Predicting Student Performance in University Introductory Physics: The Role of Physics Concepts and Math Skills.

Is there a physics placement test?

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20 year continuing project to improve undergraduate education with contributions by:
Many faculty and graduate students of U of M Physics Department
In collaboration with U of M Physics Education Group

Details at http://groups.physics.umn.edu/physed/

Supported in part by Department of Education (FIPSE), NSF, and the University of Minnesota

1. **Two Populations Both Calculus Based Physics**
   - **Engineering and Physical Science Majors (77% male)**
     Emphasizing the behavior of single objects
   - **Pre-med and Biological Science Majors (59% female)**
     Emphasizing the behavior of complex systems

2. **Measuring Basic Physics Concepts (FCI).**
   - **Gender Differences?**
   - **Predict Success?**

2. **Measuring Math Skills**
   - **Gender Differences?**
   - **Predict Success?**

3. **Correlations and Background factors?**
   - **High School Physics**
   - **High School Math**

U of M Physics Course Structure

Not applied perfectly

LECTURES

Three hours each week, sometimes with informal cooperative groups. Model constructing knowledge, model problem solving framework.

DISCUSSION SECTION

One hour each Thursday -- groups practice using problem-solving framework to solve context-rich problems in cooperative groups. Peer & instructor coaching.

LABORATORY

Two hours each week -- *same* cooperative groups practice using framework to solve concrete experimental problems. *Same* TA. Peer & instructor coaching.

TESTS

Friday -- problem-solving quiz & conceptual questions (usually multiple choice) every three weeks.

6% drop out rate, 3% D/F rate

Engineering and Physical Science Students Topics – first semester
Emphasizing the behavior of single objects

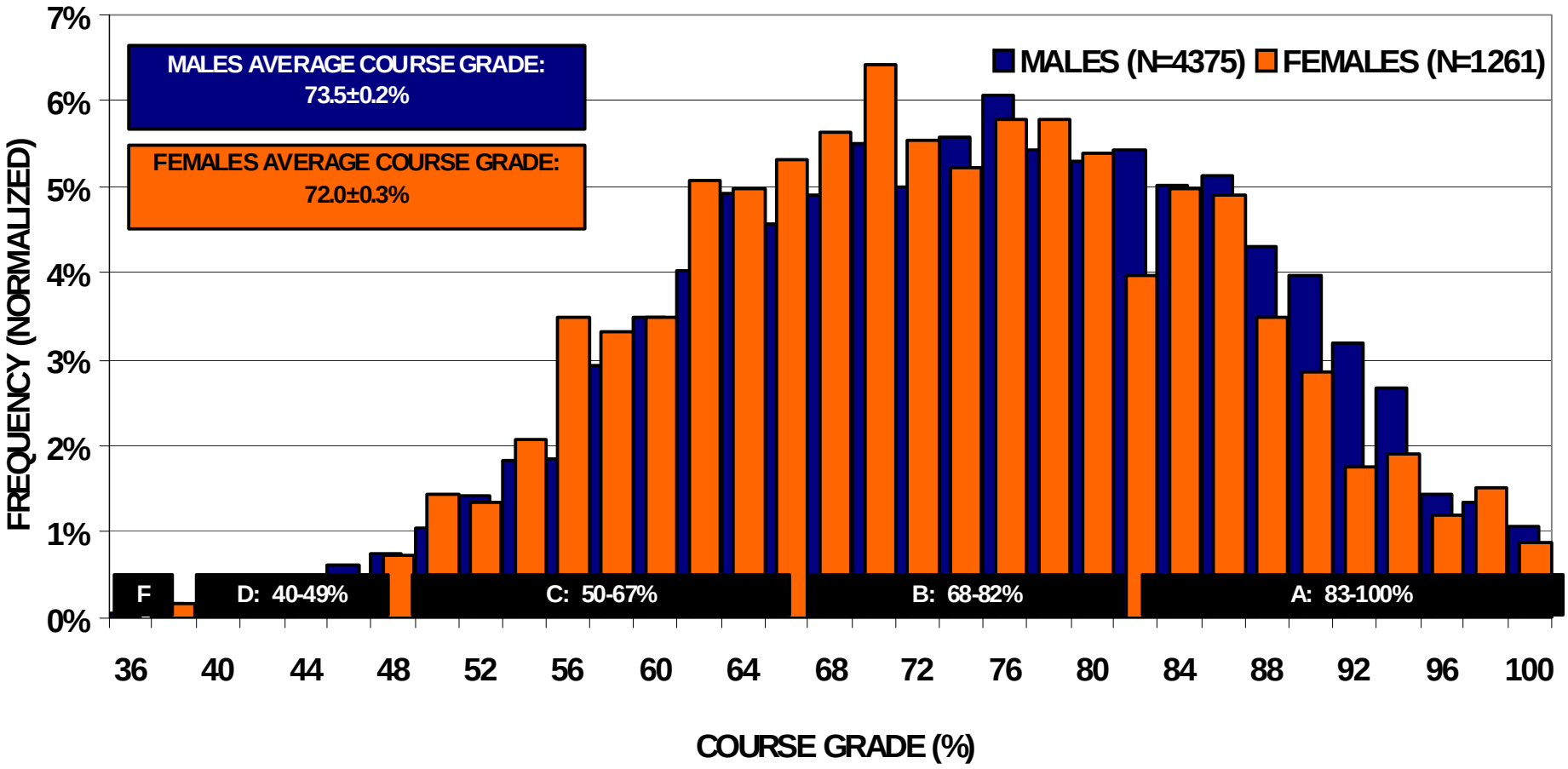
- **Kinematics – constant acceleration (2 wks)**
- **Circular motion & relative motion (1 wk)**
- **Forces and acceleration (3 wks)**
- **Energy (2 wks)**
- **Momentum (1 wk)**
- **Rotations (1 wk)**
- **Angular momentum (2 wks)**
- **Statics (1 wk)**
- **Oscillations (2 wks)**

Pre-Med and Biological Science Students Topics – first semester
Emphasizing the behavior of complex systems

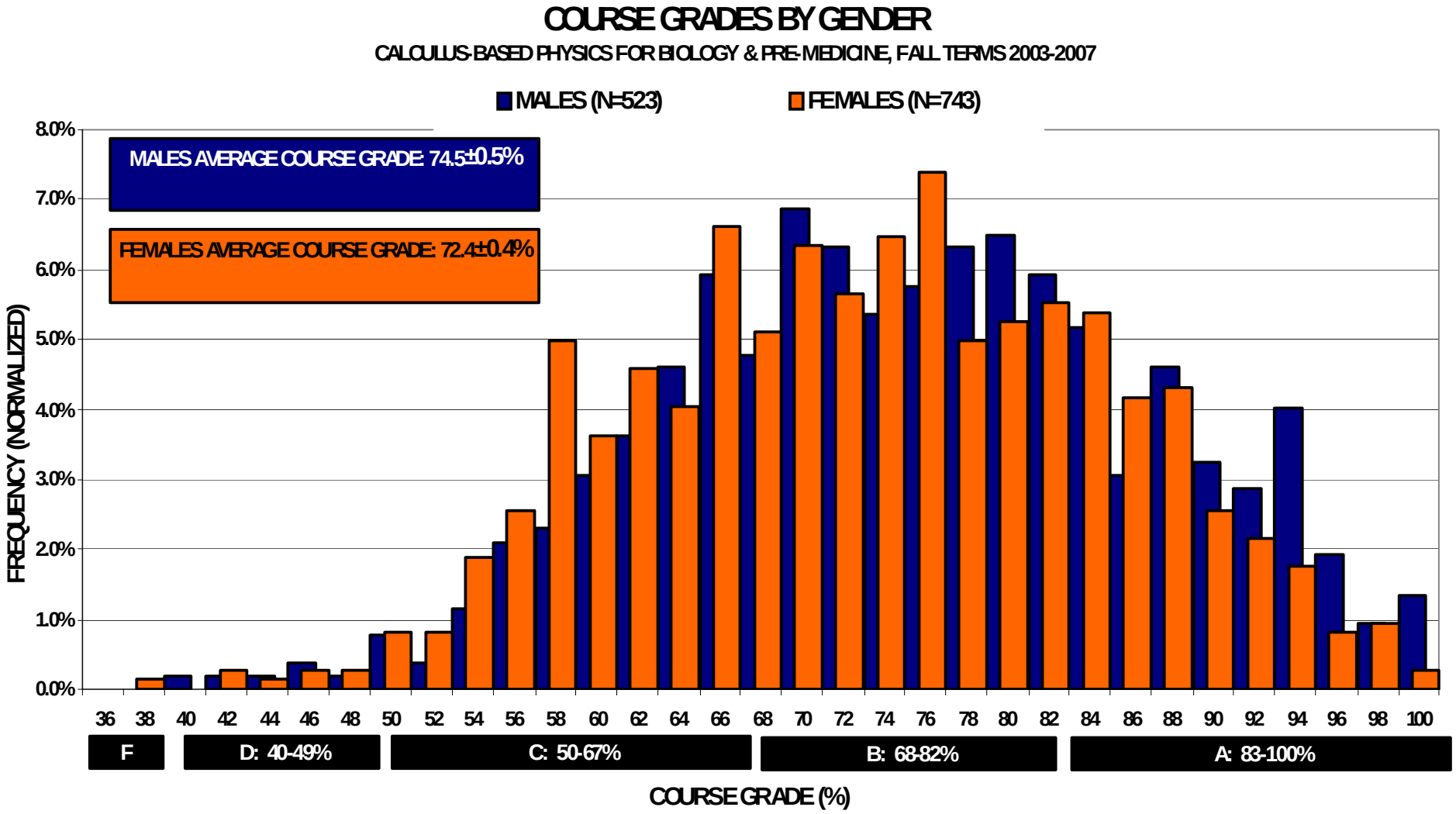
- **Forces and Torque in Equilibrium including fluids (3 wks)**
- **Energy including fluid flow (4 wks)**
- **Forces and acceleration including oscillations (2 wks)**
- **Kinematics including non-constant acceleration (2 wks)**
- **Thermodynamics (4 weeks)**

COURSE GRADES BY GENDER

CALCULUS-BASED PHYSICS FOR SCIENTISTS & ENGINEERS, FALL TERMS 1997-2007

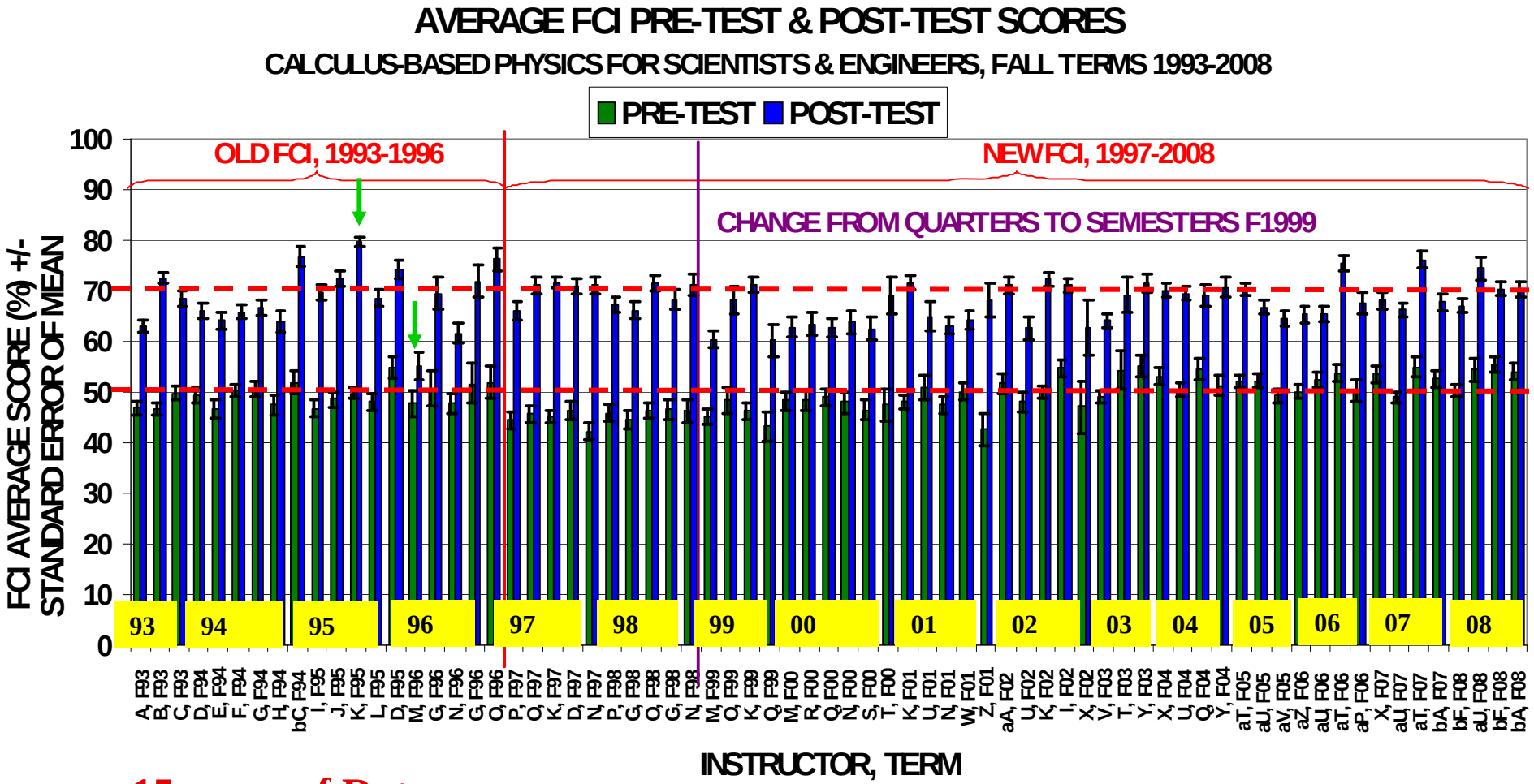


Males and females do about as well in the course.
Absolute grading scale.



Males and females do about as well in the course.

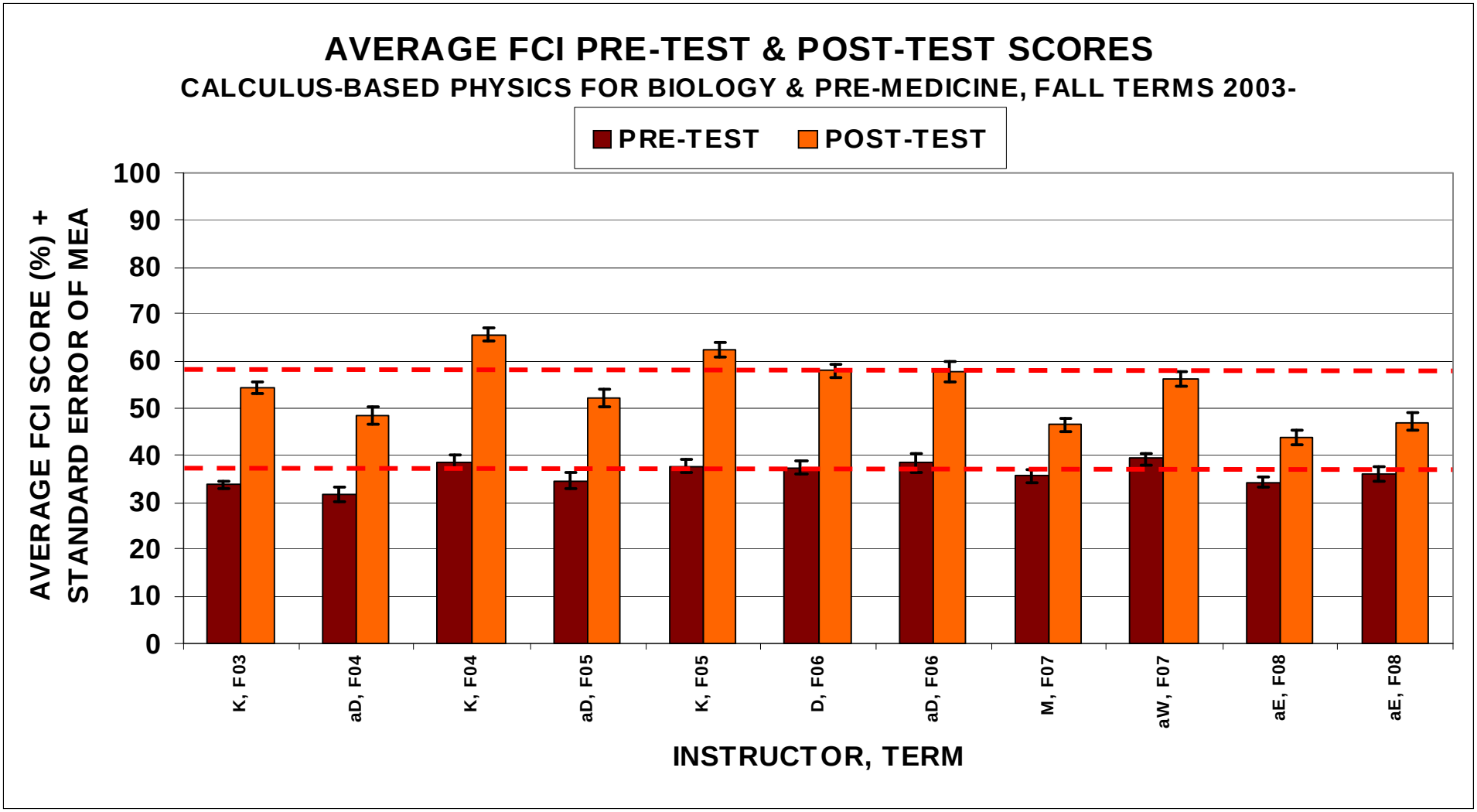
Students do about as well as in course for Engineering & PS students



15 years of Data

Each letter represents one of 37 different professors

- **Incoming student scores are slowly rising (better high school preparation)**
- **Our standard course (CGPS) achieves average FCI ~70%**
- **Our "best practices" course achieves average FCI ~80%**
- **Not executing any cooperative group procedures achieves average FCI ~50%**

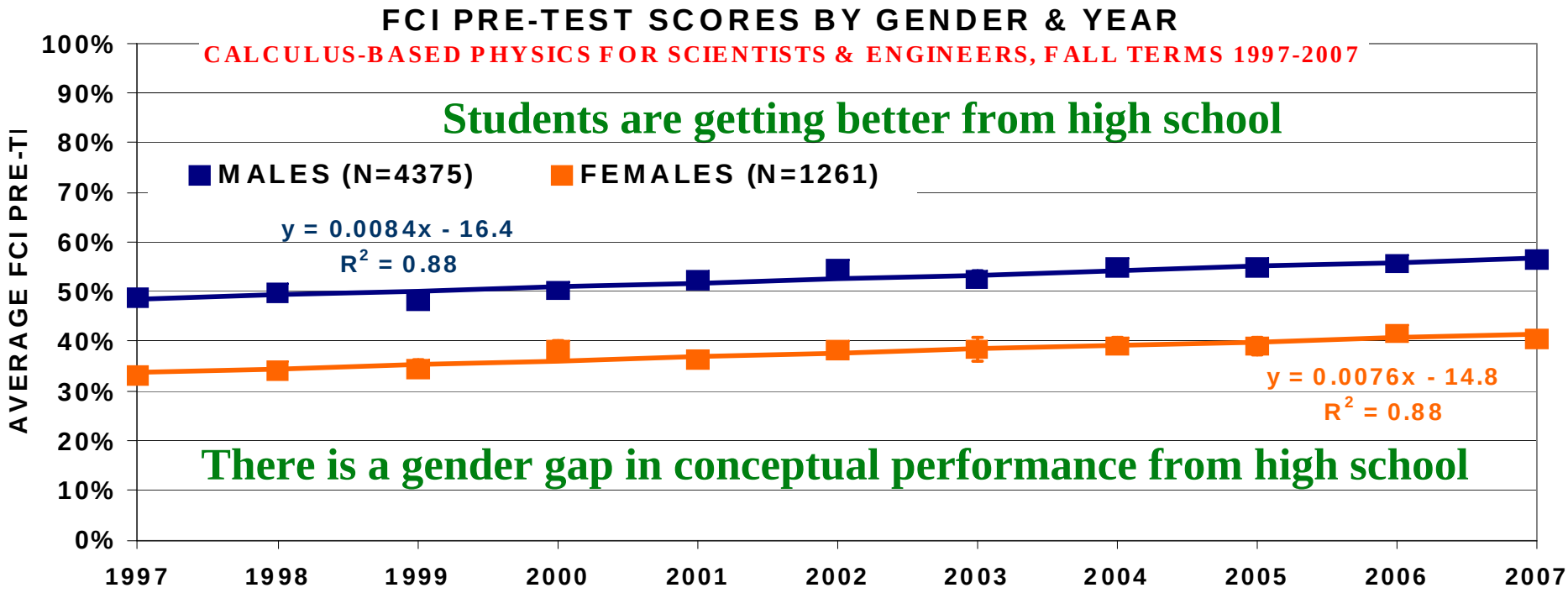


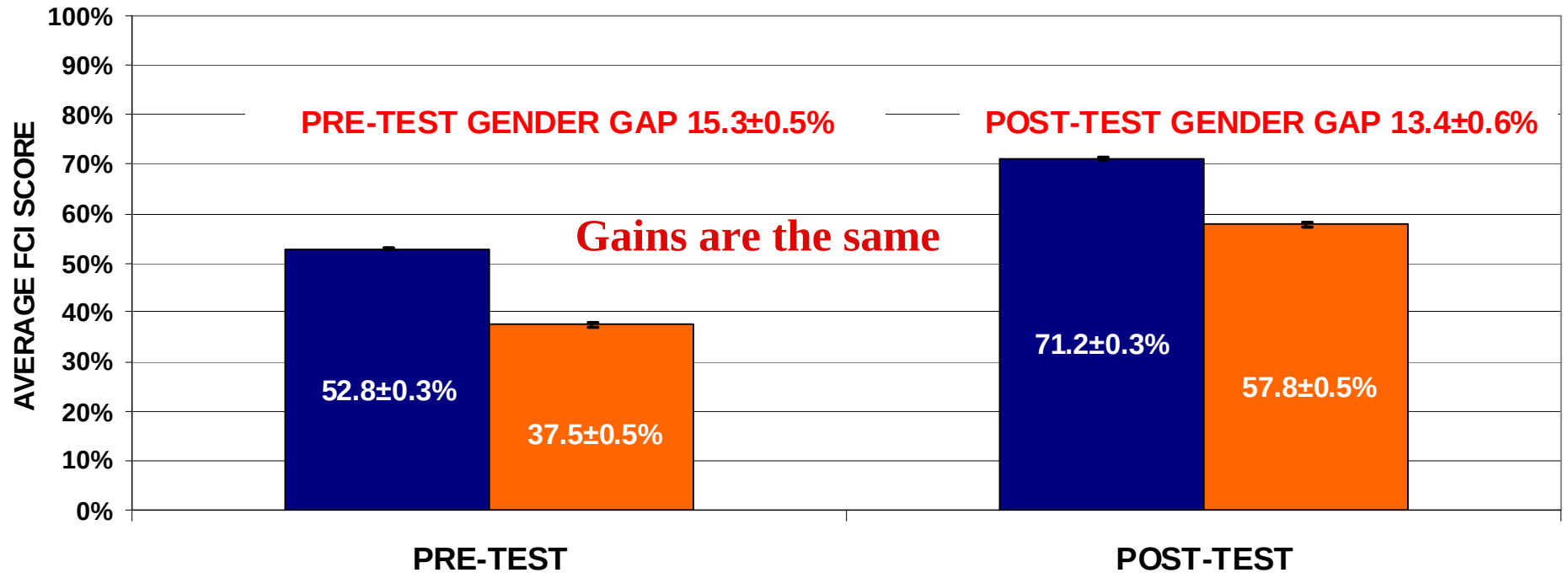
5 years of Data

Each letter represents one of 6 different professors

Course is still under development

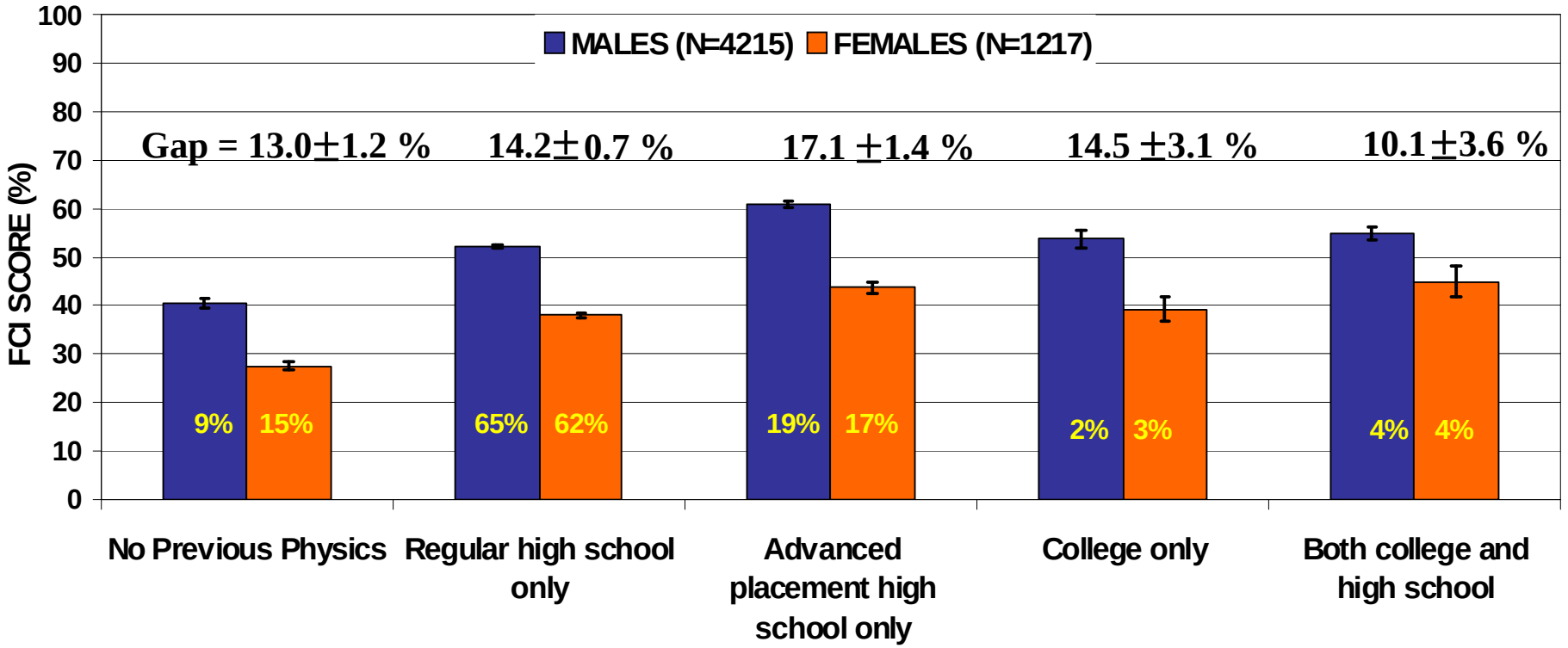
Gains are the same as in course for Engineers and Physical Science Students


FCI PRE-TEST SCORES BY GENDER & YEAR
CALCULUS-BASED PHYSICS FOR SCIENTISTS & ENGINEERS, FALL TERMS 1997-2007
Students are getting better from high school
MALES (N=4375)
FEMALES (N=1261)
y = 0.0084x - 16.4
R2 = 0.88
y = 0.0076x - 14.8
R2 = 0.88
There is a gender gap in conceptual performance from high school
AVERAGE FCI PRE-TI
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007

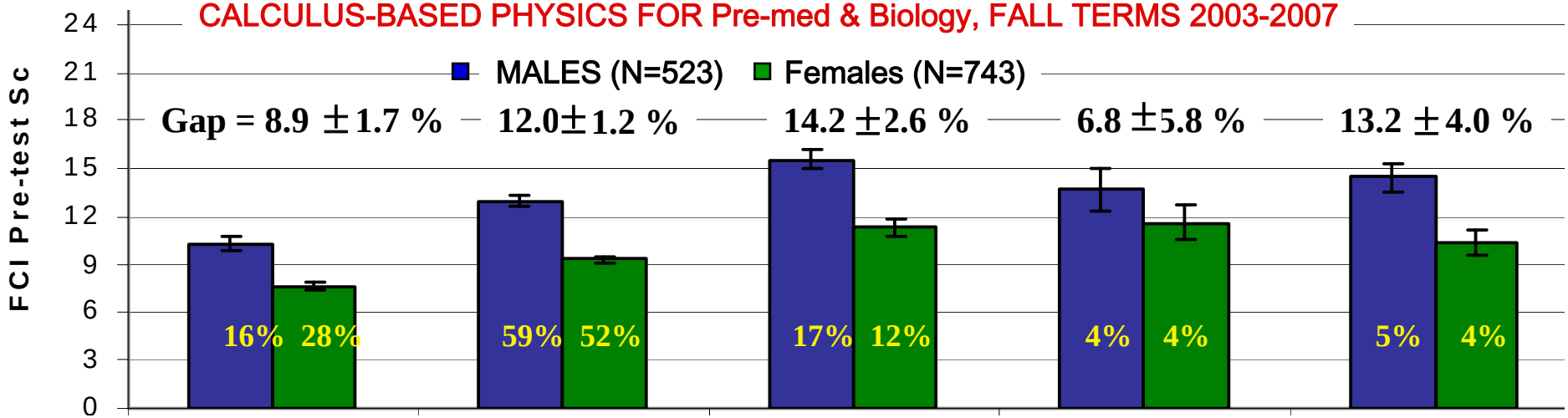

PRE-TEST GENDER GAP 15.3±0.5%
POST-TEST GENDER GAP 13.4±0.6%
Gains are the same
AVERAGE FCI SCORE
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
52.8±0.3%
37.5±0.5%
71.2±0.3%
57.8±0.5%
PRE-TEST
POST-TEST

AVERAGE FCI PRE-TEST SCORES BY PREVIOUS PHYSICS

CALCULUS-BASED PHYSICS FOR SCIENTISTS & ENGINEERS, FALL TERMS 1997-2007

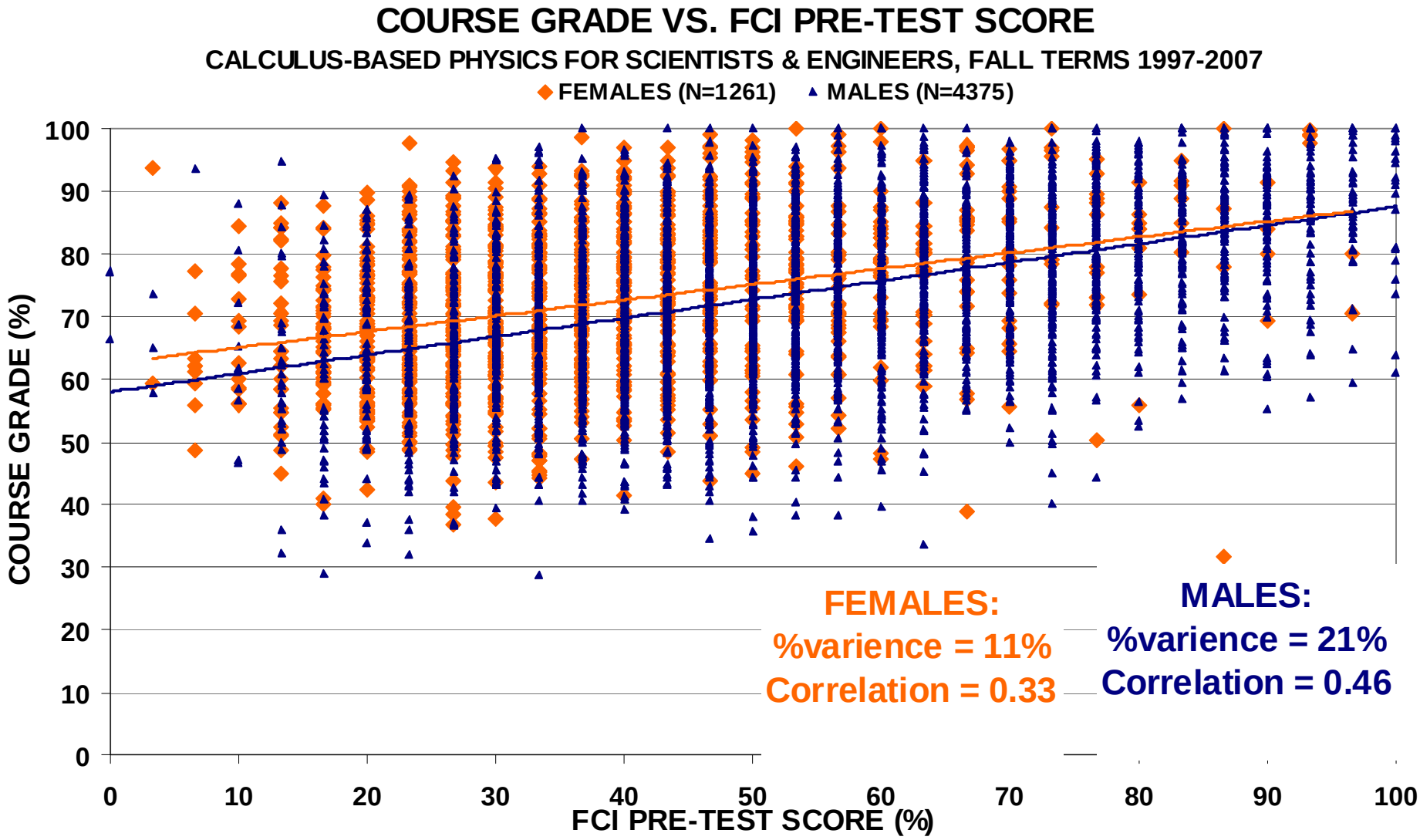


CALCULUS-BASED PHYSICS FOR Pre-med & Biology, FALL TERMS 2003-2007



Gap for every type of High School Physics Course

Can the FCI be used as a placement test?



The FCI is not a good predictor of performance.

Can a Math Skills Test be used as a placement test?

30 Questions

Powers of ten

Triangles

Graphs

Algebra

Simultaneous Equations

Derivatives

Anti-Derivatives

Algebra

Solve for **a in the equation $a^2x + cy = t$**

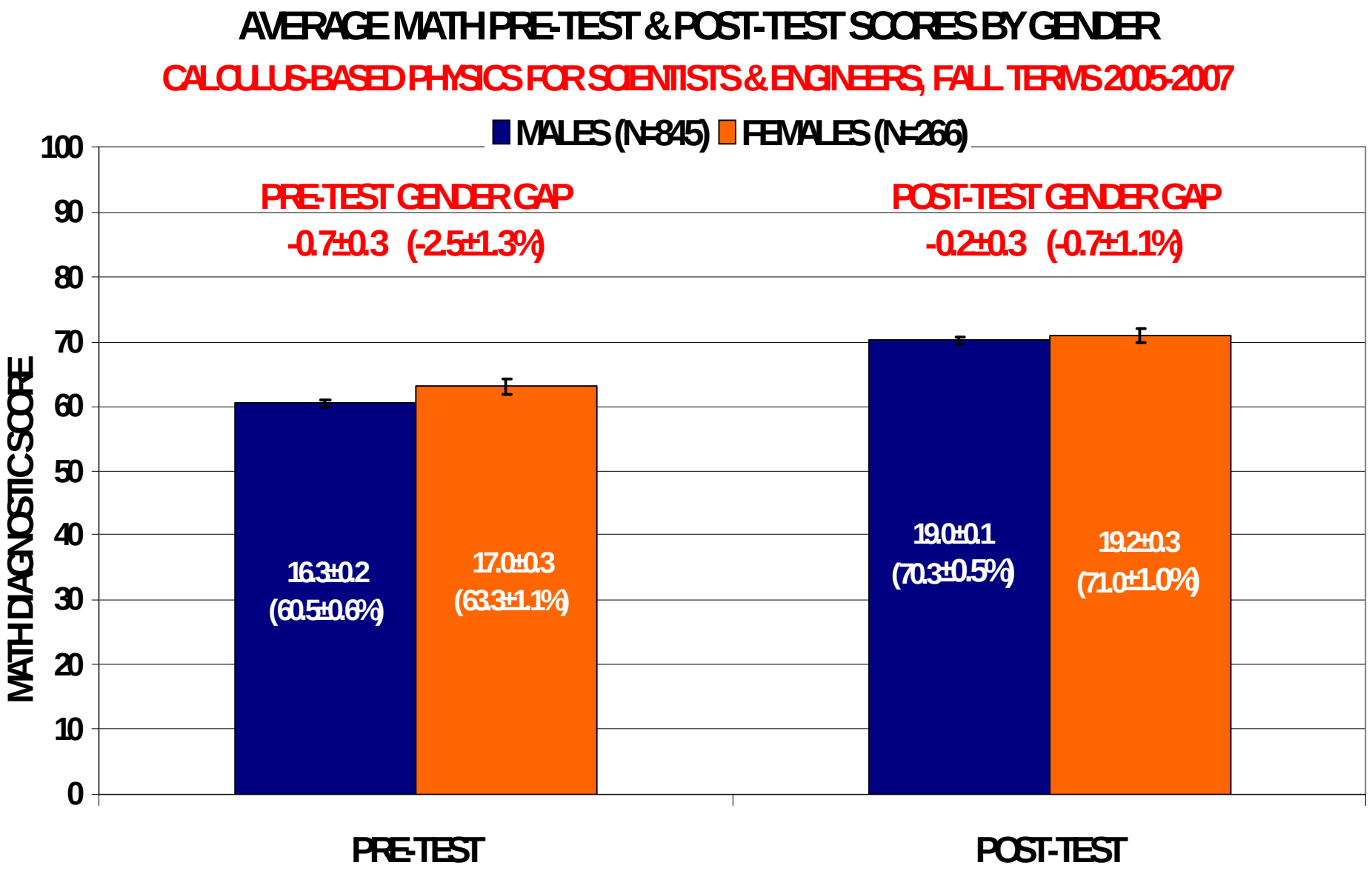
(a) $\pm\sqrt{t - cy - x}$ ***(b)*** $\pm\sqrt{\dfrac{t - cy}{x}}$ ***[95-99%]*** (c) $\pm\dfrac{1}{a}\sqrt{t - cy}$

(d) $\dfrac{t - cy}{2x}$ (e) $(cy - t)(cy + t)$

Solve for **y in the equation** $\dfrac{\mathbf{ax + b}}{\mathbf{cy + d}} = \mathbf{f}$

(a) $\dfrac{ax + b - df}{cf} = y$ ***[49-72%]*** ***(***b) $\dfrac{ax + b}{f + d}$ (c) $\dfrac{ax + b}{d}\left(\dfrac{1}{cf}\right)$

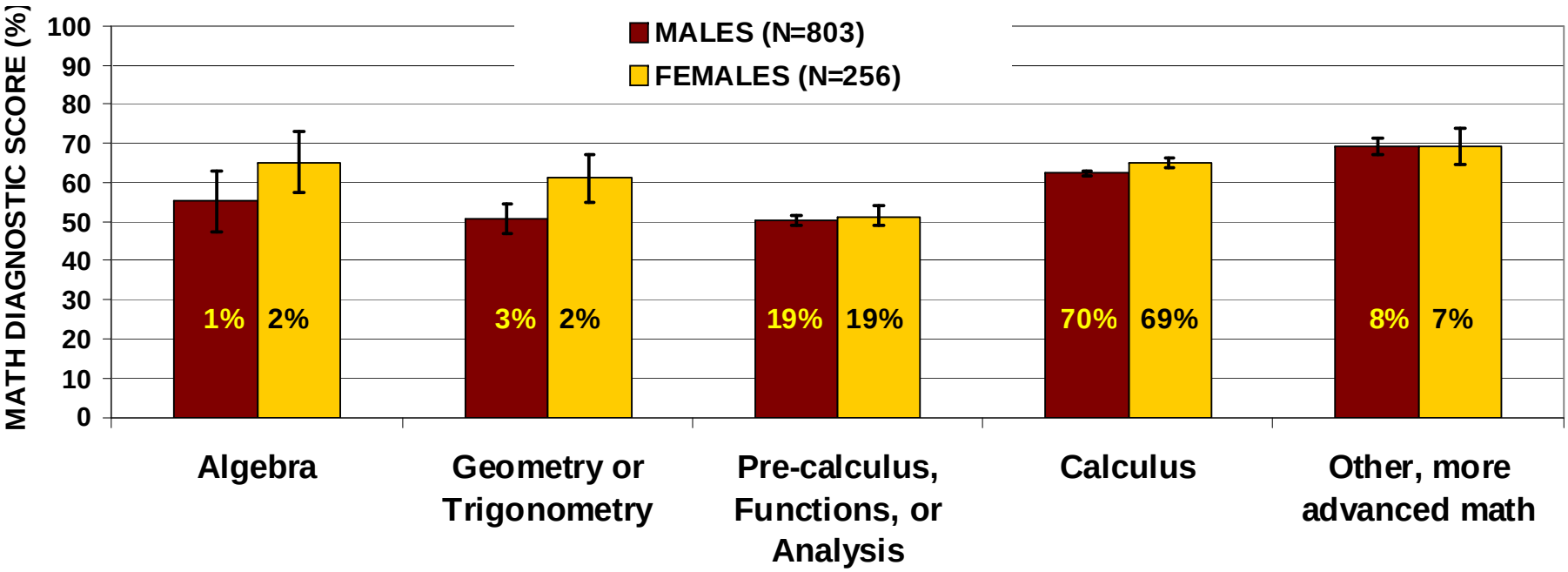
(d) $\dfrac{ax + b}{cf + d}$ (e) $\dfrac{1}{c}\left(\dfrac{f}{ax + b} - d\right)$ [15-34%]



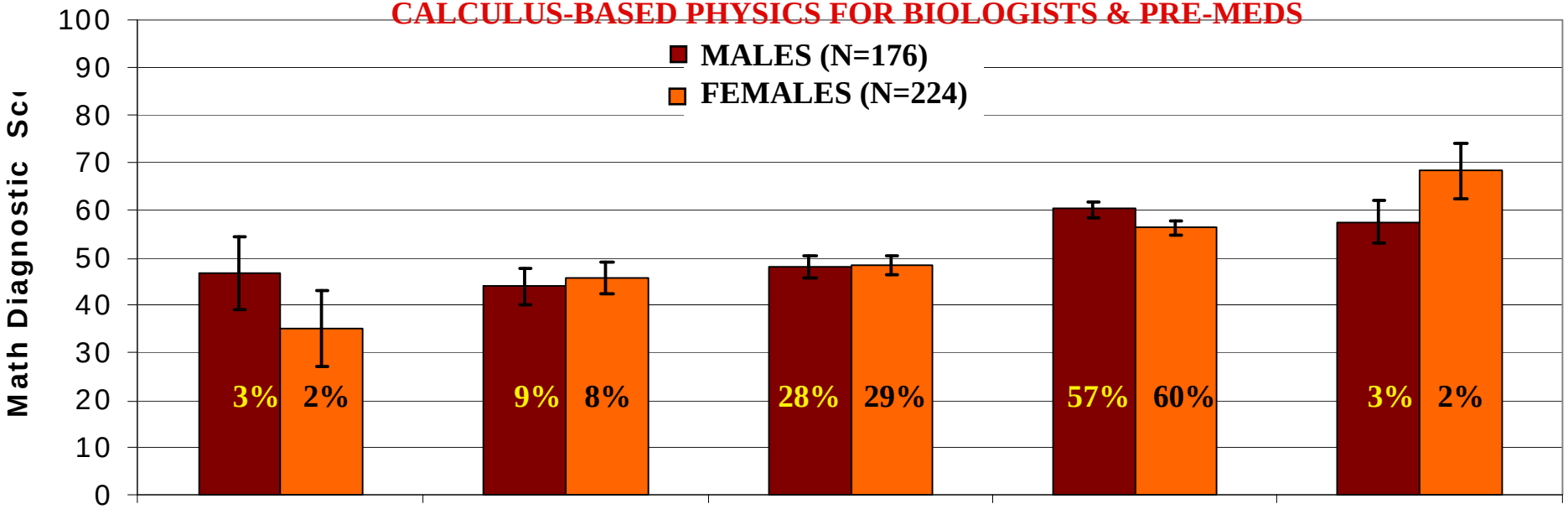
Females do slightly better.

AVERAGE MATH PRE-TEST SCORES BY HIGH SCHOOL MATH

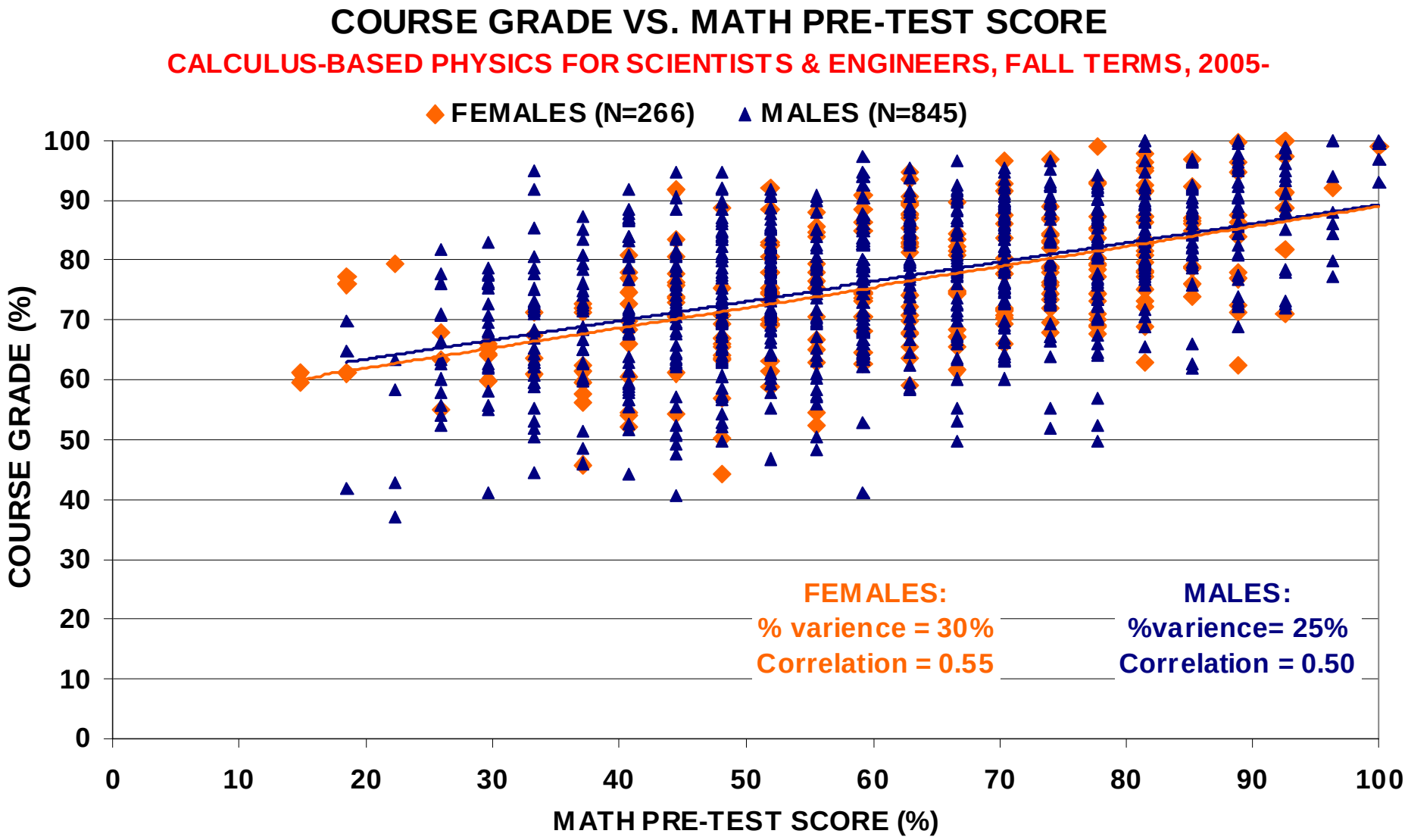
CALCULUS-BASED PHYSICS FOR SCIENTISTS & ENGINEERS



CALCULUS-BASED PHYSICS FOR BIOLOGISTS & PRE-MEDS



Can a Math Skills Test be used as a placement test?



The Math Skills Test is not a good predictor of performance. Better than FCI

Predictive Power – Stepwise Multiple Regression
% variance of course grade predicted

Engineering and Physical Science

Female
Math skills test: 31% of grade
FCI add: 6% of grade
HS background add: negligible
FCI pre – Math pre correlate 31%

Male
Math skills test: 25% of grade
FCI add: 7% of grade
HS background add: negligible
FCI pre – Math pre correlate 44%

Pre-med and Biological Science

Female
Math skills test: 18% of grade
FCI add: 6% of grade
HS background add: negligible
FCI pre – Math pre correlate 34%

Male
Math skills test: 20% of grade
FCI add: 4% of grade
HS background add: negligible
FCI pre – Math pre correlate 39%

No effective placement test for our introductory physics

- Interactive Engagement Pedagogy
  - Cooperative Group Problem Solving
- Emphasizing Problem Solving Skills
- Good Conceptual Gains

The End

Please visit our website for more information:

http://groups.physics.umn.edu/physed/