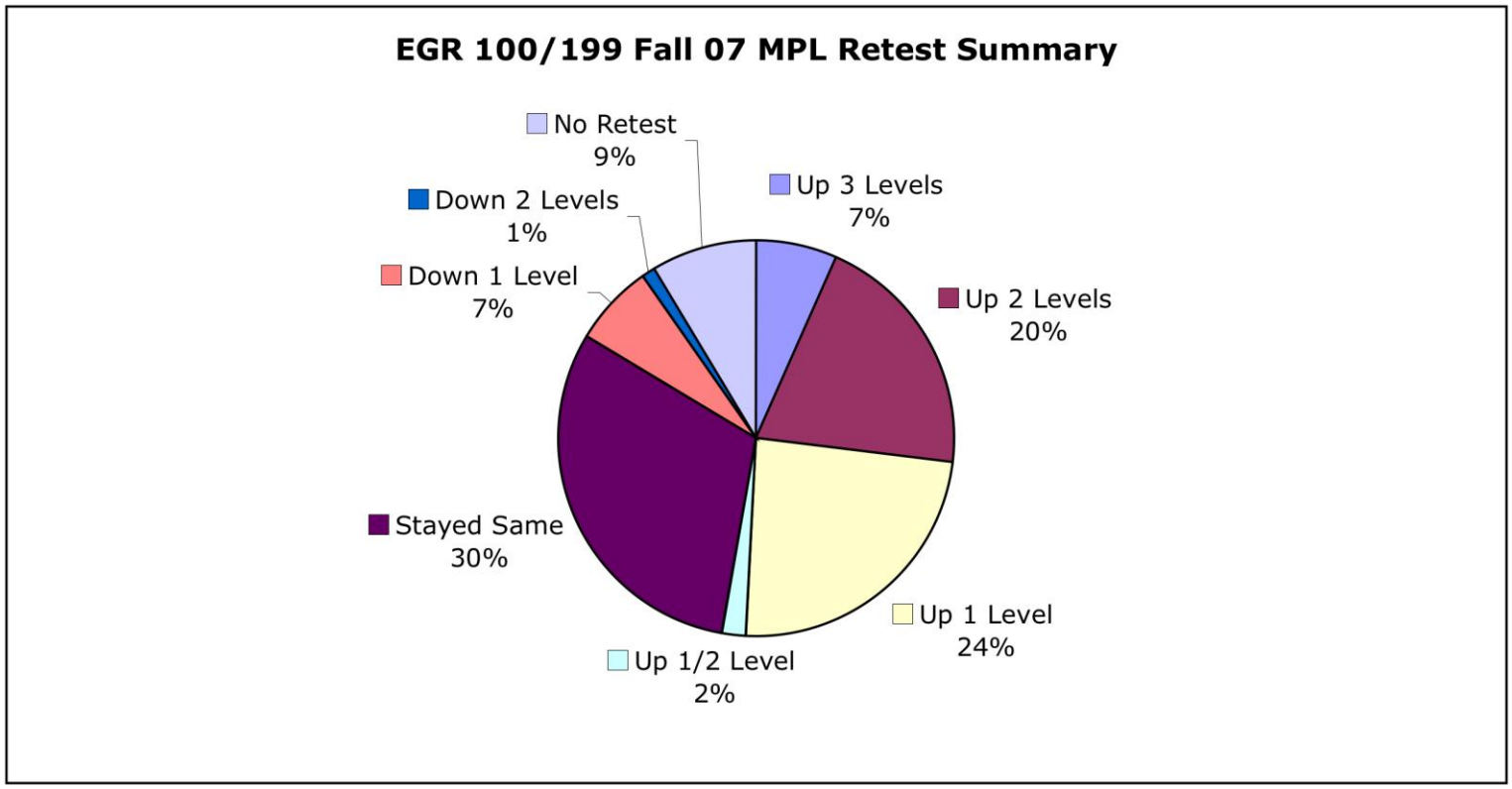
- Despite the success of EGR 101, our curriculum was still not immediately accessible to our *average* incoming student, who has an MPL of around 4.3

- 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

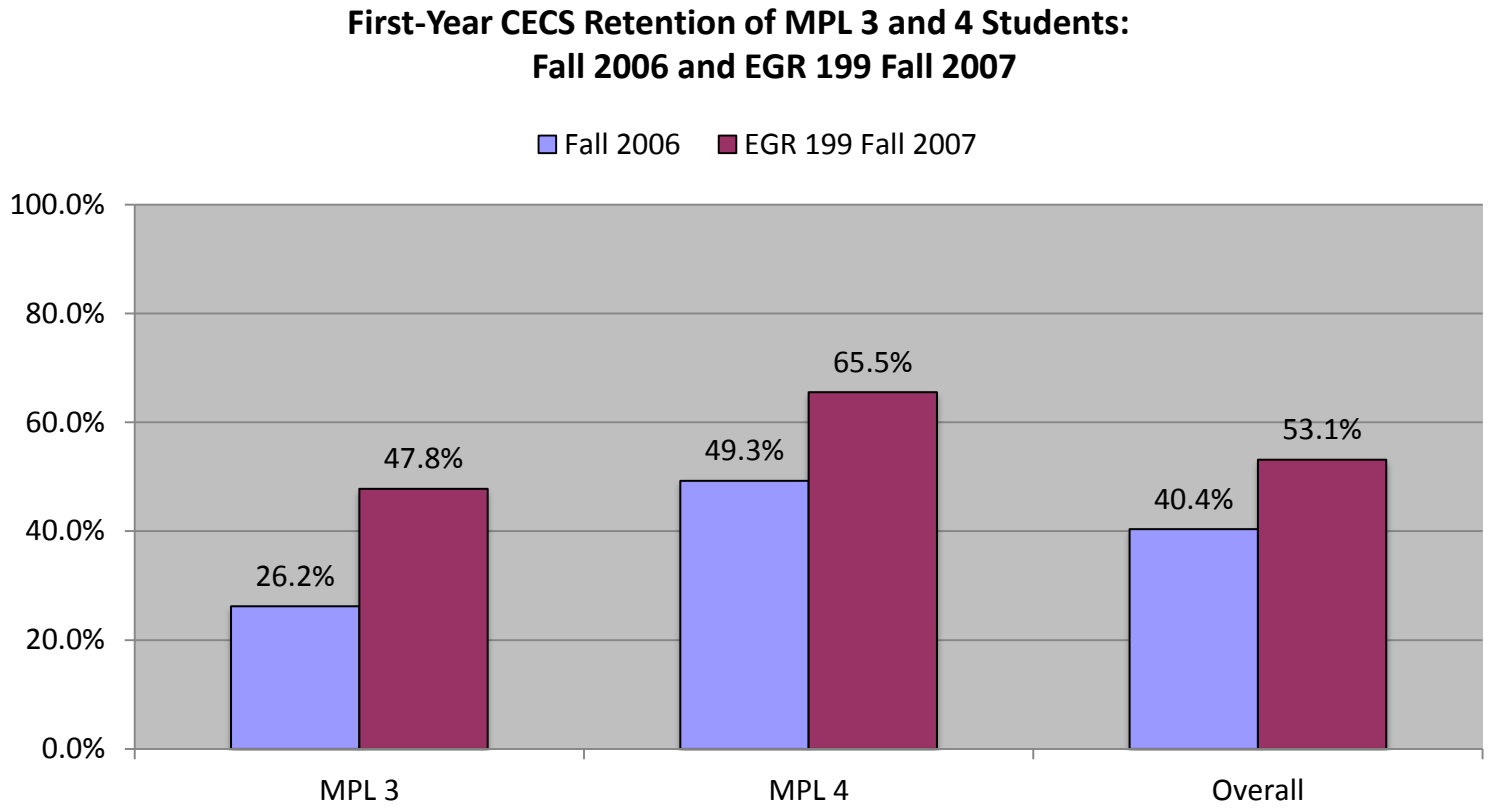
  - EGR 100/199 serves as an alternative prerequisite to EGR 101, and provides an opportunity for incoming students (including CS/CEG majors) to raise their MPL scores and avoid as many as three remedial math courses before advancing in their chosen degree programs

Results of EGR 100/199
(Initial Offering, Fall 2007)



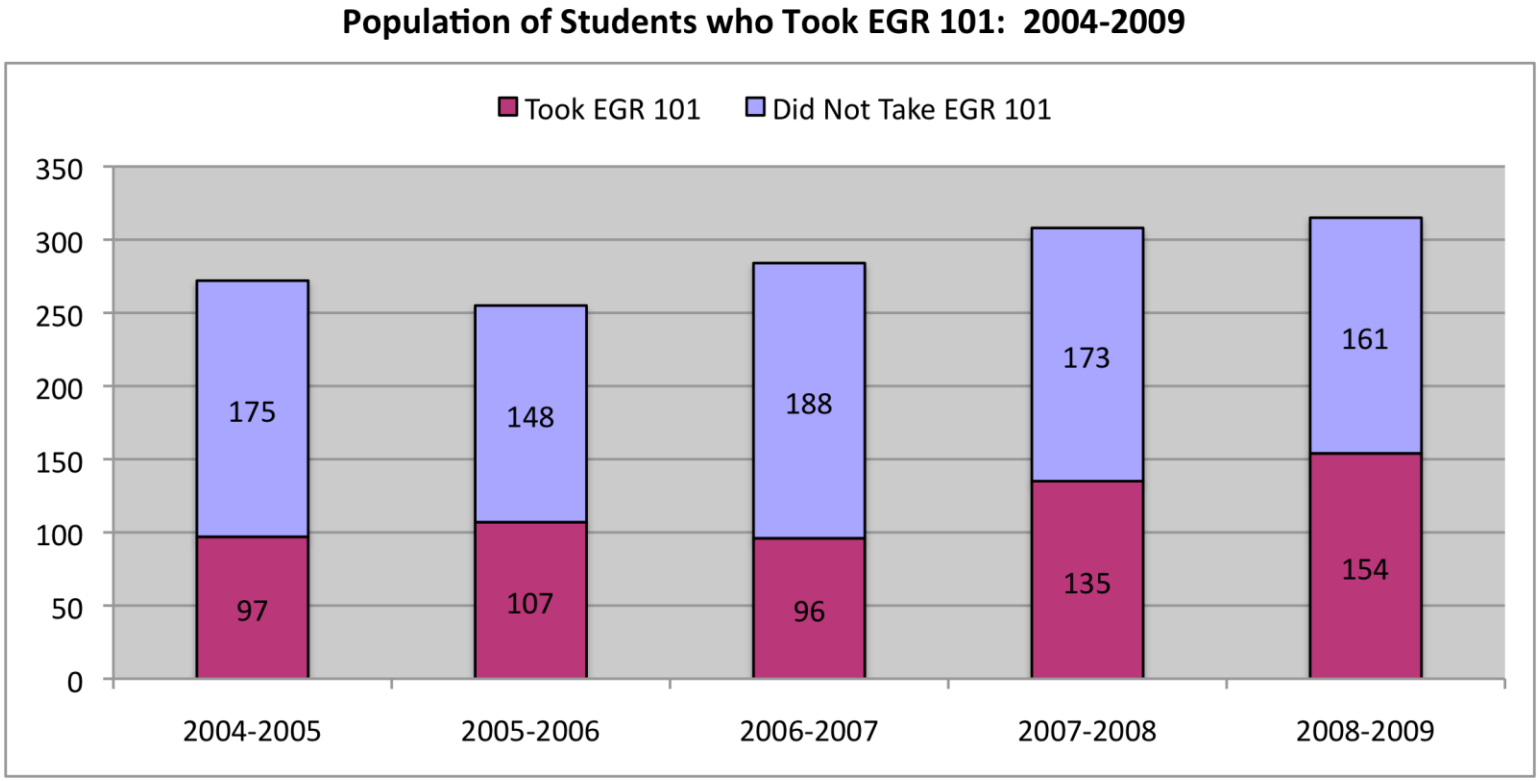
- The majority of EGR 199 students increased their MPL score by at least one level, and some by as many as three (avoiding an entire year of remedial math courses).

Results of EGR 100/199
(Initial Offering, Fall 2007)



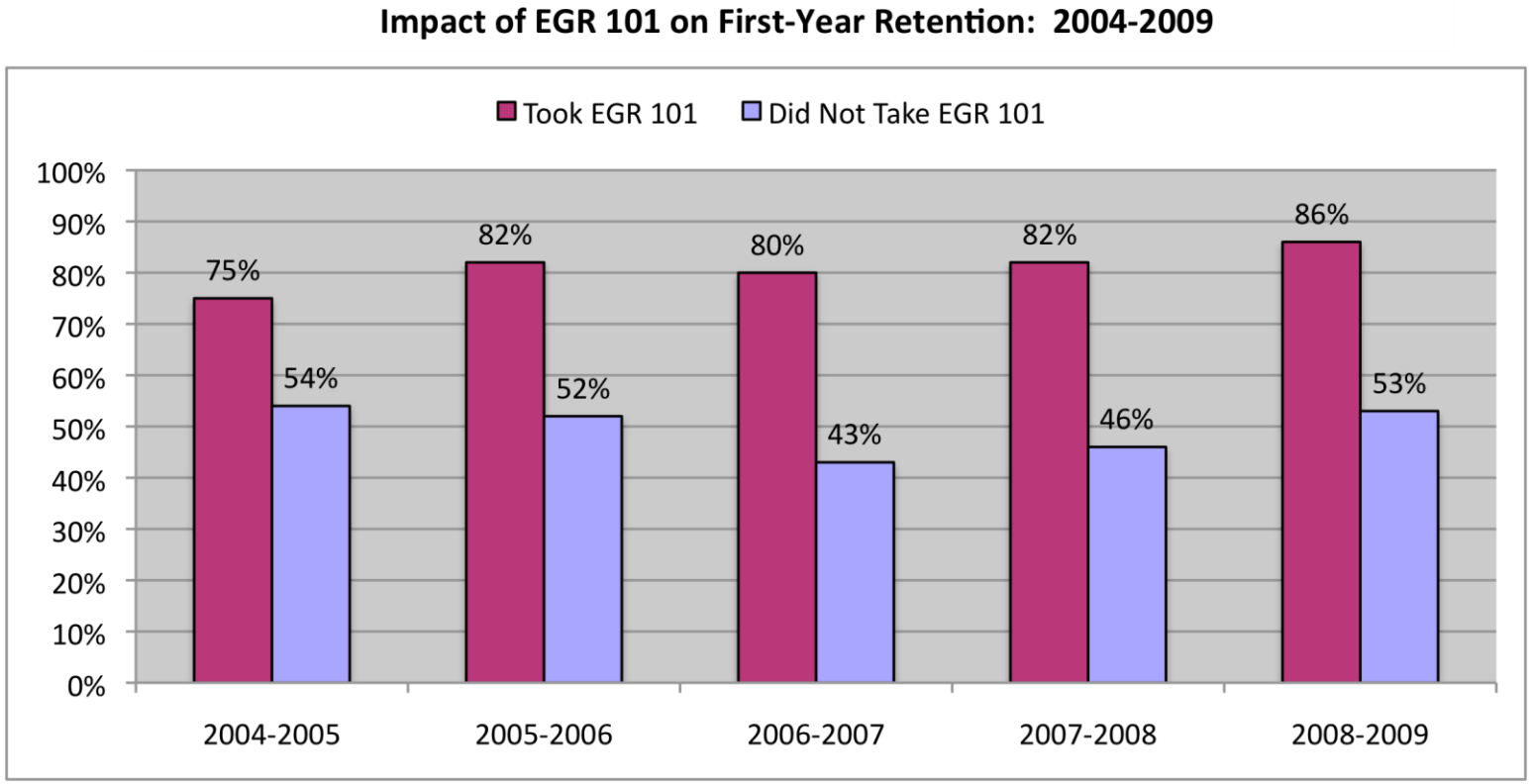
- The introduction of EGR 100/199 nearly doubled the first-year retention rate of MPL 3 students, and had a significant impact on MPL 4 students as well.

Impact of EGR 100/199 on Student Enrollment in EGR 101



- The introduction of EGR 100/199 has increased the number of first-year students enrolled in EGR 101 by roughly 50%.

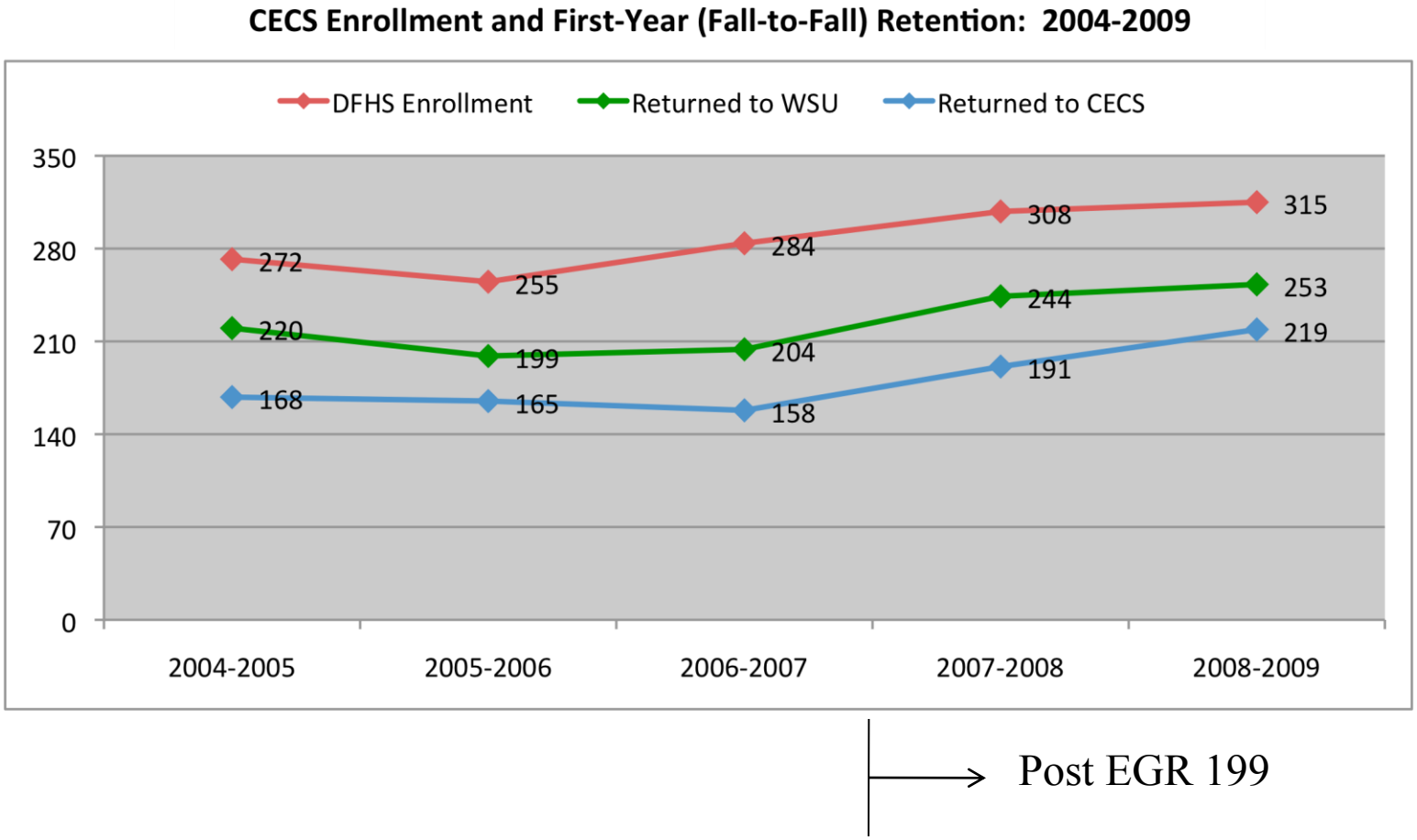
Impact of EGR 101 on First-Year Retention: Post EGR 199



Post EGR 199

- Despite a significant increase in the number of initially underprepared students enrolled in the course, first-year retention for students who took EGR 101 has now reached an all-time high of 86%.

In Terms of Raw Numbers…



- It is estimated that the combination of EGR 101 and EGR 100/199 has resulted in at least 30 additional sophomores per year in the Wright State engineering programs.

Pre-College Implementations of EGR 101 Materials

- Dual-Enrollment of EGR 101 at Dayton-area high schools
  - Bellbrook High School in Fall 2008 and 2009
  - Multiple additional school districts under consideration
- Dayton Regional Summer STEM Academy: Three week summer program for rising juniors and seniors (with credit for College Algebra at Clark State and Sinclair Community Colleges)
- 36 week high school engineering mathematics curriculum under development at Chantilly Academy (Fairfax County, VA)

NSF CCLI Phase 2 Program

"A National Model for Engineering Mathematics Education"

Grant Number DUE-0618571, 08/15/06-07/31/10.

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 Type 1 Program

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

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

PI: N. Klingbeil (Replacing M. Wheatly)
Co-PI's: K. Koenig, 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

NSF CCLI Phase 3 Program

"A National Model for Engineering Mathematics Education"

Grant Number DUE-0817332, 08/01/08-07/31/12

Total Funding: $2,000,000

15 Collaborating Institutions:

California Baptist University, California State University-Long Beach, Chantilly Academy (Fairfax County Public Schools, VA), Oklahoma Christian University, Oklahoma State University, San Antonio College, Texas A&M University - Kingsville, University of Cincinnati, 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

Summary

- We propose an application-driven, just-in-time approach to engineering mathematics education, 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 Wright State Model has the potential for an extremely broad impact, including significant increases in retention and graduation rates at universities across the country

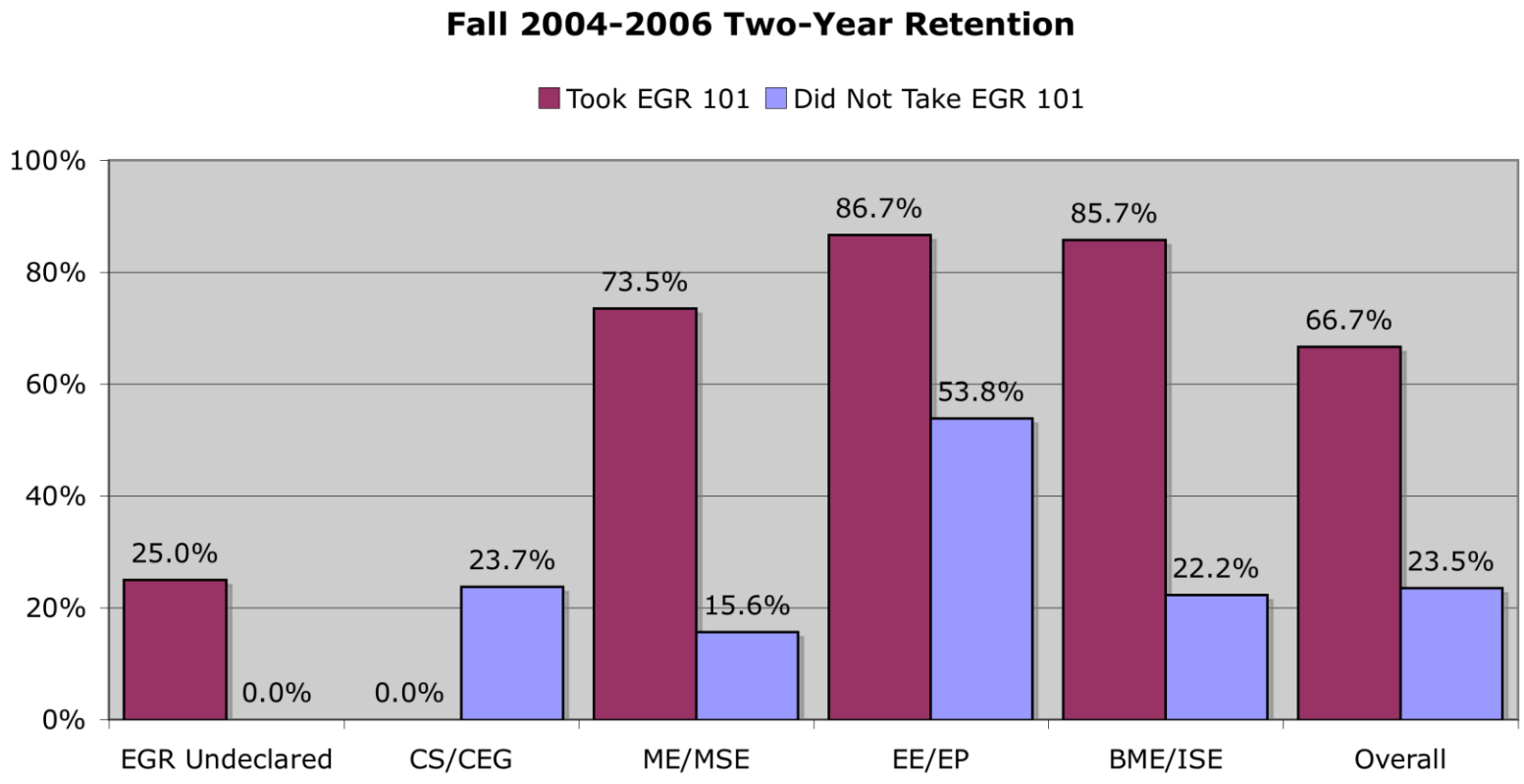
Questions



Assessment

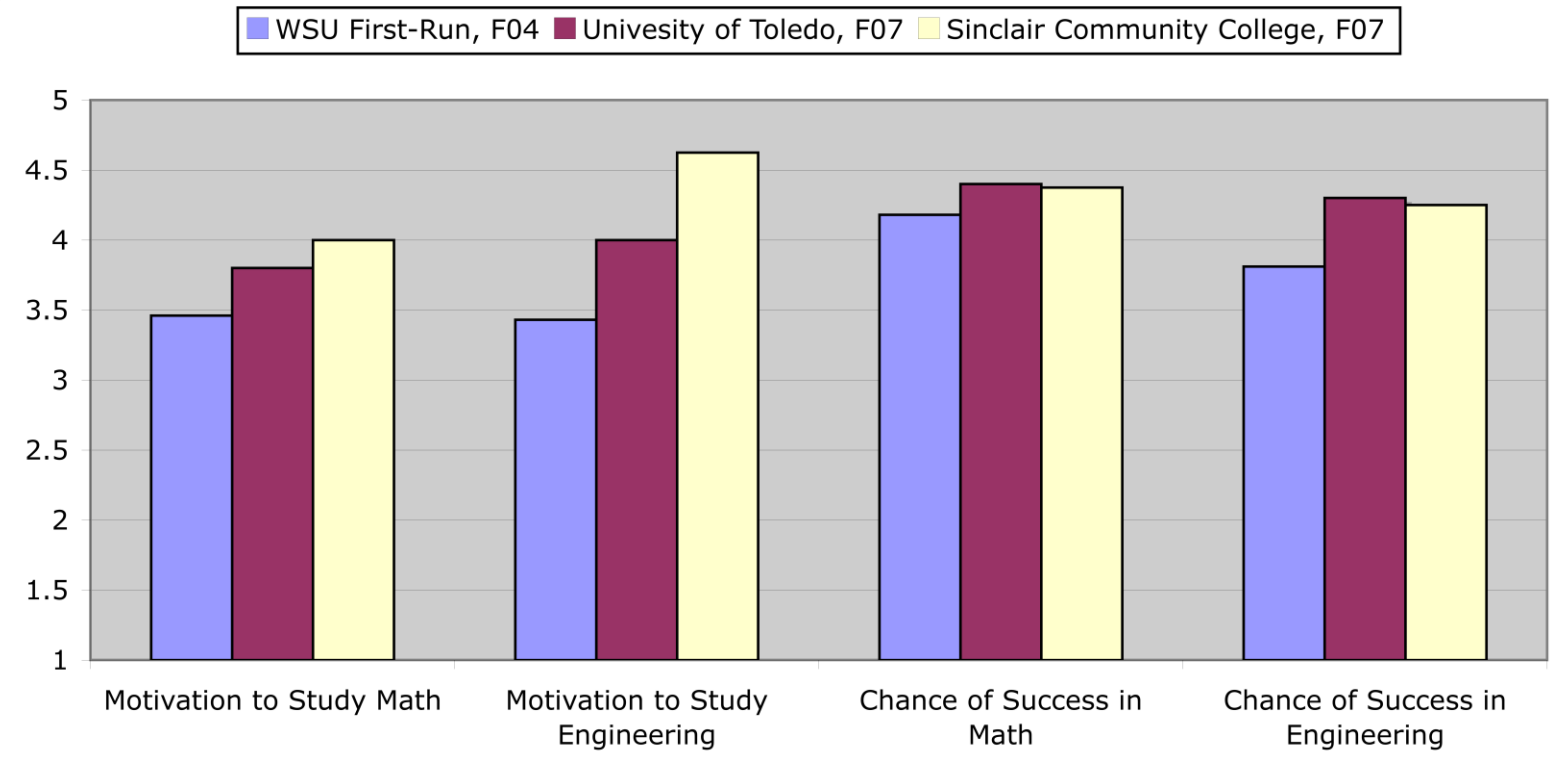
- WSU has obtained multi-year NSF support to provide a rigorous evaluation of the program, and to enable a widespread dissemination of results
- Quantitative data readily available on student
  - Retention in engineering
  - Success in future math and engineering courses
  - Ultimate graduation rates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

Two-Year Retention
(College-Wide)



- Of the 11 CS/CEG students who took EGR 101, none was retained in CS/CEG. However, 5 were retained in other CECS majors (45.4%)…

Results at Collaborating Institutions



- Student perception following the Fall 2007 implementations at Sinclair and Toledo was even stronger than that following the inaugural offering at WSU