# Investigation into the mathematical preparation of introductory physics students

David E. Meltzer,[1] Dakota H. King,[1] and John D. Byrd[1,2]

[1]Arizona State University
[2]Michigan State University (present address)

Supported in part by NSF DUE #1504986 and #1914712

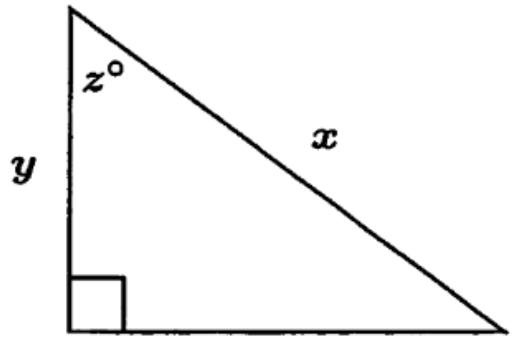
# Data Sources

- Diagnostic pretests covering pre-college mathematics given to over 7000 introductory physics students (non-credit; calculators allowed):
- More than 80 one-on-one problem-solving interviews
- Pre-instruction tests of scientific reasoning skill and physics concept knowledge.

# Examples of Test Items

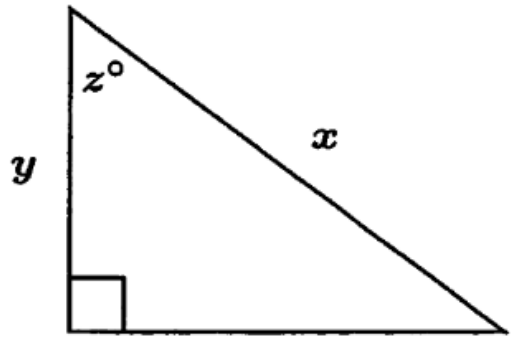
# Find Unknown Side

**1. What is the length of side $x$?**



# Find Unknown Side

**1. What is the length of side $x$?**

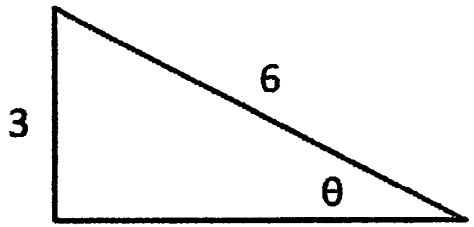



$\cos z° = \frac{y}{x}$

$x = \frac{y}{\cos z°}$

# Find Unknown Angle

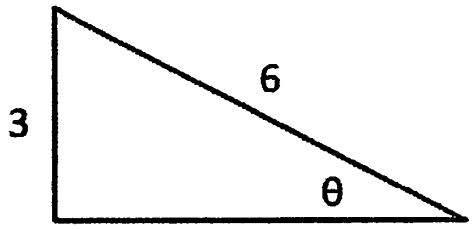
3.




What is the value of θ?

# Find Unknown Angle

3.




What is the value of θ?

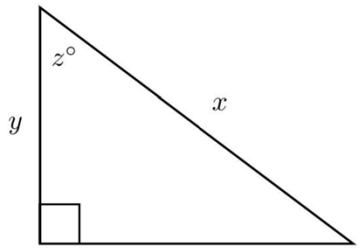
$\sin^{-1}(\theta) = \sin^{-1}\left(\frac{3}{6}\right)$

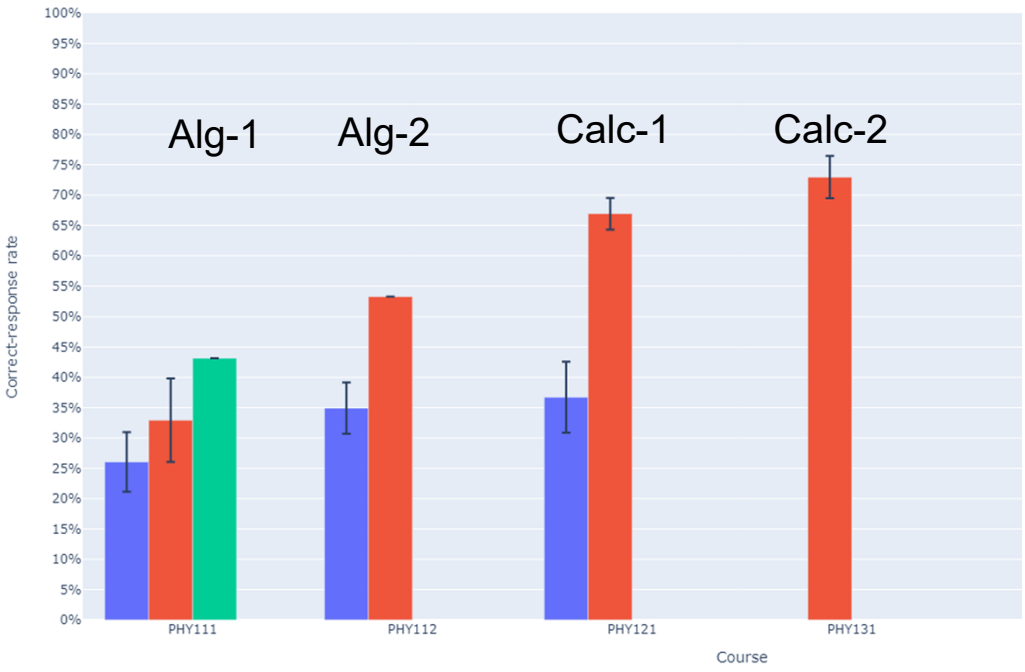
$\theta = 30^{\circ}$

# Correct-response rates (written, free-response)

**(36 classes; *N* > 3000)**

What is the length of side $x$?

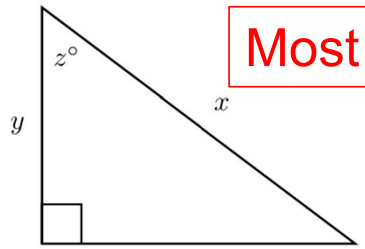


# Correct-response rates (written, free-response)

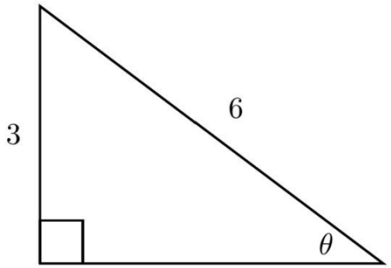
**(36 classes; *N* > 3000)**

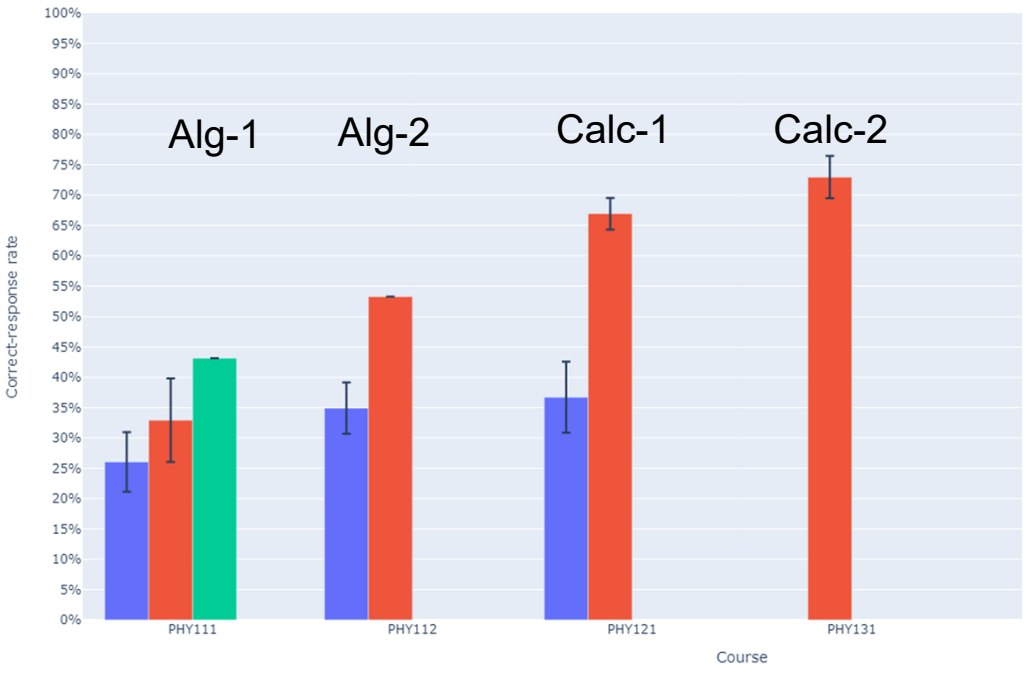
What is the length of side $x$?

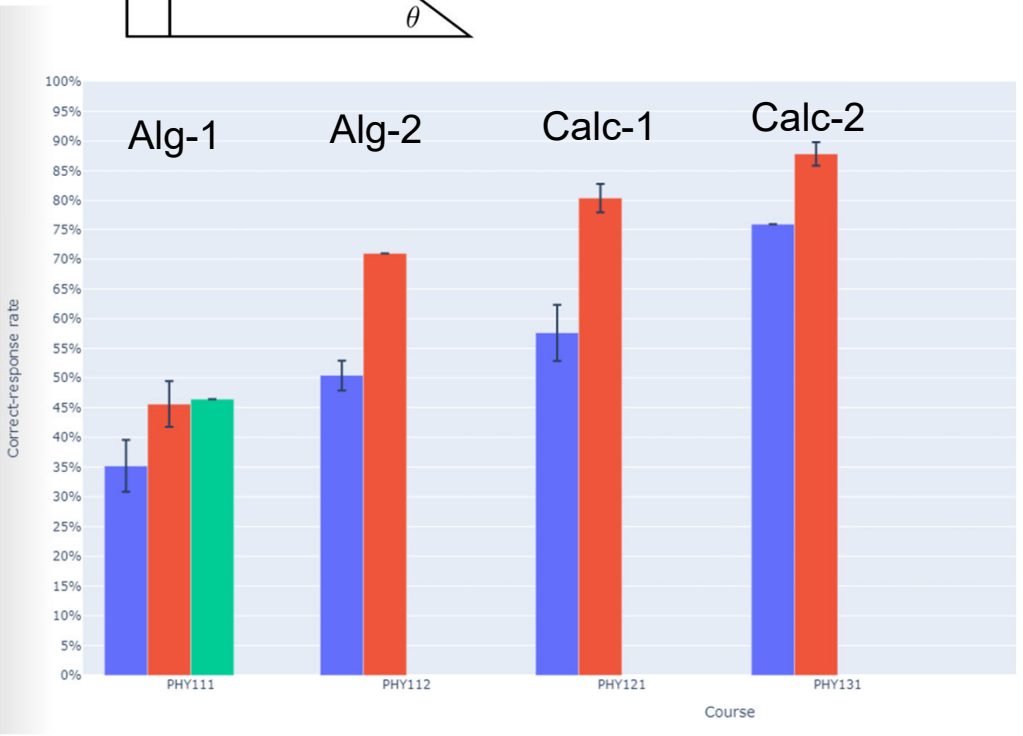



Most results in the 30-70% range

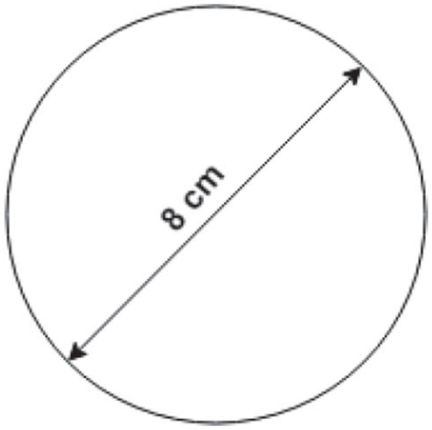
What is the value of $\theta$?



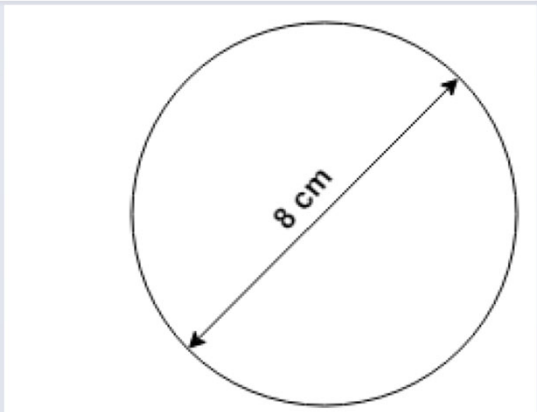



# Find Area




(a) Area of the circle =

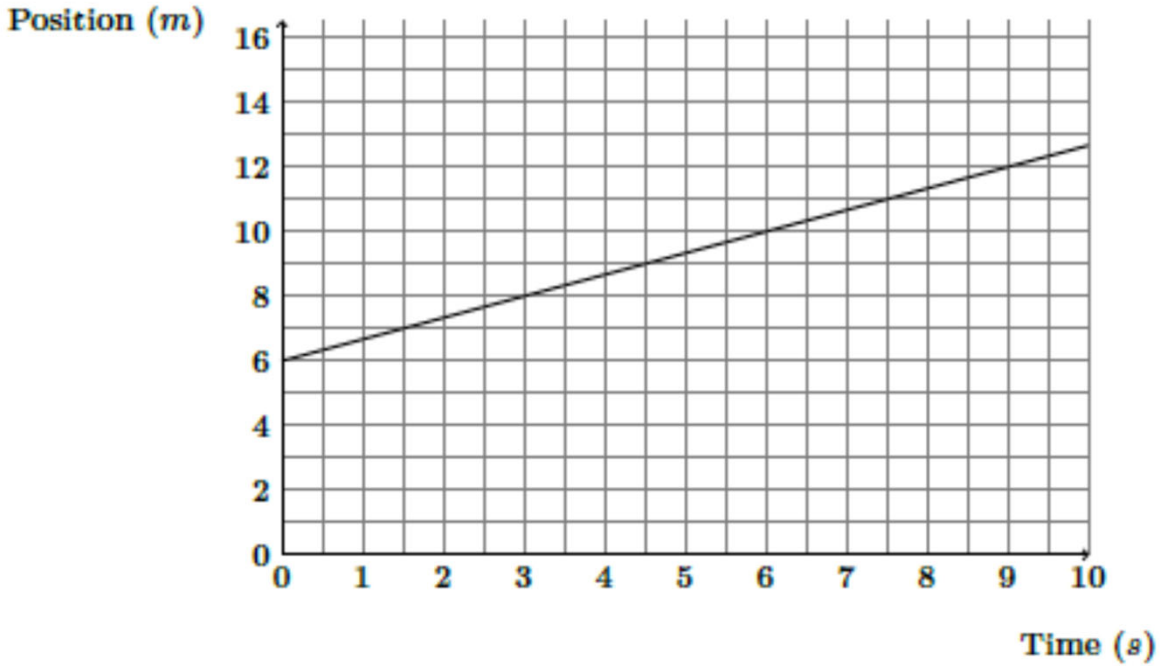



**Area of Circle: Algebra- and Calculus-based courses combined, 2018**

| | *N* | Numerically correct | Correct with correct units |
|---|---|---|---|
| ASU-Polytechnic | 250 | 57% | 29% |
| ASU-Tempe | 1086 | 76% | 45% |

# Find Slope of Graph

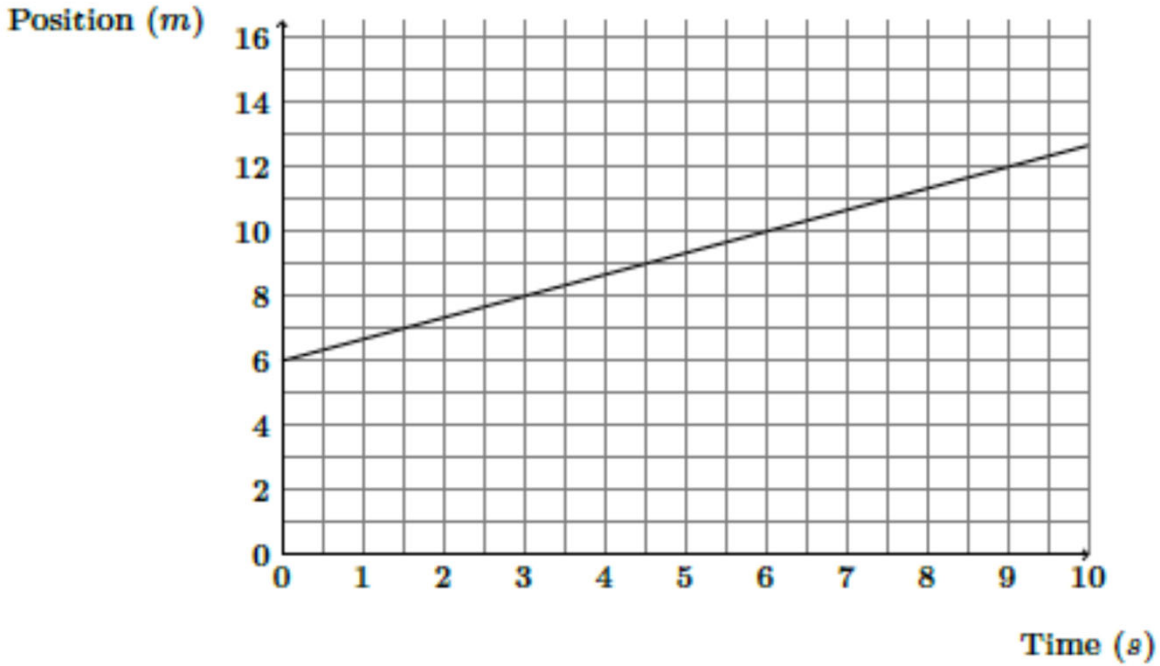
**What is the slope of the graph below?**



## *Correct-response rate: 30-60% (N > 4000)*

*(nearly independent of course or campus)*

What is the slope of the graph below?




***Most common error:*** *Counting grid squares and ignoring numbers on axes*

# Symbolic notation degrades student performance

- Use of symbols to replace numbers in otherwise identical algebraic equations lowered correct-response rates by ≈25%.

# Algebra: Simultaneous Equations (**Algebra**-based course, ASU-T)

$0.5y = 2x$
$78.4 - y = 8x$

[Solve for $x$]

Numeric Version 61% correct ($N$ = 470)

# Algebra: Simultaneous Equations (**Algebra**-based course, ASU-T)

$0.5y = 2x$
$78.4 - y = 8x$

[Solve for $x$]

Numeric Version 61% correct ($N$ = 470)

$cy = dx$
$a - y = bx$

[Solve for $x$]

Symbolic Version 31% correct ($N$ = 372)

# Algebra: Simultaneous Equations (**Calculus**-based course, ASU-T)

$0.5y = 2x$
$78.4 - y = 8x$

[Solve for $x$]

Numeric Version 79% correct ($N$ = 1205)

## Algebra: Simultaneous Equations (**Calculus**-based course, ASU-T)

$0.5y = 2x$
$78.4 - y = 8x$

[Solve for $x$]

Numeric Version 79% correct ($N$ = 1205)

$cy = dx$
$a - y = bx$

[Solve for $x$]

Symbolic Version 55% correct ($N$ = 1202)

**Symbolic**

$cy = dx$

$a - y = bx$

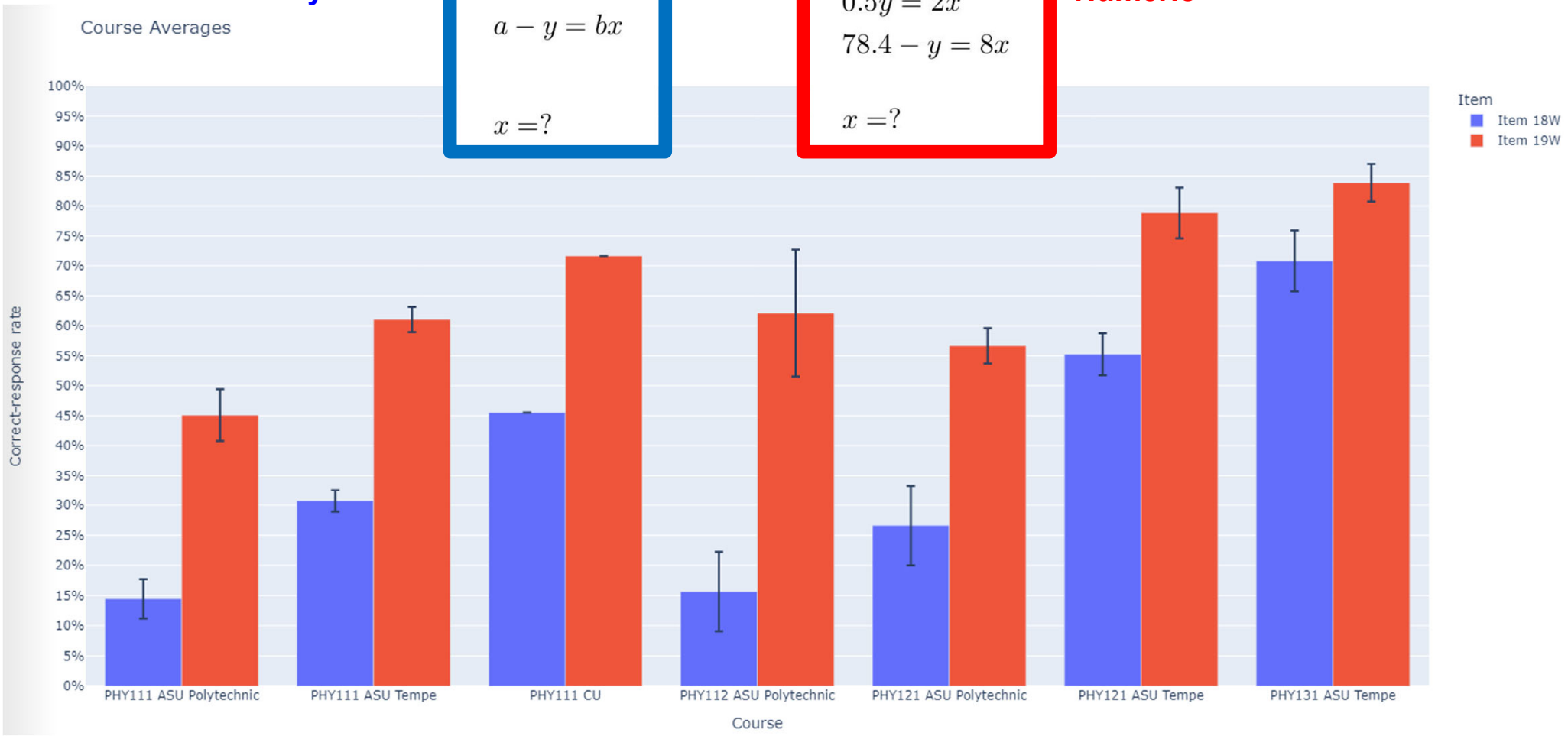
$x = ?$

$0.5y = 2x$

$78.4 - y = 8x$

$x = ?$

**Numeric**



Confusion can result from the nature of the symbols themselves

**Solve for $\theta$.**

$$\gamma\theta + \eta = \lambda\theta + \omega$$

**Solve for $x$.**

$$ax + b = cx + d$$

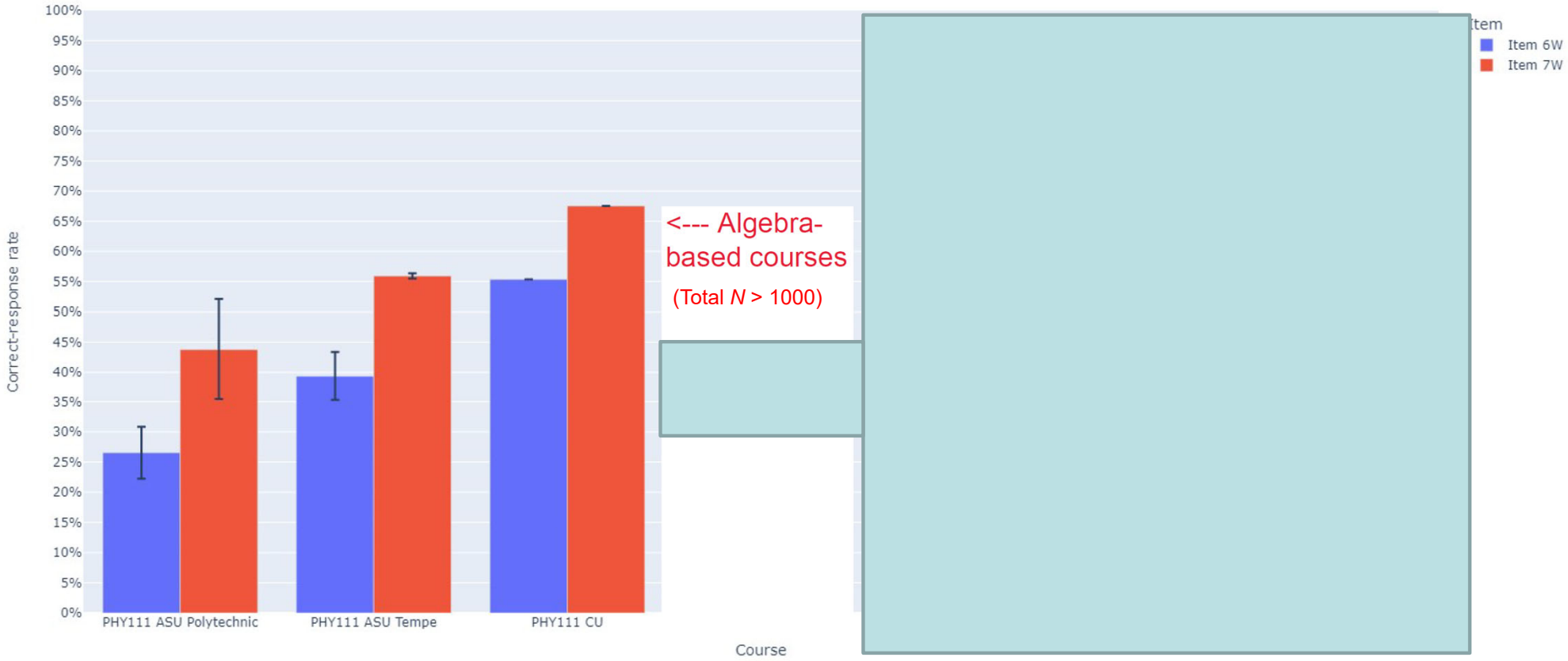
**Solve for $\theta$.**

$$\gamma\theta + \eta = \lambda\theta + \omega$$

Significantly lower correct-response rates on Greek-letter version in algebra-based courses

**Solve for $x$.**

$$ax + b = cx + d$$



**Solve for $\theta$.**

$$\gamma\theta + \eta = \lambda\theta + \omega$$

Significantly lower correct-response rates on Greek-letter version in algebra-based courses

**Solve for $x$.**

$$ax + b = cx + d$$

# Students favor non-standard solution methods

- Introductory physics students favor semi-arithmetic methods for solving solve algebraic equations; they do not “isolate the unknown variable.”

13. What is the numerical value of $d$?

$$v^2 = v_0^2 + 2ad$$

13. What is the numerical value of $d$?

$v^2 = v_0^2 + 2ad$

$v_0 = 0$

$a = \dfrac{\Delta v}{\Delta t}$

$\Delta v = 60$

$\Delta t = 8$

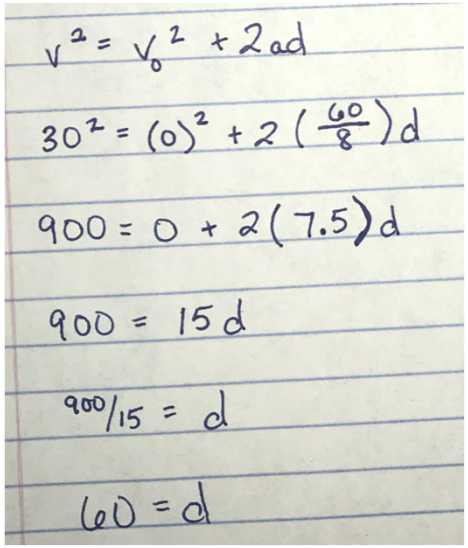
$v = 30$

$d = ?$

(Please clearly *circle* your answer and show all work.)

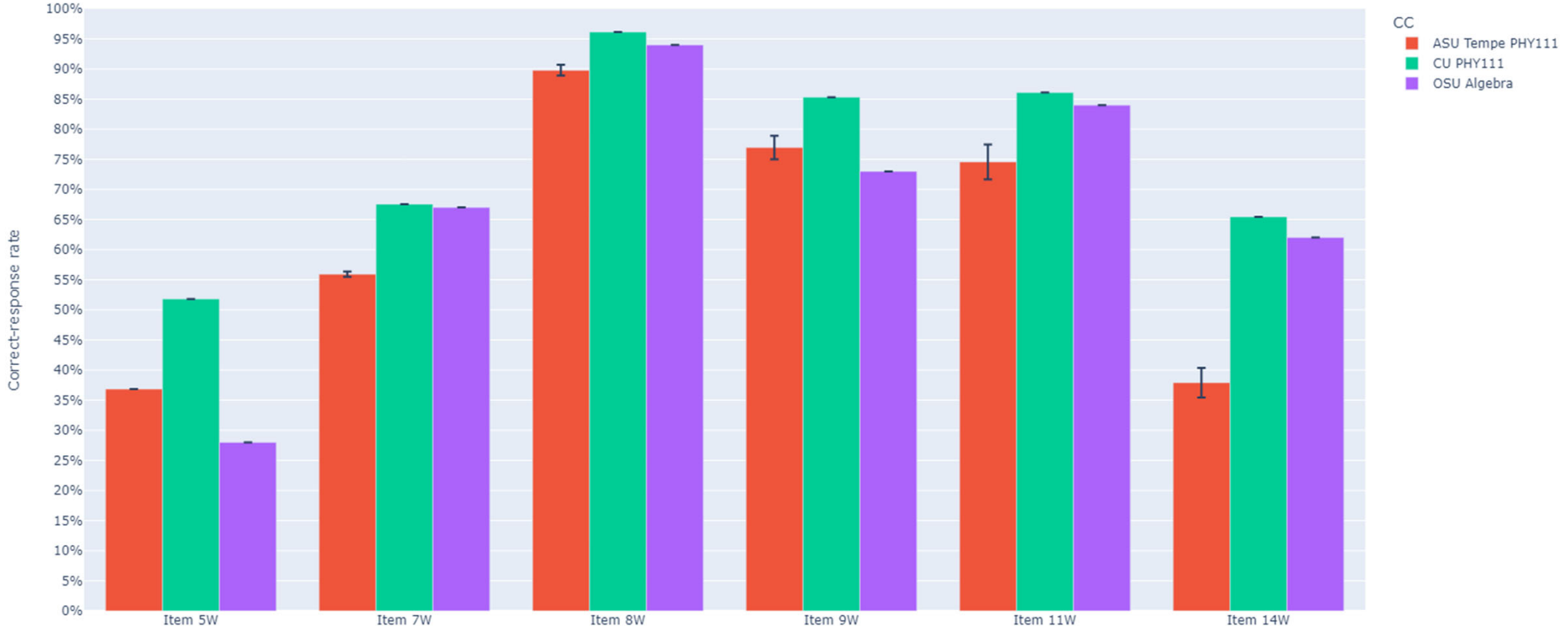
A. $d = 30$ B. $d = 60$ C. $d = 120$ D. $d = 240$ E. $d = 480$

53/53 students solved it this way:




We observed these methods used on *thousands* of students' submissions

# *Results consistent among different universities*



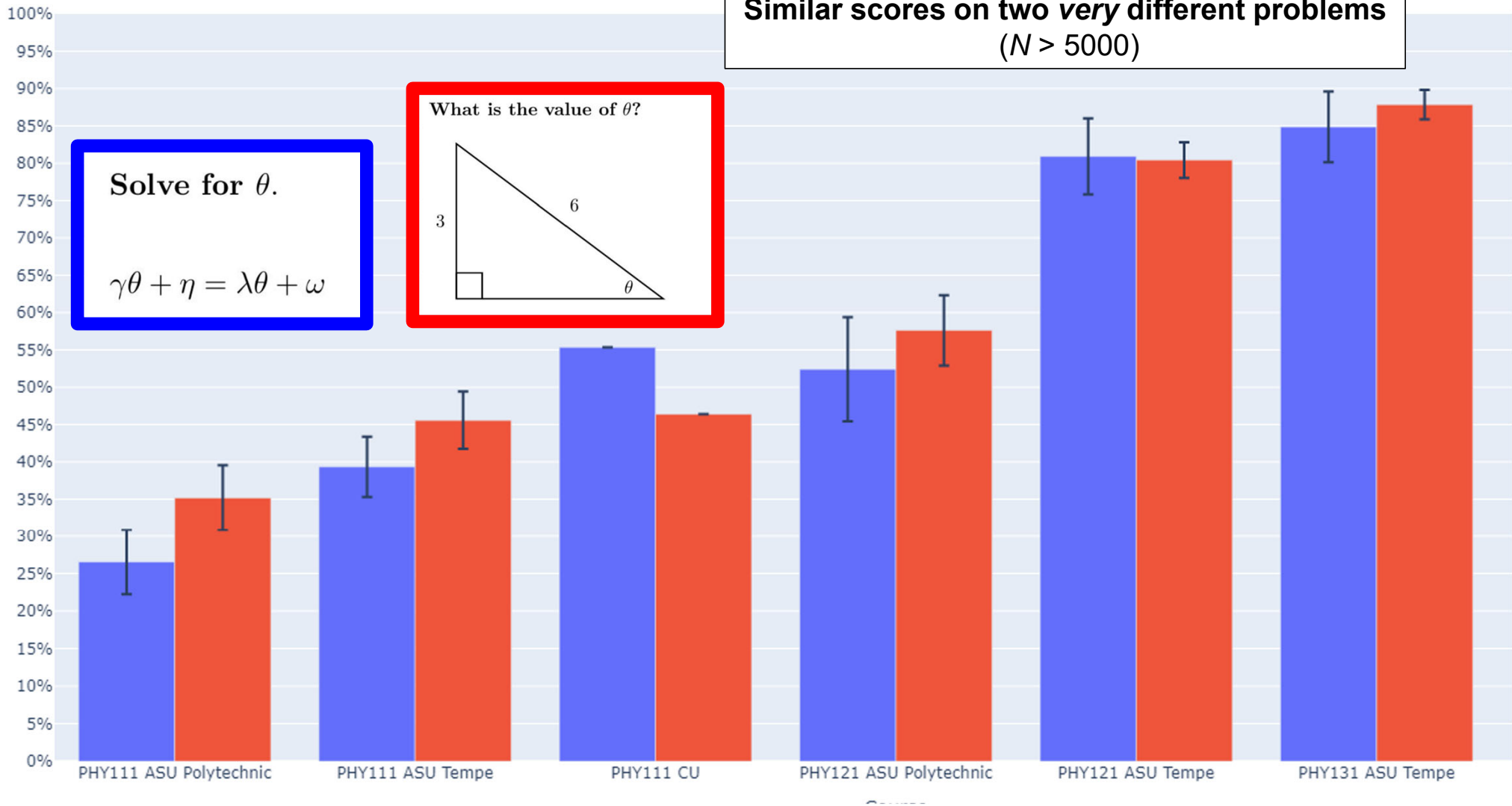

ASU Tempe (N>500) CU (N>350) OSU (N>500)

*Correct-response rates: algebra-based course*

# *Caution:* Difficulties with one topic implies difficulties with others as well

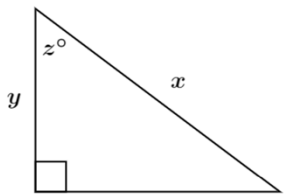
- Students' scores on different problem types tend to track each other closely: relatively low scores on one type imply relatively low scores on the others
- Factor analysis shows only a single factor for entire diagnostic

**Similar scores on two *very* different problems**
($N$ > 5000)



# On-line Version

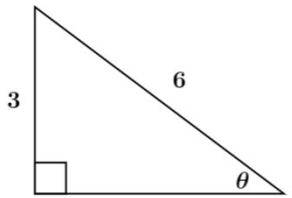
What is the length of side $x$?




A. $ycos(z°)$ D. $y/cos(z°)$ G. $cos(z°)/y$ J. $\sqrt{y^2+z^2}$
B. $ysin(z°)$ E. $y/sin(z°)$ H. $sin(z°)/y$ K. $\sqrt{z^2-y^2}$
C. $ytan(z°)$ F. $y/tan(z°)$ I. $tan(z°)/y$ L. $y/z$

(There may be more than one correct answer, but please select only ONE answer.)

What is the value of $\theta$?




A. $cos(3/6)$ D. $cos^{-1}(3/6)$ G. $30°$ J. $27°$
B. $sin(3/6)$ E. $sin^{-1}(3/6)$ H. $45°$ K. $3/6$
C. $tan(3/6)$ F. $tan^{-1}(3/6)$ I. $60°$ L. $0.524$

(There may be more than one correct answer, but please select only ONE answer.)

$cos(0°) = ?$

A. 0 B. 1 C. undefined D. 0.707 E. 0.894

(There may be more than one correct answer, but please select only ONE answer.)

$sin(90°) = ?$

A. 0 B. 1 C. undefined D. 0.707 E. 0.894

(There may be more than one correct answer, but please select only ONE answer.)

$tan(0°) = ?$

A. 0 B. 1 C. undefined D. 0.707 E. 0.894

(There may be more than one correct answer, but please select only ONE answer.)

Solve for $\theta$.

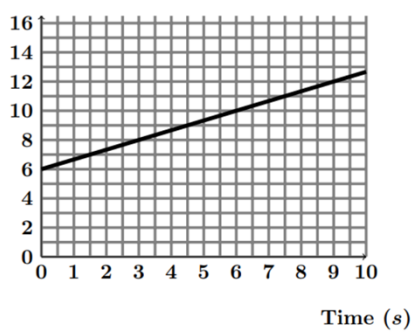
$\gamma\theta + \eta = \lambda\theta + \omega$

A. $\frac{\eta+\omega}{\gamma-\lambda}$ C. $\frac{\gamma-\lambda}{\omega-\eta}$ E. $\frac{\eta-\omega}{\gamma\lambda}$ G. $\frac{\omega-\eta}{\gamma-\lambda}$ I. $\frac{\eta-\omega+\gamma}{\lambda}$

B. $\frac{\eta-\omega}{\lambda-\gamma}$ D. $\frac{\lambda-\gamma}{\eta-\omega}$ F. $\frac{\omega-\eta}{\gamma\lambda}$ H. $\frac{\omega-\eta}{\gamma+\lambda}$ J. $\frac{\omega-\eta+\lambda}{\gamma}$

(There may be more than one correct answer, but please select only ONE answer.)

What is the slope of the graph below?




A. $\frac{1}{3}$ m/s because the object moves 1 meter in 3 seconds.

B. $\frac{1}{3}$ m/s because the line rises 1 box while it goes 3 boxes in the horizontal direction.

C. $\frac{2}{3}$ m/s because the object moves 2 meters in 3 seconds.

D. $\frac{2}{3}$ m/s because the line rises 2 boxes while it goes 3 boxes in the horizontal direction.

(There may be more than one correct answer, but please select only ONE answer.)

$\left(\frac{a}{3}\right)^3 = ?$

A. $\frac{a^3}{3}$ B. $\frac{a}{27}$ C. $\frac{a^3}{27}$

(There may be more than one correct answer, but please select only ONE answer.)

$2\left(\frac{a}{b}\right) = ?$

A. $\frac{2a}{b}$ B. $\frac{2a}{2b}$ C. $\frac{a}{2b}$

(There may be more than one correct answer, but please select only ONE answer.)

$\frac{a/b}{c^2/d} = ?$

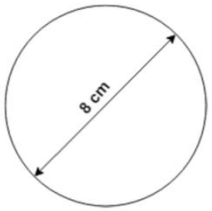
A. $\frac{ac^2}{bd}$ B. $\frac{ad}{bc^2}$ C. $\frac{bd}{ac^2}$ D. $\frac{bc^2}{ad}$

(There may be more than one correct answer, but please select only ONE answer.)

$2\left(\frac{3}{4}\right) = ?$

A. $\frac{6}{8}$ B. $\frac{12}{8}$ C. $\frac{3}{8}$ D. $\frac{3}{2}$ E. $\frac{3}{4}$

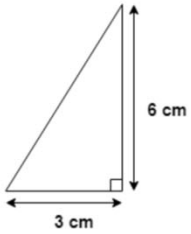
(There may be more than one correct answer, but please select only ONE answer.)




(a) Area of the circle = ?

| | | |
|---|---|---|
| A. $8\pi$ cm$^3$ | F. $8\pi$ cm$^2$ | K. $8\pi$ cm |
| B. $16\pi$ cm$^3$ | G. $16\pi$ cm$^2$ | L. $16\pi$ cm |
| C. $32\pi$ cm$^3$ | H. $32\pi$ cm$^2$ | M. $32\pi$ cm |
| D. $64\pi$ cm$^3$ | I. $64\pi$ cm$^2$ | N. $64\pi$ cm |
| E. $128\pi$ cm$^3$ | J. $128\pi$ cm$^2$ | O. $128\pi$ cm |

(There may be more than one correct answer, but please select only ONE answer.)




(b) Area of the triangle = ?

| | | |
|---|---|---|
| A. 4.5 cm$^3$ | F. 4.5 cm$^2$ | K. 4.5 cm |
| B. 9 cm$^3$ | G. 9 cm$^2$ | L. 9 cm |
| C. 12 cm$^3$ | H. 12 cm$^2$ | M. 12 cm |
| D. 18 cm$^3$ | I. 18 cm$^2$ | N. 18 cm |
| E. 36 cm$^3$ | J. 36 cm$^2$ | O. 36 cm |

(There may be more than one correct answer, but please select only ONE answer.)

Solve for x.

$$\frac{3}{2} = 7x$$

A. $\frac{14}{3}$ B. $\frac{3}{14}$ C. $\frac{21}{2}$ D. $\frac{21}{14}$

(There may be more than one correct answer, but please select only ONE answer.)

$$v^2 = v_0^2 + 2ad$$

$$v_0 = 0$$

$$a = \frac{\Delta v}{\Delta t}$$

$$\Delta v = 60$$

$$\Delta t = 8$$

$$v = 30$$

$d$ =?

A. $d = 30$ B. $d = 60$ C. $d = 120$ D. $d = 240$ E. $d = 480$

(There may be more than one correct answer, but please select only ONE answer.)

$$cy = dx$$

$$a - y = bx$$

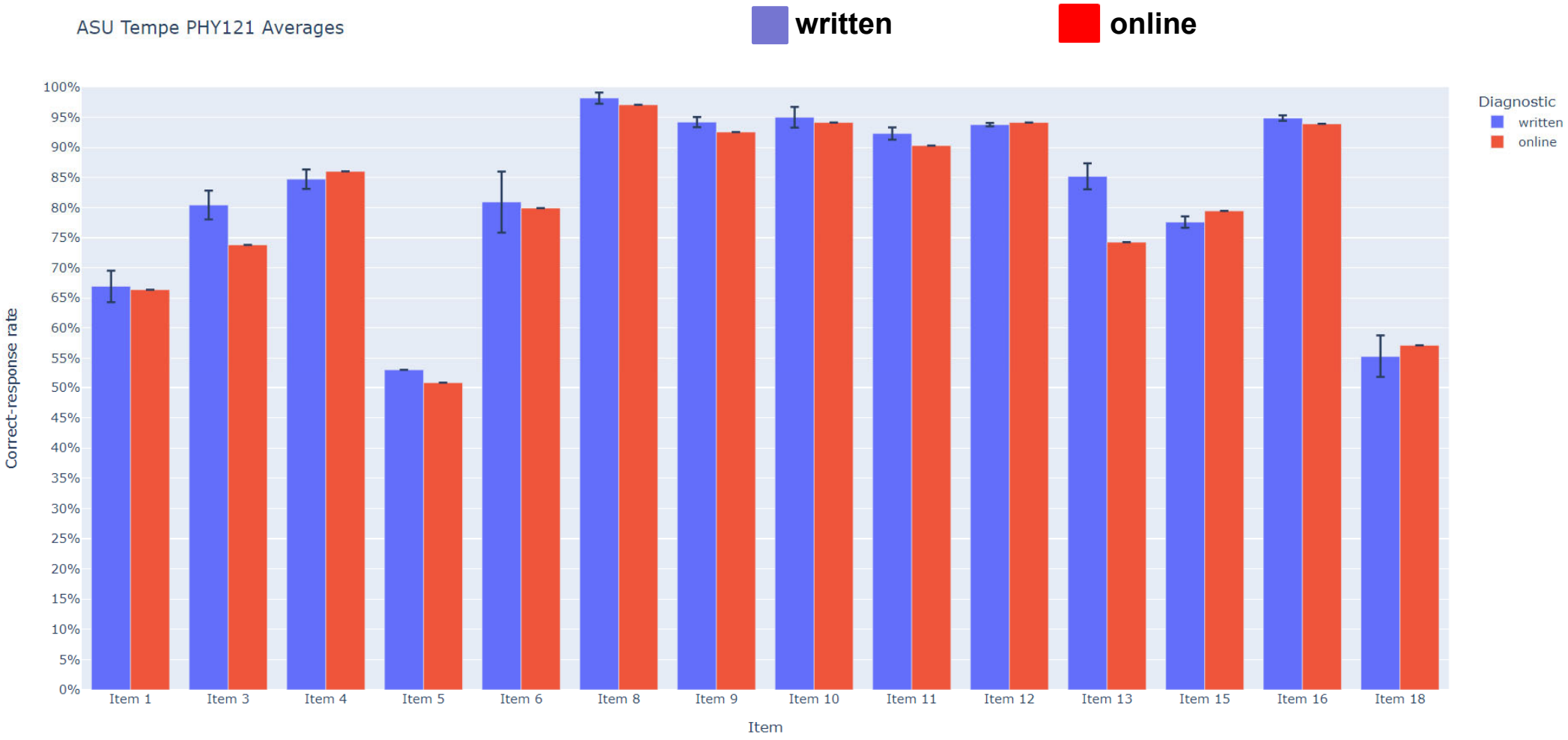
$x$ =?

A. $\frac{ac}{d+b}$ C. $\frac{ac}{bc-d}$ E. $\frac{ac}{db}$ G. $\frac{a}{b+\frac{d}{c}}$ I. $\frac{1}{b}\left(a-\frac{d}{c}\right)$

B. $\frac{ac}{d-b}$ D. $\frac{ac}{bc+d}$ F. $\frac{a}{db}$ H. $\frac{a}{b+d}$ J. $\frac{c}{d}\left(a-b\right)$

(There may be more than one correct answer, but please select only ONE answer.)

# On-line and written versions yield consistent results



# Findings from >80 Interviews: Students make many “careless” errors

- During interviews, students tended to self-correct approximately 60% of their initial errors with little or no prompting, suggesting that many errors are “careless.”
- These findings suggest that increased focus on improving students’ self-checking behavior might provide significant performance dividends.
  - However, studies have shown that making these improvements is quite challenging

# Relation Between Scores and Grades

- Performance on **full online diagnostic** can *approximately* predict final course grade

## *Low* Course Grade vs. Full Diagnostic Score

| Course | Campus | *N* | Overall % grade ≤ C+ | Score ≥ 81% % grade ≤ C+ | Score ≤ 57% % grade ≤ C+ | Low-grade Ratio score ≤ 57% vs. score ≥ 81% |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

## *Low* Course Grade vs. Full Diagnostic Score

| Course | Campus | *N* | Overall % grade ≤ C+ | | | |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 78 | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Alg-1: Algebra-based course, first semester

## *Low* Course Grade vs. Full Diagnostic Score

| Course | Campus | *N* | Overall % grade ≤ C+ | | | |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 78 | 26% | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Alg-1: Algebra-based course, first semester

## *Low* Course Grade vs. Full Diagnostic Score

| Course | Campus | *N* | Overall % grade ≤ C+ | Score ≥ 81% % grade ≤ C+ | Score ≤ 57% % grade ≤ C+ | Low-grade Ratio score ≤ 57% vs. score ≥ 81% |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 78 | 26% | 19% | 38% | 2.1 |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Alg-1: Algebra-based course, first semester

*Students who scored low on math diagnostic pretest had more "C" course grades than those who scored high*

## *Low* Course Grade vs. Full Diagnostic Score

| Course | Campus | *N* | | | | |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 78 | | | | |
| Alg-1 2022 | ASU-P | 93 | | | | |
| Alg-2 | ASU-P | 72 | | | | |
| Calc-1 | UWF | 103 | | | | |

Alg-1: Algebra-based course, first semester
Alg-2: Algebra-based course, second semester
Calc-1: Calculus-based course, first semester

ASU-P: Arizona State University, Polytechnic campus
UWF: University of West Florida

## *Low* Course Grade vs. Full Diagnostic Score

| Course | Campus | *N* | Overall % grade ≤ C+ | | | |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 78 | 26% | | | |
| Alg-1 2022 | ASU-P | 93 | 19% | | | |
| Alg-2 | ASU-P | 72 | 29% | | | |
| Calc-1 | UWF | 103 | 39% | | | |

Alg-1: Algebra-based course, first semester
Alg-2: Algebra-based course, second semester
Calc-1: Calculus-based course, first semester

ASU-P: Arizona State University, Polytechnic campus
UWF: University of West Florida

## *Low* Course Grade vs. Full Diagnostic Score

| Course | Campus | *N* | Overall % grade ≤ C+ | Score ≥ 81% % grade ≤ C+ | Score ≤ 57% % grade ≤ C+ | Low-grade Ratio score ≤ 57% vs. score ≥ 81% |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 78 | 26% | | | |
| Alg-1 2022 | ASU-P | 93 | 19% | | | |
| Alg-2 | ASU-P | 72 | 29% | | | |
| Calc-1 | UWF | 103 | 39% | | | |

Alg-1: Algebra-based course, first semester
Alg-2: Algebra-based course, second semester
Calc-1: Calculus-based course, first semester

ASU-P: Arizona State University, Polytechnic campus
UWF: University of West Florida

## *Low* Course Grade vs. Full Diagnostic Score

| Course | Campus | *N* | Overall % grade ≤ C+ | Score ≥ 81% % grade ≤ C+ | Score ≤ 57% % grade ≤ C+ | Low-grade Ratio score ≤ 57% vs. score ≥ 81% |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 78 | 26% | 19% | 38% | 2.1 |
| Alg-1 2022 | ASU-P | 93 | 19% | 8% | 28% | 3.4 |
| Alg-2 | ASU-P | 72 | 29% | 14% | 35% | 2.6 |
| Calc-1 | UWF | 103 | 39% | 26% | 54% | 2.1 |

Alg-1: Algebra-based course, first semester
Alg-2: Algebra-based course, second semester
Calc-1: Calculus-based course, first semester

ASU-P: Arizona State University, Polytechnic campus
UWF: University of West Florida

*Students who scored low on math diagnostic pretest had **consistently** more "C" course grades than those who scored high*

## High Course Grade vs. Full Diagnostic Score

| Course | Campus | *N* | Overall % grade ≥ A- | Score ≥ 81% % grade ≥ A- | Score ≤ 57% % grade ≥ A- | High-grade Ratio score ≥ 81% vs. score ≤ 57% |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 78 | | | | |
| Alg-1 2022 | ASU-P | 93 | | | | |
| Alg-2 | ASU-P | 72 | | | | |
| Alg-2 | ASU-T | 129 | | | | |
| Calc-1 | UWF | 103 | | | | |
| Calc-2 | UWF | 59 | | | | |

Alg-1: Algebra-based course, first semester
Alg-2: Algebra-based course, second semester
Calc-1: Calculus-based course, first semester
Calc-2: Calculus-based course, second semester

ASU-P: Arizona State University, Polytechnic campus
ASU-T: Arizona State University, Tempe campus
UWF: University of West Florida

## High Course Grade vs. Full Diagnostic Score

| Course | Campus | *N* | Overall % grade ≥ A- | Score ≥ 81% % grade ≥ A- | Score ≤ 57% % grade ≥ A- | High-grade Ratio score ≥ 81% vs. score ≤ 57% |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 78 | 35% | | | |
| Alg-1 2022 | ASU-P | 93 | 45% | | | |
| Alg-2 | ASU-P | 72 | 39% | | | |
| Alg-2 | ASU-T | 129 | 60% | | | |
| Calc-1 | UWF | 103 | 22% | | | |
| Calc-2 | UWF | 59 | 49% | | | |

Alg-1: Algebra-based course, first semester
Alg-2: Algebra-based course, second semester
Calc-1: Calculus-based course, first semester
Calc-2: Calculus-based course, second semester

ASU-P: Arizona State University, Polytechnic campus
ASU-T: Arizona State University, Tempe campus
UWF: University of West Florida

## High Course Grade vs. Full Diagnostic Score

| Course | Campus | *N* | Overall % grade ≥ A- | Score ≥ 81% % grade ≥ A- | Score ≤ 57% % grade ≥ A- | High-grade Ratio score ≥ 81% vs. score ≤ 57% |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 78 | 35% | 63% | 15% | 4.2 |
| Alg-1 2022 | ASU-P | 93 | 45% | 67% | 28% | 2.4 |
| Alg-2 | ASU-P | 72 | 39% | 64% | 25% | 2.6 |
| Alg-2 | ASU-T | 129 | 60% | 67% | 55% | 1.2 |
| Calc-1 | UWF | 103 | 22% | 40% | 0% | "∞" |
| Calc-2 | UWF | 59 | 49% | 61% | 38% | 1.6 |

Alg-1: Algebra-based course, first semester
Alg-2: Algebra-based course, second semester
Calc-1: Calculus-based course, first semester
Calc-2: Calculus-based course, second semester

ASU-P: Arizona State University, Polytechnic campus
ASU-T: Arizona State University, Tempe campus
UWF: University of West Florida

*Students who scored high on math diagnostic pretest had **consistently** more "A" course grades than those who scored low*

# Factors other than math preparation may influence course performance

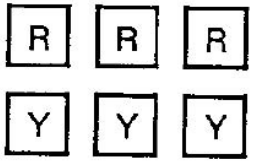
- For example:
  - Scientific reasoning skills, as measured by the Lawson Test of Scientific Reasoning
  - Physics concept knowledge, as measured by the Force Concept Inventory

# Scientific reasoning skills: The 24-item Lawson test

Suppose you are given two clay balls of equal size and shape. The two clay balls also weigh the same. One ball is flattened into a pancake-shaped piece. *Which of these statements is correct?*

a. The pancake-shaped piece weighs more than the ball
b. The two pieces still weigh the same
c. The ball weighs more than the pancake-shaped piece

Six square pieces of wood are put into a cloth bag and mixed about. The six pieces are identical in size and shape, however, three pieces are red and three are yellow. Suppose someone reaches into the bag (without looking) and pulls out one piece. *What are the chances that the piece is red?*




a. 1 chance out of 6
b. 1 chance out of 3
c. 1 chance out of 2
d. 1 chance out of 1
e. cannot be determined

## High Course Grade vs. Lawson Test of Scientific Reasoning Pretest Score

| Course | Campus | *N* | Overall % grade ≥ A- | Top-quartile Lawson % grade ≥ A- | Bottom-quartile Lawson % grade ≥ A- | High-grade Ratio<br>Top quartile vs. Bottom quartile |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 73 | 35% | 65% | 17% | 3.9 |
| Alg-1 2022 | ASU-P | 99 | 45% | 62% | 28% | 2.2 |
| Alg-2 | ASU-P | 73 | 39% | 60% | 15% | 4.0 |
| Alg-1 | CU | 469 | 22% | 43% | 6% | 7.7 |
| Calc-2 | CU | 276 | 25% | 55% | 9% | 6.4 |
| Alg-1 2007 | LMU | 24 | 42% | 83% | 0% | "∞" |
| Alg-1 2014 | LMU | 33 | 36% | 88% | 0% | "∞" |
| Alg-1 2018 | LMU | 47 | 38% | 77% | 17% | 4.6 |
| Alg-1 2021 | LMU | 27 | 48% | 63% | 0% | "∞" |

Alg-1: Algebra-based course, first semester
Alg-2: Algebra-based course, second semester
Calc-2: Calculus-based course, second semester

ASU-P: Arizona State University, Polytechnic campus
CU: University of Colorado, Boulder
LMU: Loyola Marymount University

*Students who scored high on Lawson reasoning pretest had **consistently** more "A" course grades than those who scored low*

## Low Course Grade vs. Lawson Test of Scientific Reasoning Pretest Score

| Course | Campus | *N* | Overall % grade ≤ C+ | Top-quartile Lawson % grade ≤ C+ | Bottom-quartile Lawson % grade ≤ C+ | Low-grade Ratio Bottom quartile vs. Top quartile |
|---|---|---|---|---|---|---|
| Alg-1 2021 | ASU-P | 73 | 26% | 5% | 56% | 11.1 |
| Alg-1 2022 | ASU-P | 99 | 19% | 10% | 28% | 2.9 |
| Alg-2 | ASU-P | 73 | 29% | 10% | 35% | 3.5 |
| Alg-1 | CU | 469 | 43% | 21% | 68% | 3.2 |
| Calc-2 | CU | 276 | 34% | 13% | 59% | 4.5 |
| Alg-1 2007 | LMU | 24 | 17% | 0% | 29% | "∞" |
| Alg-1 2014 | LMU | 33 | 24% | 0% | 67% | "∞" |
| Alg-1 2018 | LMU | 47 | 19% | 15% | 25% | 1.6 |
| Alg-1 2021 | LMU | 27 | 26% | 13% | 86% | 6.9 |

Alg-1: Algebra-based course, first semester
Alg-2: Algebra-based course, second semester
Calc-2: Calculus-based course, second semester

ASU-P: Arizona State University, Polytechnic campus
CU: University of Colorado, Boulder
LMU: Loyola Marymount University

*Students who scored low on Lawson reasoning pretest had **consistently** more "C" course grades than those who scored high*

# What Grade is Predicted by FCI Pretest Score?

- Henderson (2002), University of Minnesota (*N* > 1000)

| **FCI Pretest score:** | **0-30%** | **63-100%** | |
|---|---|---|---|
| | ***A*:** 10% | ***A*:** 47% | *Ratio: 4.7* |
| | ***C*:** 46% | ***C*:** 9% | *Ratio: 5.1* |

*Students who scored high on FCI pretest had higher course grades than those who scored low*

# What Grade is Predicted by FCI Pretest Score?

- Meltzer (2012/13), Arizona State University (*N* > 100)

| **FCI Pretest score:** | **0-30%** | **63-100%** | |
|---|---|---|---|
| | ***A*:** 12% | ***A*:** 65% | *Ratio: 5.4* |
| | ***C*:** 26% | ***C*:** 13% | *Ratio: 2.0* |

*Students who scored high on FCI pretest had higher course grades than those who scored low*

# What Grade is Predicted by FCI Pretest Score?

- Pollock & Dubson (2005), University of Colorado (*N* =470)

| **FCI Pretest score:** | **0-30%** | **63-100%** | |
|---|---|---|---|
| | ***A*:** 13% | ***A*:** 59% | *Ratio: 4.7* |
| | ***C*:** 50% | ***C*:** 19% | *Ratio: 2.7* |

*Students who scored high on FCI pretest had higher course grades than those who scored low*

# Factors are correlated, but not 100%

- Outliers using one prediction method can often be explained by high pretest scores on another predictor
- Students with  uniformly low pretest scores can sometimes perform well with exceptional efforts in class

# Summary

- Numerous factors influence students' physics course performance
- Previous preparation in calculational and reasoning skills is important, as well as physics concept knowledge, motivation, and effort