Collaborative Research: Succeeding in Introductory Physics: Building Math Fluency in a Physics Context

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SUMMARY

- We have administered written and online diagnostic tests covering topics in pre-college mathematics to over 7500 students enrolled in introductory physics courses at four state universities.
- Students' responses consistently reflected many operational errors, to a degree that could strongly impact students' course performance.
- Study of small selected subsamples shows consistently that students' pre-instruction math scores are predictive of their final course grades.
- Our findings have instructional implications that we have used to make modifications in our own instruction.
- In collaboration with Ohio State U., we are testing regular online homework exercises, with limited success in improving performance.

KEY FINDINGS AND INSTRUCTIONAL IMPLICATIONS

- Error rates of 30-60% appear consistently among all populations.

  Implication: Instructors may need to adjust expectations of students' operational abilities with trigonometry, algebra, graphing, etc.

- Use of symbols to replace numbers in otherwise identical algebraic equations *significantly* lowered students' correct-response rate.

  Implication: Instructors may choose to be much more cautious in using symbolic manipulation to explain or demonstrate concepts.

- Virtually no physics students tended to solve algebraic equations by "isolating the unknown variable"; semi-arithmetic methods were favored instead.

  Implication: Physics instructors' standard and habitual approach to algebraic manipulation may appear foreign and confusing to their introductory students.

- Many students in both algebra- and calculus-based physics courses were extremely weak in handling units: they ignored units on graph-axis labels, and provided no or incorrect units for area and velocity.

  Implication: Instructors may not fully appreciate the degree to which many physics students are challenged in handling units.

- Students' errors on specific topics are highly correlated with errors on other, disparate topics (trigonometry, geometry, graphing, algebra).

  Implication: Student difficulties with a specific type of mathematical operation strongly implies existence of difficulties with *other* topics.

- Class-average scores on even a *single* diagnostic test item are highly predictive of average scores on other items covering varied topics.

  Implication: It may be possible to diagnose the level of students' difficulties with only one or very few mathematics pretest items.

- Very high and very low pre-instruction math scores—on as few as three test items—are predictive of students' final course grades.

  Implication: It may be possible to flag students at risk with short diagnostic math pre-tests.

- During interviews, students tended to self-correct approximately 60% of their initial errors, suggesting many errors are "careless."

  Implication: Instruction on error-detecting, checking, and self-correcting strategies may offer disproportionately high returns in helping students address their mathematical difficulties.

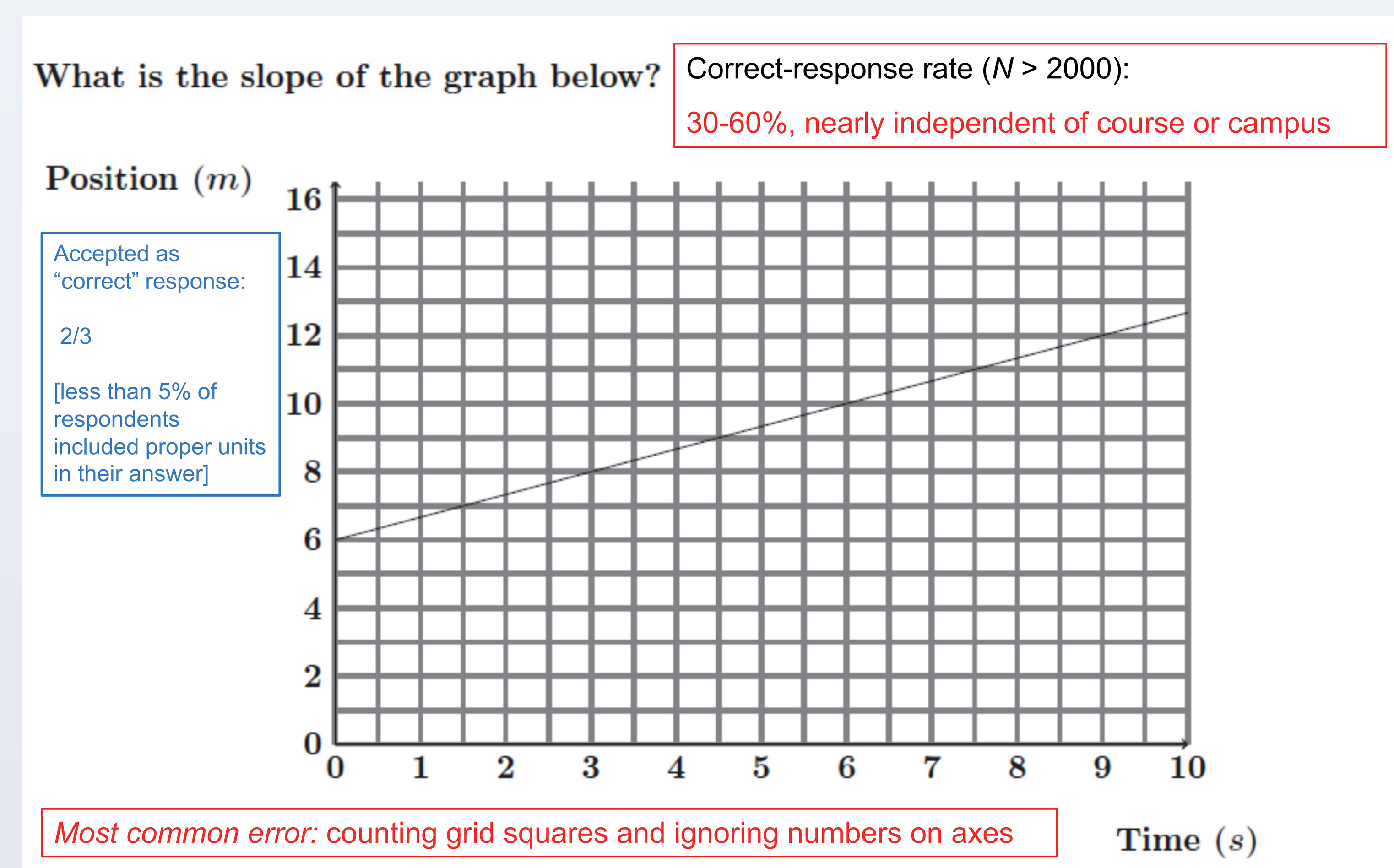
- Regular online math-practice homework assignments may improve speed and/or accuracy, depending on the specific topic.

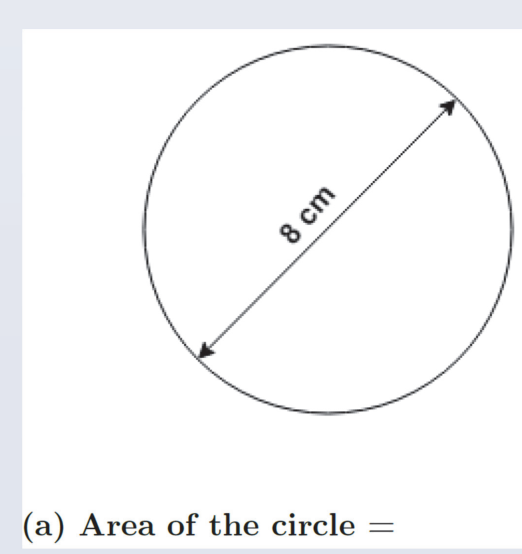
  Implication: Interventions to address students' difficulties in long-practiced topics such as trigonometry and algebra may improve speed but not accuracy, while those targeted at more recently learned topics (such as vectors) may improve accuracy as well.

Algebra: Simultaneous Equations

Correct response rates ≈25% lower on "symbolic" versions.

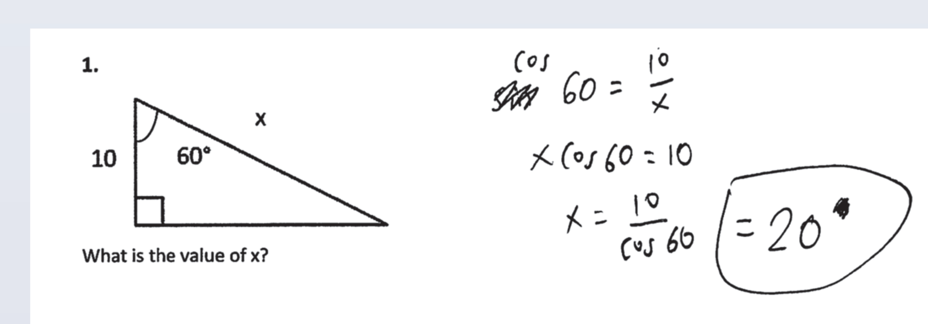
Equations	Task	Version	Result
$0.5y = 2x$ $78.4 - y = 8x$	[Solve for x]	Numeric Version	79% correct (N = 1043)
$cy = dx$ $a - y = bx$	[Solve for x]	Symbolic Version	55% correct (N = 862)

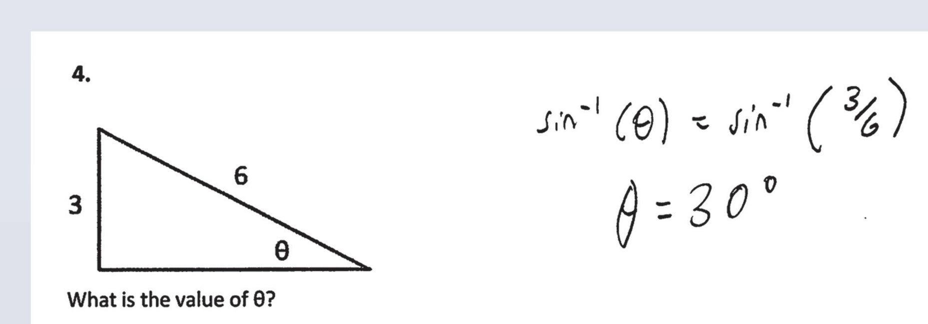




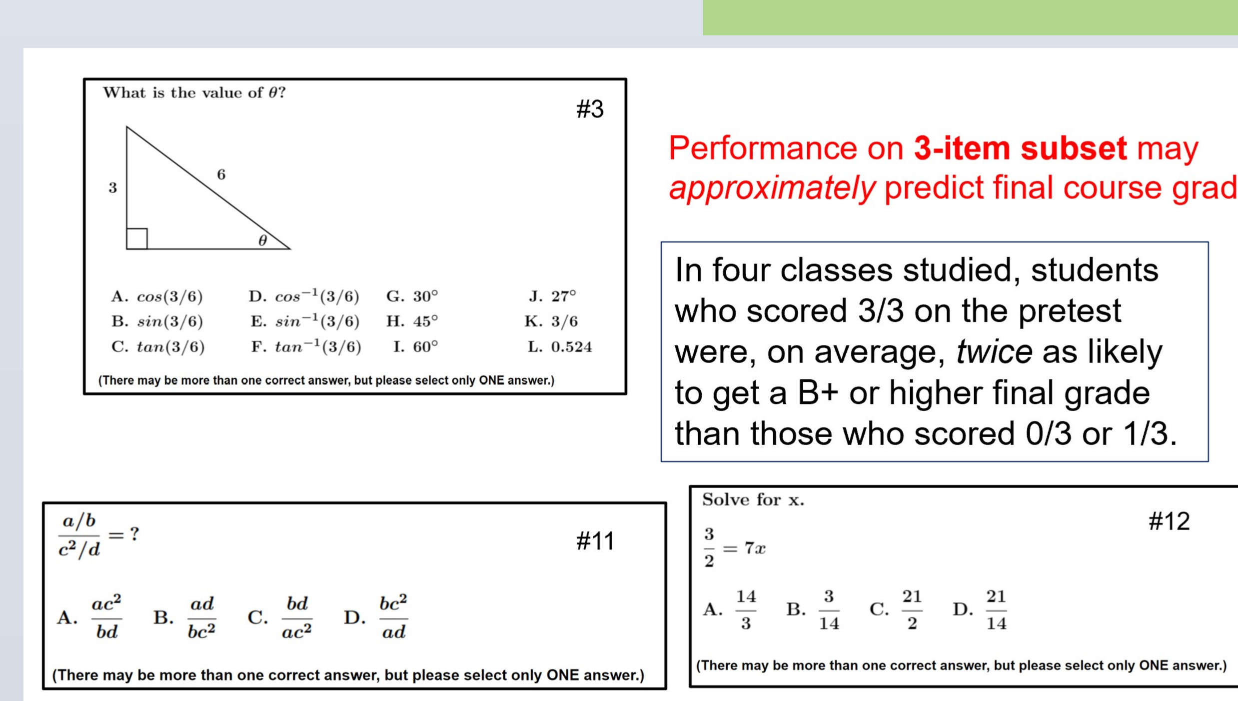
Area of Circle:
ASU-Poly: 57% correct (N = 250)
ASU-Tempe: 76% correct (N = 1086)

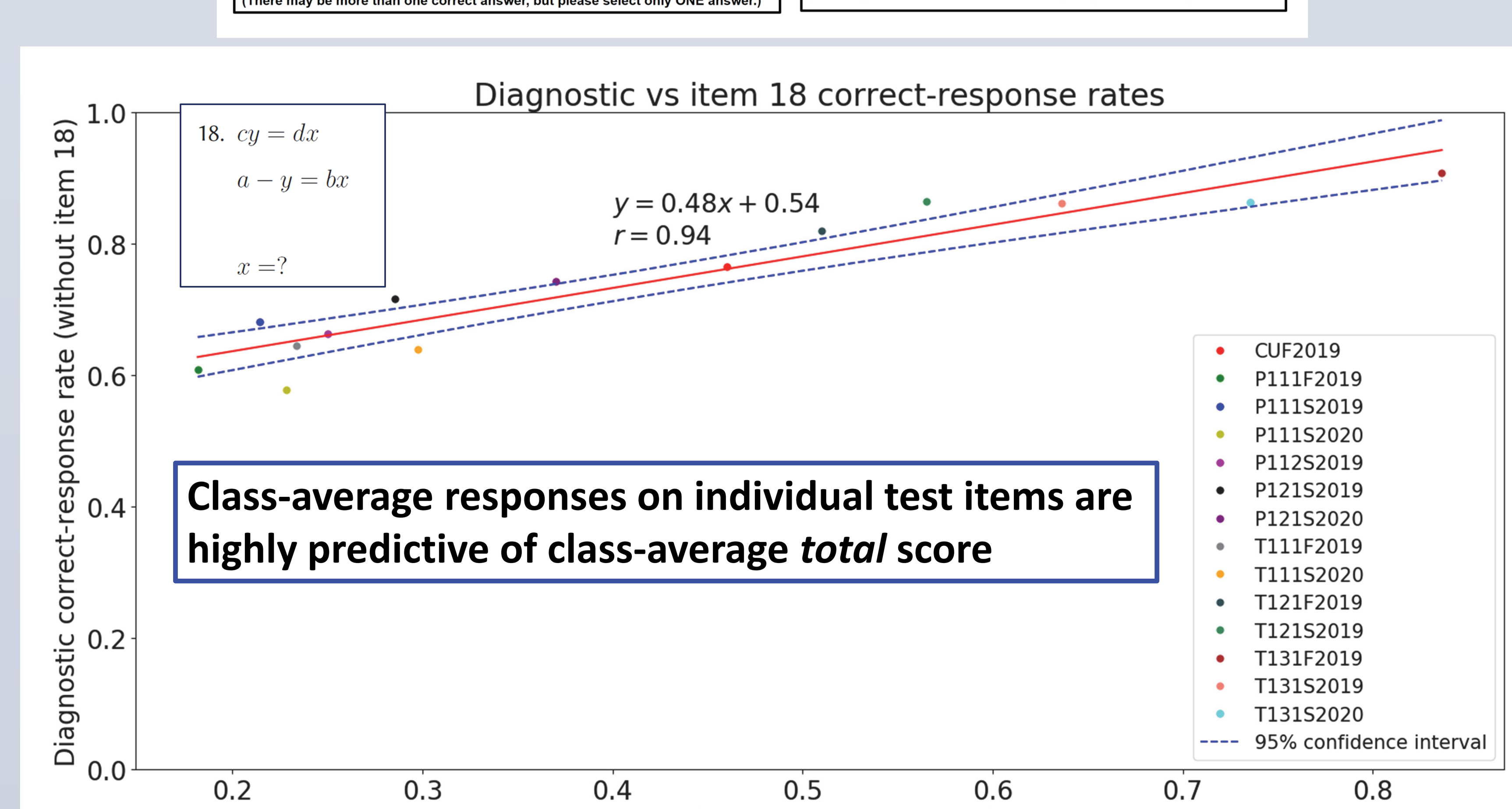
…with correct units: 29% and 45% correct, respectively





Trigonometry Problems:
Algebra-based course: 20-55% correct





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