

Pre-instruction indicators of potential success in introductory physics courses

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Overview

We have administered a number of diagnostic pre-instruction tests to introductory physics students at three campuses of two universities, including measures of mathematical skill, scientific reasoning, and physics knowledge. In addition, we have recently re-analyzed additional related data from two other universities. We find consistently, in every class analyzed, that the top scorers on these pre-instruction tests have substantially higher probability of receiving high course grades (A- or higher) than low-scorers on the tests, typically by a factor of two or more. Similarly, the high scorers have a much lower probability of receiving a low course grade (C+ or lower) than low scorers, again typically by a factor of two or more. We do note that factors such as motivation, class participation, and consistent effort may also play a significant role in course performance.

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Mathematics Diagnostic Test, sample questions:

<p>What is the length of side x?</p> <p>A. $\cos(27^\circ)$ D. $y/\cos(27^\circ)$ G. $\cos(27^\circ)/y$ J. $\sqrt{y^2 + x^2}$ B. $y\sin(27^\circ)$ E. $y/\sin(27^\circ)$ H. $\sin(27^\circ)/y$ K. $\sqrt{x^2 - y^2}$ C. $y\cos(27^\circ)$ F. $y/\tan(27^\circ)$ I. $\tan(27^\circ)/y$ L. y/z</p> <p>(There may be more than one correct answer, but please select only ONE answer.)</p>	<p>What is the value of θ?</p> <p>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. 0.521</p> <p>(There may be more than one correct answer, but please select only ONE answer.)</p>
<p>$\cos(\theta^\circ) = 7$</p> <p>A. 0 B. 1 C. undefined D. 0.707 E. 0.894</p> <p>(There may be more than one correct answer, but please select only ONE answer.)</p>	<p>Solve for θ.</p> <p>$7\theta + \eta = 3\theta + \omega$</p> <p>A. $\frac{\eta + \omega}{7 - 3}$ C. $\frac{\eta - \omega}{4}$ E. $\frac{\eta - \omega}{7}$ G. $\frac{\omega - \eta}{7 - 3}$ I. $\frac{\eta - \omega + \eta}{4}$ B. $\frac{\eta - \omega}{4}$ D. $\frac{\omega - \eta}{4}$ F. $\frac{\omega - \eta}{7 - 3}$ H. $\frac{\omega - \eta}{7 - 3}$ J. $\frac{\omega - \eta + \omega}{4}$</p> <p>(There may be more than one correct answer, but please select only ONE answer.)</p>
<p>What is the slope of the graph below?</p> <p>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.</p> <p>(There may be more than one correct answer, but please select only ONE answer.)</p>	<p>$\left(\frac{a}{b}\right)^3 = ?$</p> <p>A. $\frac{a^3}{3}$ B. $\frac{a}{27}$ C. $\frac{a^3}{27}$</p> <p>(There may be more than one correct answer, but please select only ONE answer.)</p>
<p>$\frac{a/b}{c^2/d} = ?$</p> <p>A. $\frac{ac^2}{bd}$ B. $\frac{ad}{bc^2}$ C. $\frac{bd}{ac^2}$ D. $\frac{bc^2}{ad}$</p> <p>(There may be more than one correct answer, but please select only ONE answer.)</p>	<p>$2\left(\frac{a}{b}\right) = ?$</p> <p>A. $\frac{2a}{b}$ B. $\frac{2a}{2b}$ C. $\frac{a}{2b}$</p> <p>(There may be more than one correct answer, but please select only ONE answer.)</p>
<p>$2\left(\frac{a}{d}\right) = ?$</p> <p>A. $\frac{a}{8}$ B. $\frac{12}{8}$ C. $\frac{3}{8}$ D. $\frac{3}{2}$ E. $\frac{3}{4}$</p> <p>(There may be more than one correct answer, but please select only ONE answer.)</p>	

Physics concept knowledge: The 30-item FCI

An elevator is being lifted up an elevator shaft at a constant speed by a steel cable as shown in the figure below. All frictional effects are negligible. In this situation, forces on the elevator are such that:

(A) the upward force by the cable is greater than the downward force of gravity.
 (B) the upward force by the cable is equal to the downward force of gravity.
 (C) the upward force by the cable is smaller than the downward force of gravity.
 (D) the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air.
 (E) none of the above. (The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable).

Elevator going up at constant speed

Scientific reasoning skills: The 24-item Lawson test

Sample Questions:

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?

R R R
Y Y Y

- 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. Math Diagnostic Score

Course	Campus	N	Overall % grade \geq A-	Score \geq 81% % grade \geq A-	Score \leq 57% % grade \geq A-	High-grade Ratio score \geq 81% vs. score \leq 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

Low Course Grade vs. Math Diagnostic Score

Course	Campus	N	Overall % grade \leq C+	Score \geq 81% % grade \leq C+	Score \leq 57% % grade \leq C+	Low-grade Ratio score \leq 57% vs. score \geq 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. Lawson Test of Scientific Reasoning Pretest Score

Course	Campus	N	Overall % grade \geq A-	Top-quartile Lawson % grade \geq A-	Bottom-quartile Lawson % grade \geq A-	High-grade Ratio 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 \leq C+	Top-quartile Lawson % grade \leq C+	Bottom-quartile Lawson % grade \leq 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
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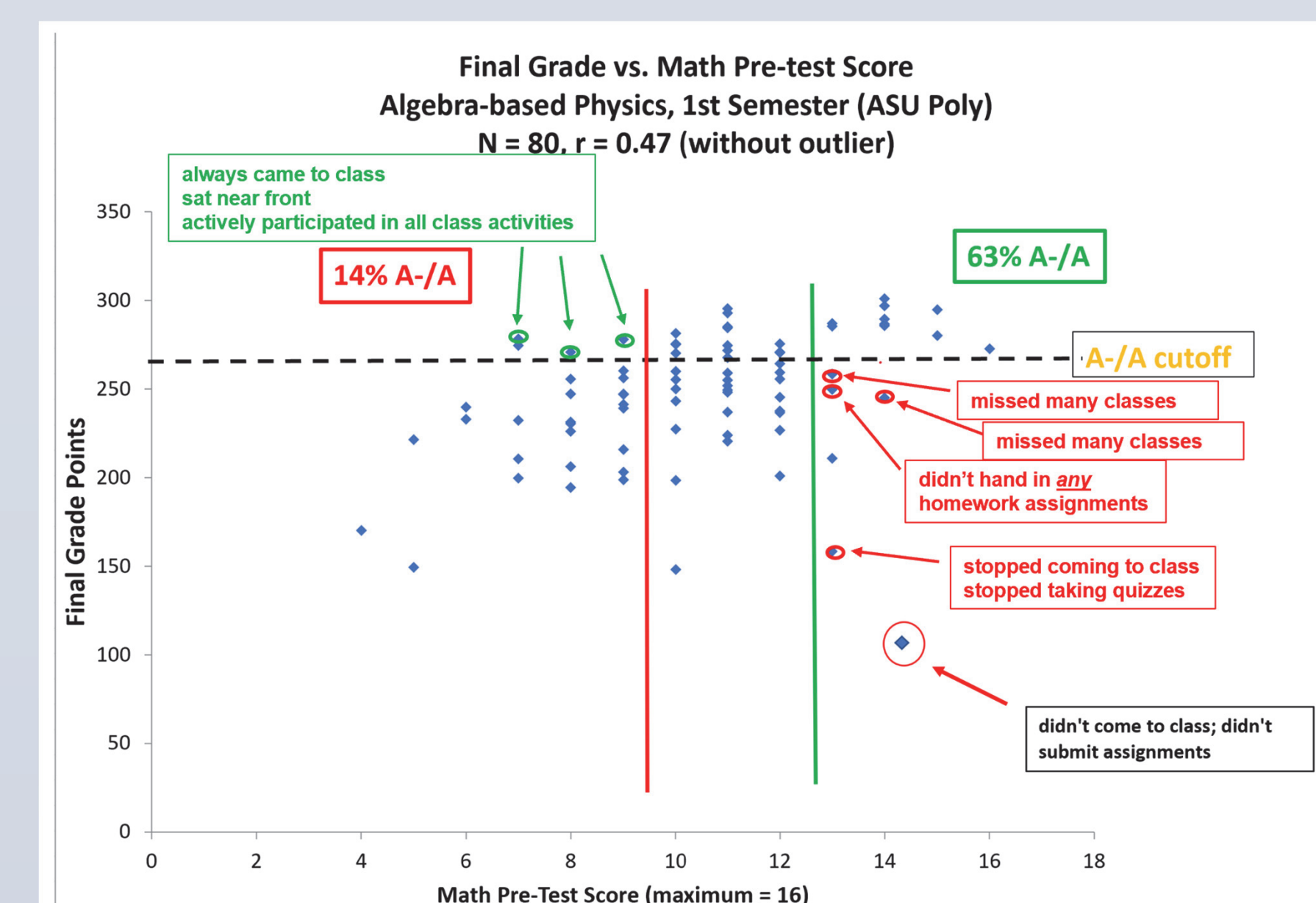
Students who scored low on Lawson reasoning pretest had consistently more "C" course grades than those who scored high

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

FCI Pretest score: **0-30%** **63-100%**

A: 12% A: 65%
 B: 44% B: 22%
 C: 26% C: 13%

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



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 can potentially compensate for relative weaknesses in skills or knowledge preparation