Pre-instruction diagnostic tests can help predict probability of obtaining high or low course grades in introductory physics

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Supported in part by NSF DUE #1504986 and #1914712

30 years ago today (+1 day): My first AAPT talk

Session FB: Contributed Session on Topics in Introductory Physics—College Level, Part I (Also see Part II–GC, January 19, 8:30 a.m.)

Wednesday, January 18, 1995; 1:15 p.m.–5:15 p.m.

Salons 11 & 12

Presiding: LARRY BADAR, Dept. of Physics, Case Western Reserve Univ., 10900 Euclid Ave., Cleveland, OH 44106-7079; 216-368-8779

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FB12 4:00 A Pilot Project for an Elementary Phys-[illegible]

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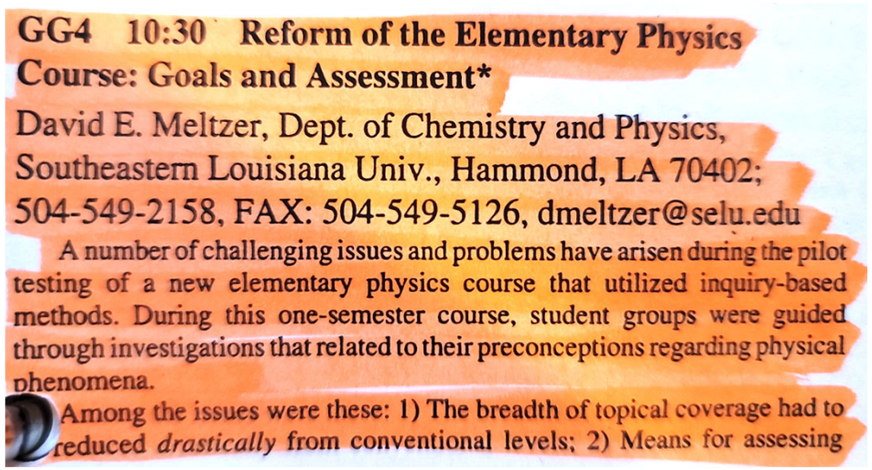
"A Pilot Project for an Elementary Physics Course Based on Guided Inquiry, with the Theme of 'Energy'"

One year later, I reported some concerning findings…

Session GG: Invited and Contributed Session on Reforms in High School Physics Education (Sponsored by the Committee on Physics in High Schools)

Thursday, January 18, 1996; 9:00 a.m.–11:00 a.m.

Bonanza B



GG4 10:30 Reform of the Elementary Physics Course: Goals and Assessment*

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A number of challenging issues and problems have arisen during the pilot testing of a new elementary physics course that utilized inquiry-based methods. During this one-semester course, student groups were guided through investigations that related to their preconceptions regarding physical phenomena.

Among the issues were these: 1) The breadth of topical coverage had to reduced *drastically* from conventional levels; 2) Means for assessing

"A number of challenging issues and problems have arisen during the pilot testing of a new elementary physics course…"

→ Typical students have very weak academic preparation

- poor algebra skills
- difficulty with proportional reasoning
- very weak graphing skills
- little experience or ability in conceptual reasoning

- A great deal of time had to be spent on "remedial" work, such as graphing skills and rate/time/distance problems

- There was sustained difficulty with rudimentary algebra and proportional reasoning

- Students had great difficulty with abstract concepts such as instantaneous velocity, acceleration, and energy

Are effects of these same issues evident in the general physics course?

- We administered a variety of diagnostic pretests to students in introductory general physics courses
- We assessed the degree to which performance on the pretests is associated with students' final grades in physics

Assessment Pretests

- Diagnostic pretest covering pre-college mathematics (“Math”)
  - calculators allowed
- Pre-instruction tests of scientific reasoning skill and physics concept knowledge:
  - Lawson Test of Scientific Reasoning (“Lawson”)
  - Force Concept Inventory (FCI)
- Why do this? Perhaps ultimately we can offer special assistance to those students who need it most.

Sample Description

- 31 introductory physics classes from 4 universities, 8 different instructors; over 2000 total students.
- Instruction in most classes was “non-traditional,” generally highly interactive using research-based instructional materials and methods

Acknowledgments

- Diagnostic data have been provided by (among others):

  Vince Coletta (Loyola Marymount University)

  Steven Pollock (University of Colorado, Boulder)

  Christopher Varney (University of West Florida)

Course and Institution Code

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

LMU: Loyola Marymount University

UWF: University of West Florida

CU: University of Colorado, Boulder

Comparing probabilities of high and low grades

- What is the probability of a student with a high score on a pre-instruction assessment getting a high grade in the class?
- How does that compare to a low-scoring student's probability of getting a high grade?

(and, same questions for probabilities of getting a *low* grade)

Consistent result:

High (top-quartile) scorers on *any one* of the diagnostic pretests were much more likely to get high (top-quartile) grades and much less likely to get low (bottom-quartile) grades than were low scorers.

But how *much* more (or less) likely?…

- High scorers on any one of the pretests were much more likely (400-600%) to receive high grades than were low scorers.
- High scorers were much *less* likely (20-30%) to receive low grades than were low scorers.
- This general pattern held for 113 out of 116 comparisons (97%) and for all four universities, although the quantitative range was large.

High-Grade Probability vs. Lawson Pretest Score

Course	Campus	*N*	Top-quartile Lawson: % with top-quartile grades	Bottom-quartile Lawson: % with top-quartile grades	High-grade odds ratio
Alg-1 2021a	ASU-P	37	49%	11%	4.3
Alg-1 2021b	ASU-P	36	41%	11%	3.7
Alg-1 2022a	ASU-P	41	49%	10%	5.0
Alg-1 2022b	ASU-P	53	58%	10%	5.8
Alg-1 2023a	ASU-P	36	39%	33%	1.2
Alg-1 2023b	ASU-P	43	55%	10%	5.5
Alg-2 2022	ASU-P	66	52%	4%	11.9
Alg-2 2023	ASU-P	76	51%	16%	3.2
Alg-2 2024	ASU-P	90	41%	5%	8.0
Alg-1 2005	CU	469	45%	8%	5.5
Calc-2 2007	CU	276	57%	8%	6.9
Alg-1 2007	LMU	24	50%	0%	[undefined]
Alg-1 2009	LMU	51	34%	11%	3.2
Alg-1 2011	LMU	57	53%	18%	2.9
Alg-1 2012	LMU	44	64%	6%	10.5
Alg-1 2013	LMU	30	53%	12%	4.6
Alg-1 2014	LMU	33	61%	0%	[undefined]
Alg-1 2015	LMU	24	63%	0%	[undefined]
Alg-1 2016	LMU	35	41%	0%	[undefined]
Alg-1 2018	LMU	47	54%	9%	6.3
Alg-1 2021	LMU	27	44%	0%	[undefined]
AVERAGE (unweighted)		***[1595]***	**50%**	**9%**	**5.8**

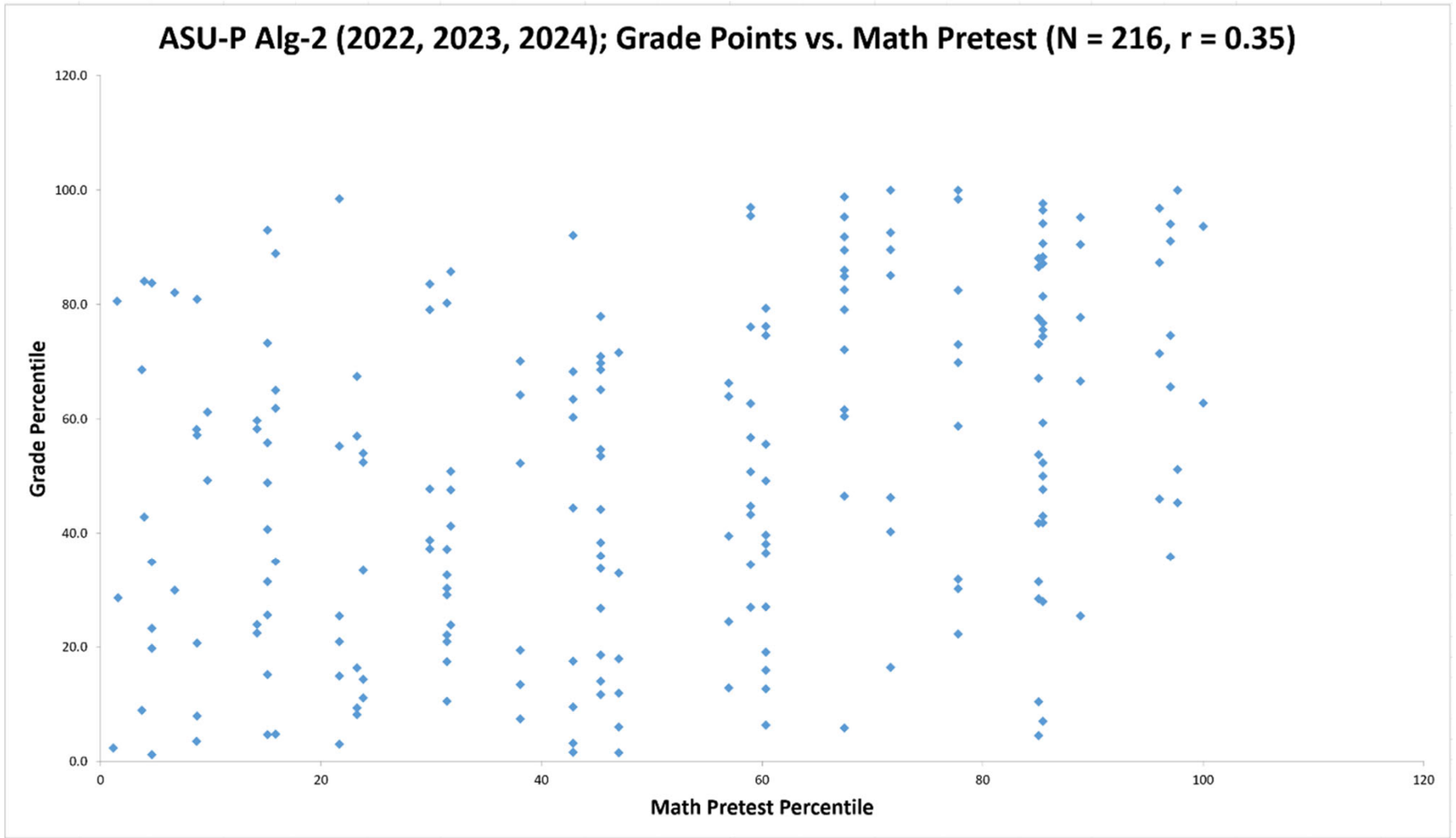
High scorers almost 6 times as likely to get top-quartile grades as low scorers

Low-Grade Probability vs. Lawson Pretest Score

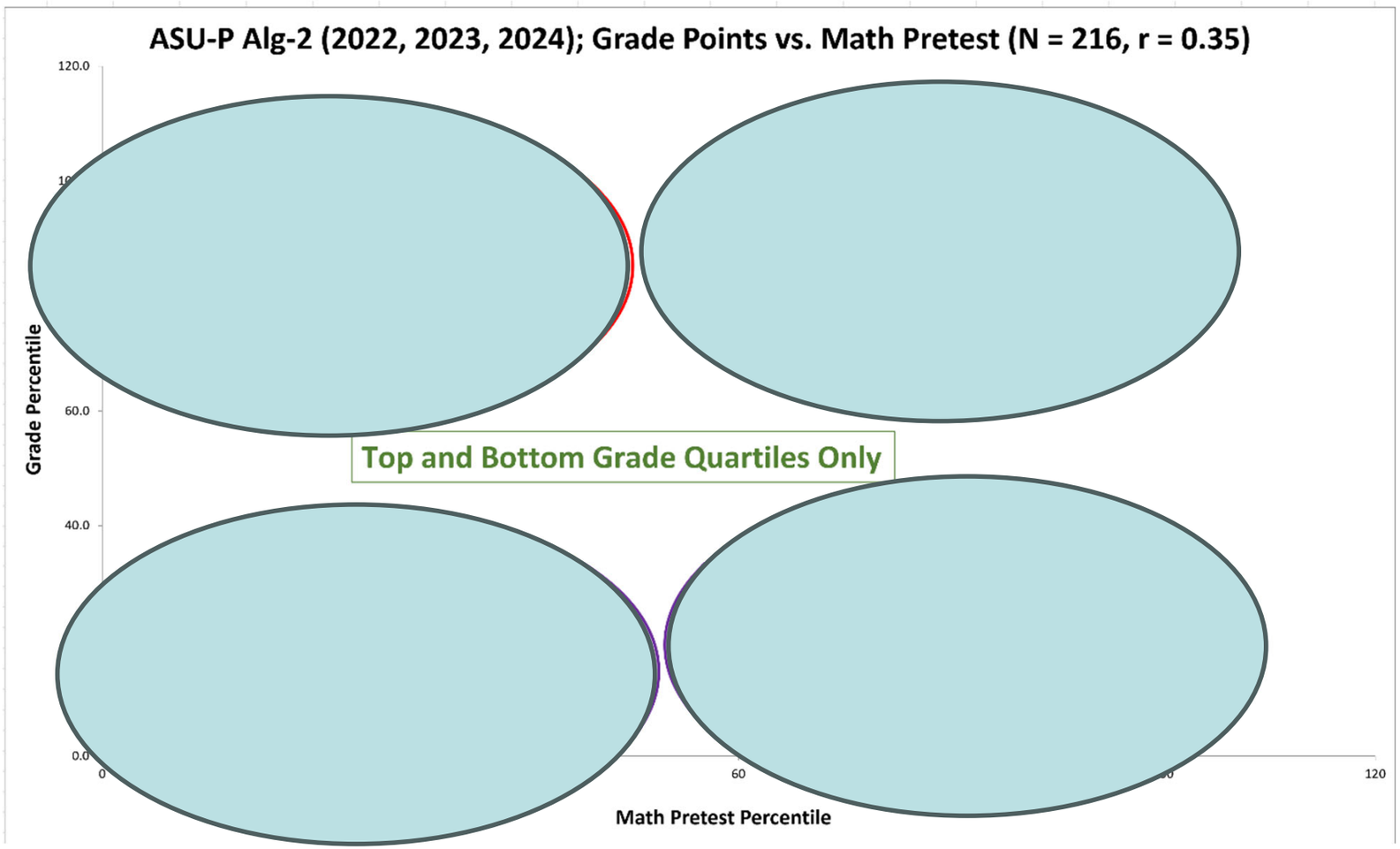
Course	Campus	*N*	Top-quartile Lawson: % with bottom-quartile grades	Bottom-quartile Lawson: % with bottom-quartile grades	Low-grade odds ratio
Alg-1 2021a	ASU-P	37	6%	44%	7.2
Alg-1 2021b	ASU-P	36	11%	47%	4.2
Alg-1 2022a	ASU-P	41	15%	28%	1.9
Alg-1 2022b	ASU-P	53	15%	45%	3.0
Alg-1 2023a	ASU-P	36	14%	36%	2.6
Alg-1 2023b	ASU-P	43	8%	50%	6.7
Alg-2 2022	ASU-P	66	12%	25%	2.1
Alg-2 2023	ASU-P	76	11%	28%	2.7
Alg-2 2024	ASU-P	90	10%	36%	3.6
Alg-1 2005	CU	469	10%	42%	4.4
Calc-2 2007	CU	276	12%	44%	3.8
Alg-1 2007	LMU	24	0%	58%	[undefined]
Alg-1 2009	LMU	51	5%	48%	10.4
Alg-1 2011	LMU	57	15%	46%	3.0
Alg-1 2012	LMU	44	9%	27%	3.0
Alg-1 2013	***LMU***	***30***	***27%***	***12%***	***0.4***
Alg-1 2014	LMU	33	0%	68%	[undefined]
Alg-1 2015	LMU	24	0%	75%	[undefined]
Alg-1 2016	LMU	35	11%	46%	4.0
Alg-1 2018	LMU	47	16%	42%	2.7
Alg-1 2021	LMU	27	0%	89%	[undefined]
AVERAGE (unweighted)		***[1595]***	**10%**	**45%**	**4.5**

Low scorers 4.5 times as likely to get bottom-quartile grades as high scorers

Grades vs. Math Pretest Score for “Combined” Sample



Grades vs. Math Pretest Score for “Combined” Sample



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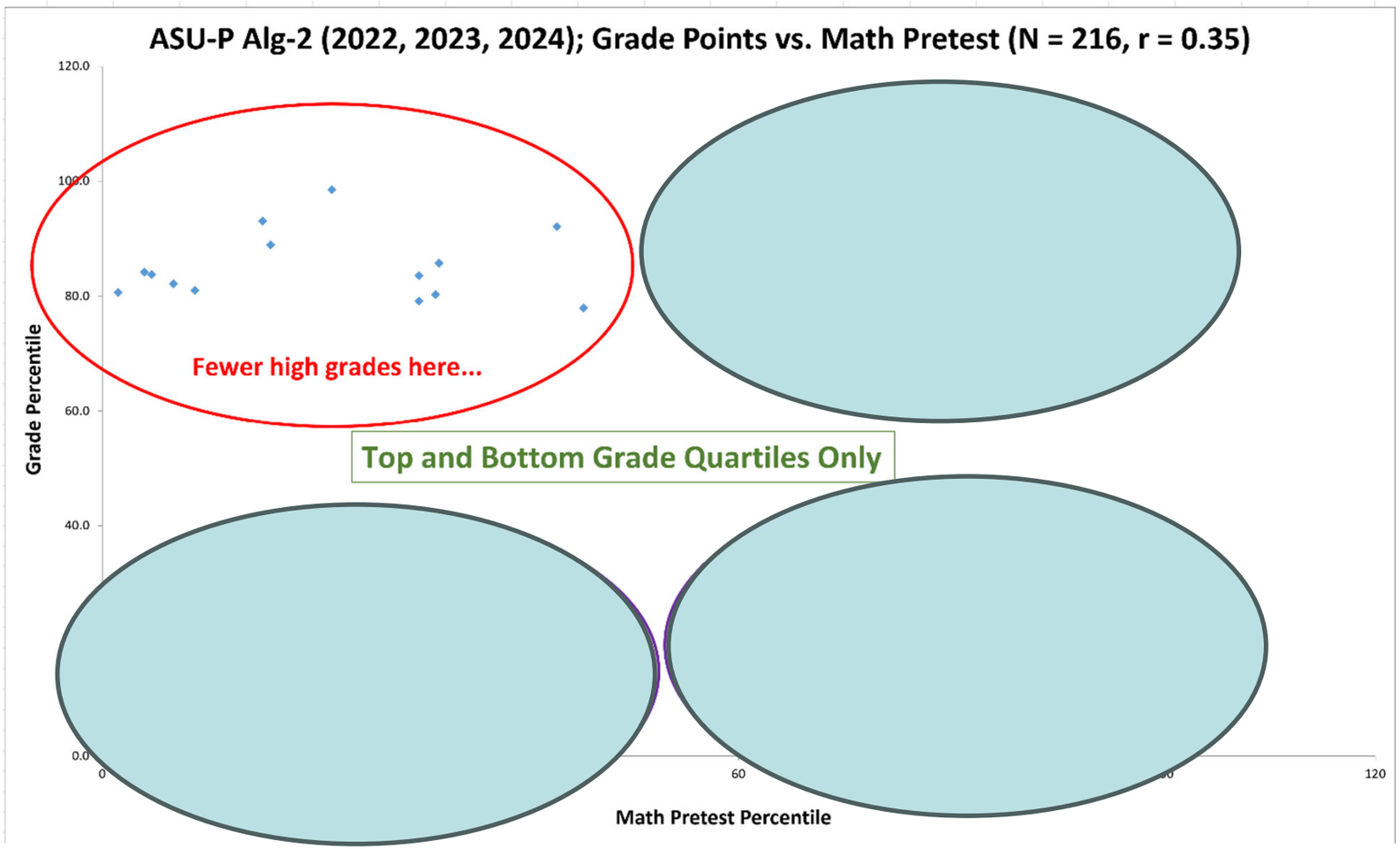

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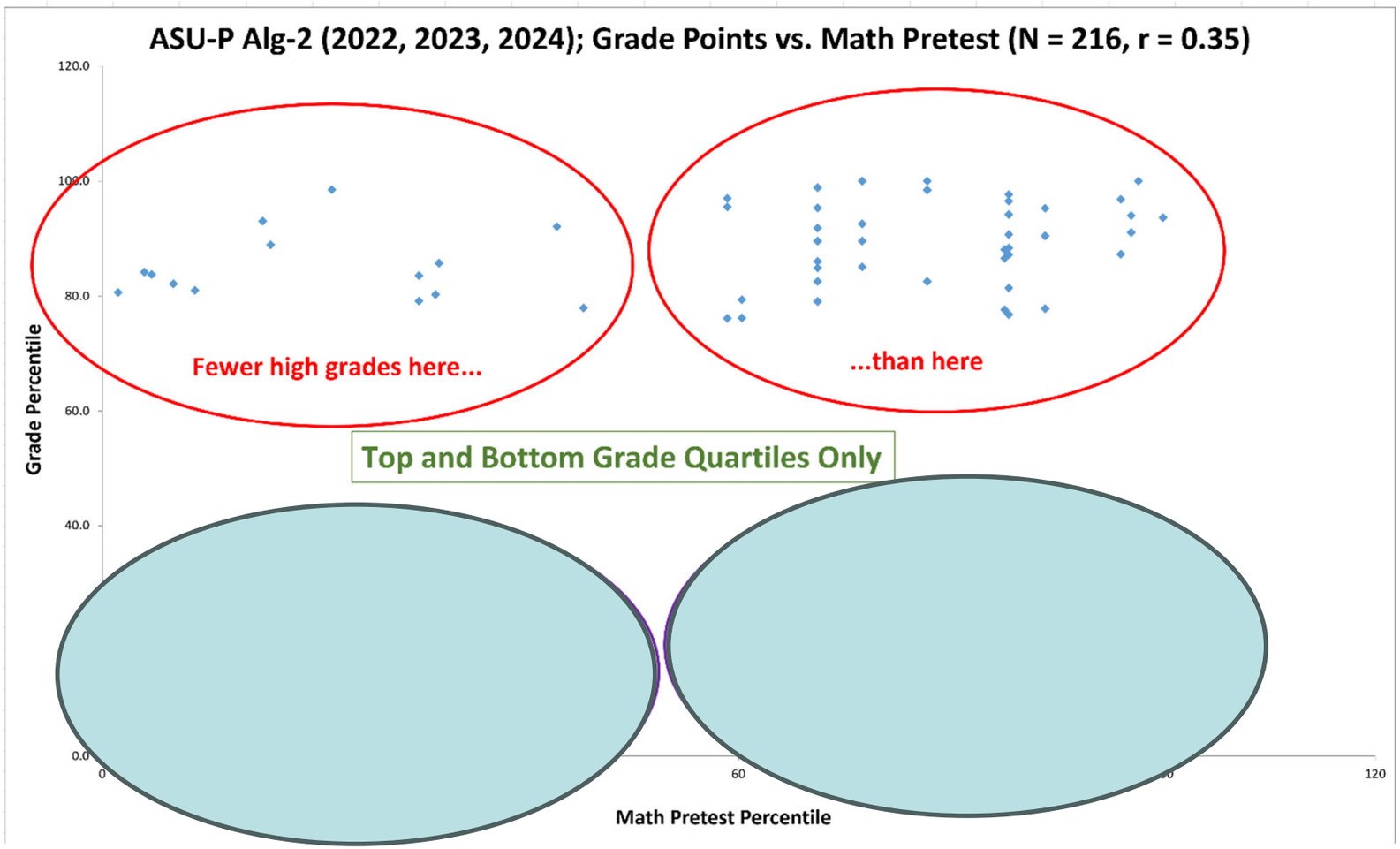

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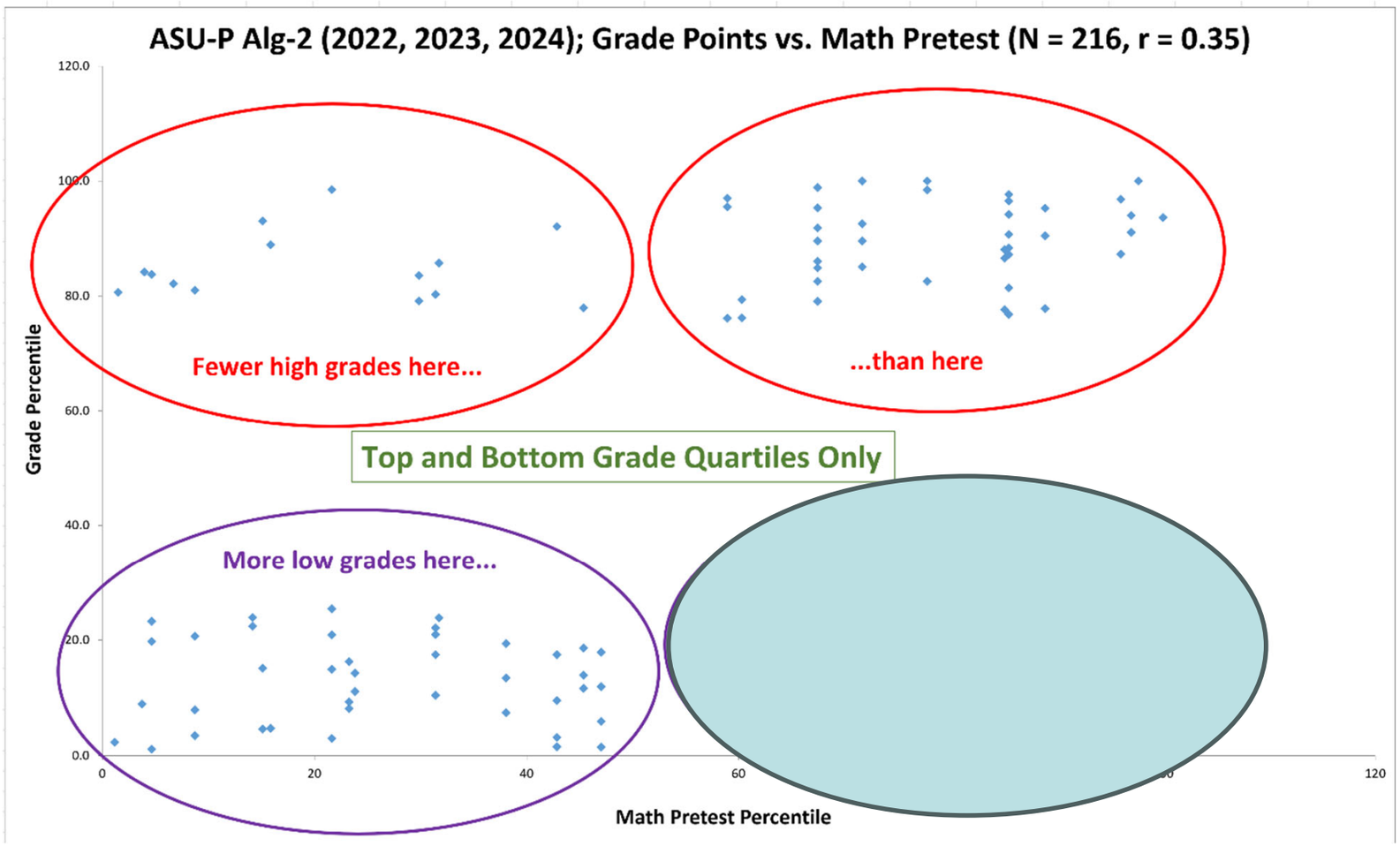

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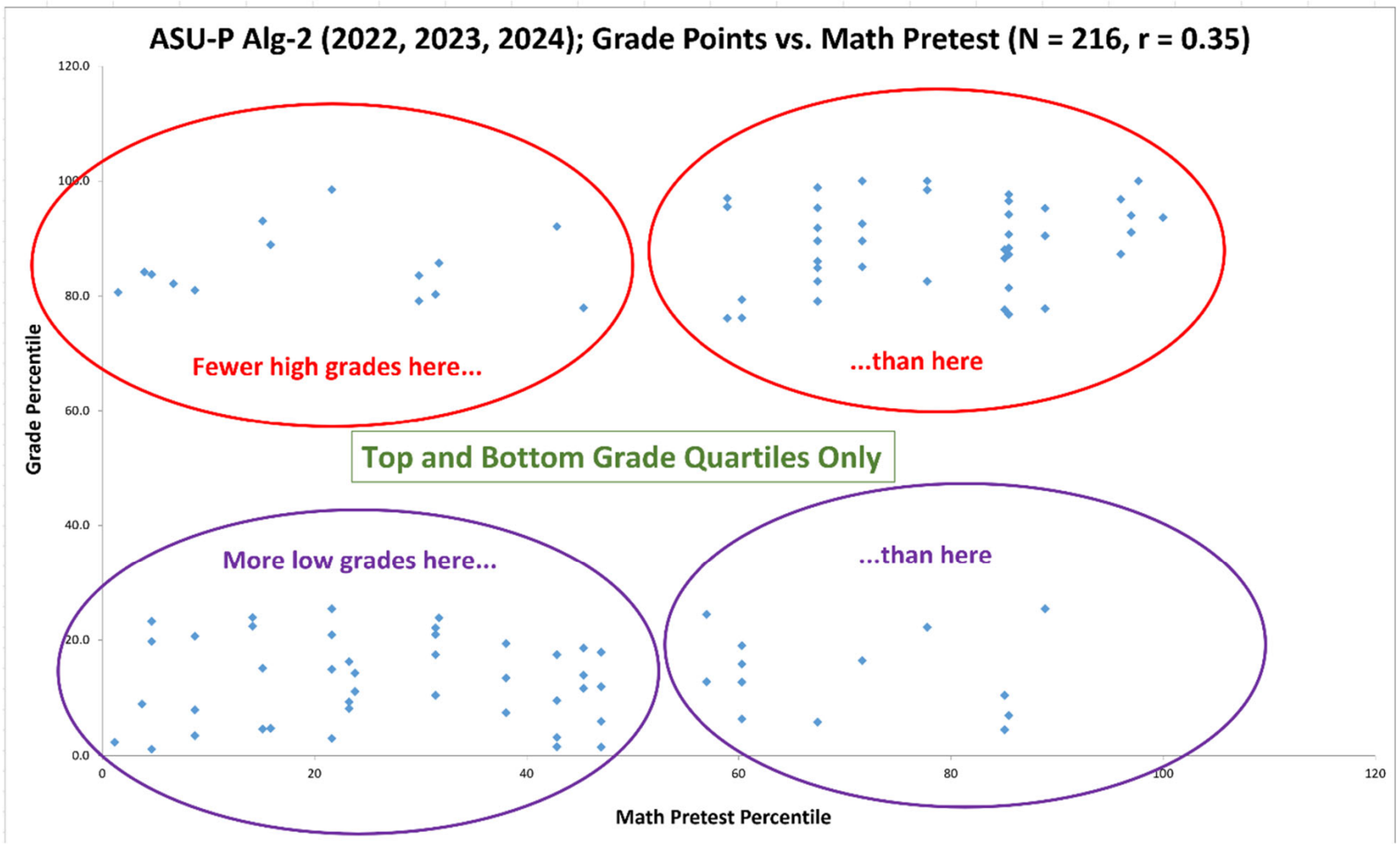
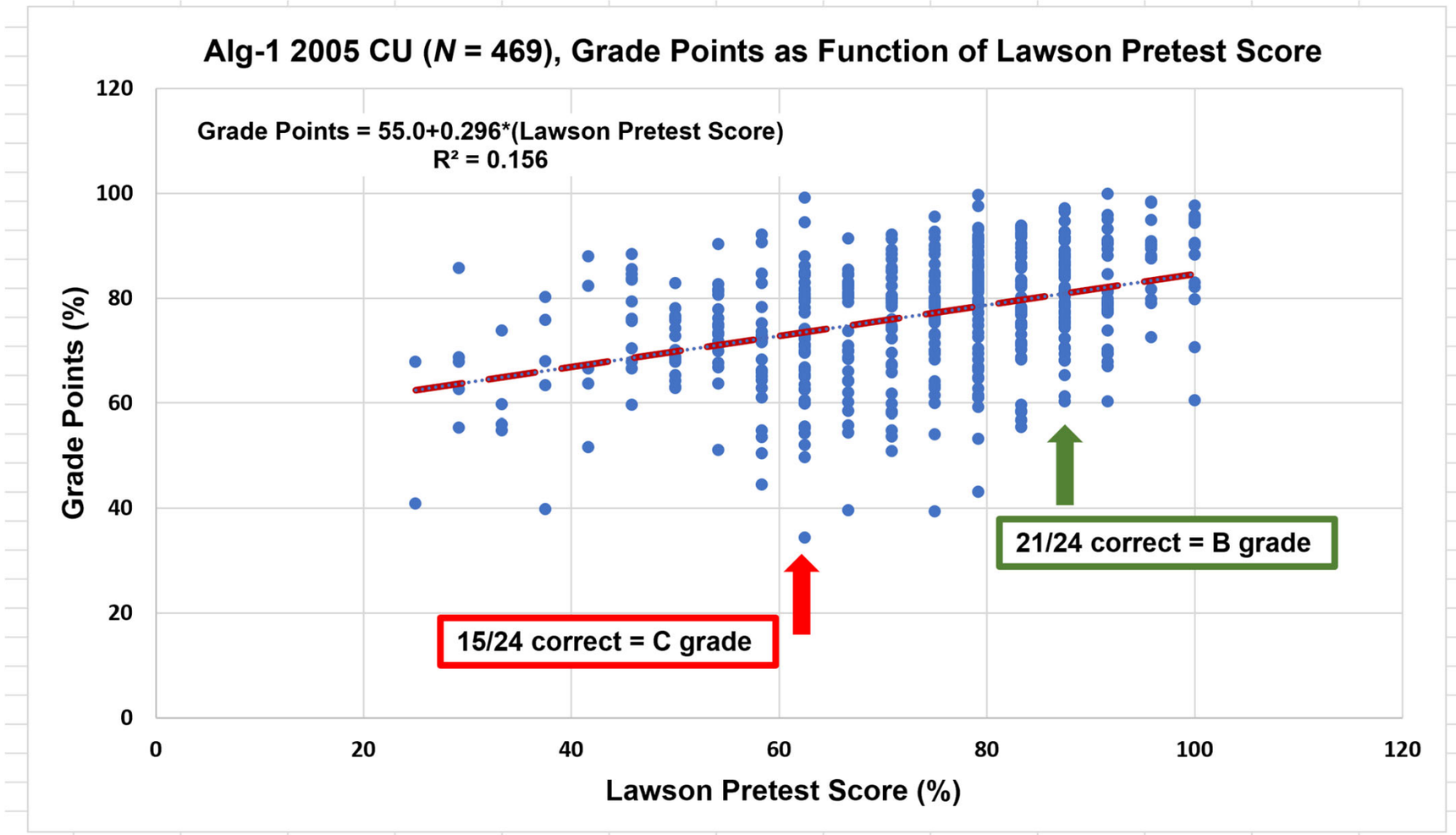


Grades vs. Lawson Pretest Score for Alg-1 2005 CU Sample

For Alg-1 CU, our largest sample (N = 469):

How do students' median course grades vary depending on their pretest scores on the Lawson test of scientific reasoning?

Grades vs. Lawson Pretest Score for Alg-1 2005 CU Sample



Some “answers” to relevant questions

- Which, if any, of the diagnostic pretests is most predictive of students’ performance? *Varies with the course*
- Does using multiple predictor variables offer greater predictive power than using just one of them? *Yes, sometimes*
- Does better performance on one predictor variable indicate that another variable is more (or less) predictive? (This would be an “interaction” effect.) *Maybe*

  [if student gets a high score on one pretest, score on the other pretest adds predictive power; if low score on one pretest, other pretest is not very predictive]

Prediction by Salehi et al. (2019)* based on their theoretical model and empirical observations in similar courses:

"These …[model-fit] values may seem modest to some, but they have career-altering implications for students who are poorly prepared….for [a typical value of the model-fitting parameter]…a student who comes in with preparation in the bottom quartile has about a factor of 4 higher probability of being in the bottom quartile of the grade distribution than a student who starts the course in the upper quartile of preparation. If one considers bottom quartile exam scores as failing, this means that poorly prepared students are 4 times more likely to fail their physics 1 final exams than peers with good incoming preparation." [Salehi et al. (2019), p. 020114-6]

Our results: "poorly prepared" students (i.e., low scorers) are 2-5 times more likely to get bottom-quartile course grades than peers with "good" preparation (i.e., high scorers)

*Shima Salehi, Eric Burkholder, G. Peter Lepage, Steven Pollock, and Carl Wieman, "Demographic gaps or preparation gaps?: The large impact of incoming preparation on performance of students in introductory physics," Phys. Rev. Phys. Educ. Res. **15**(2), 020114 (2019).

Summary

- Regardless of group *probabilities*, the course performance outcome for any *individual* student remains highly uncertain and depends on many factors.
- **It is reasonable to acknowledge that the course performance expected for the *group* of low-scorers on these pretests must be very different from that expected for the high-scorers.**
- Question: Can these findings be used to offer modified or supplemental instruction for the more “at-risk” group to improve their course outcomes?