Prerequisite Testing as a Tool to Gauge Incoming Student Capability & Knowledge in Engineering Statics

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Motivation for Obtaining Baseline Information

- New generation of college-age students have *both* capabilities and needs that are quite different than previous generation*

- Consequently, teaching techniques may have to be adjusted to meet their needs

- Question: if there are changes in performance, is it due to a change in teaching method or change in student capability?

  o Need to know the baseline capability & knowledge level of students entering the course

*Reference: Moore *et al*., 2017, "Engineering Education for Generation Z," *AJEE*, Vol. 8

Background on Student Performance in First Author's Statics Course

- Over the course of 25+ years, the first author has changed the exam structure in Statics several times

- Current 50-minute class regular exams: three calculation-based working problems similar to class and textbook examples

- Current 75-minute class exams: four working problems of same type as 50-min class plus four multiple choice concept questions

- Performance difference found: grade point average (GPA) of 75-minute classes is 16.5% higher than GPA of 50-minute classes

- Hypothesis / possible reasons:
1) Concept questions are too easy and inflates GPA of 75-minute classes *OR*
2) There is a difference in student capability between class sections
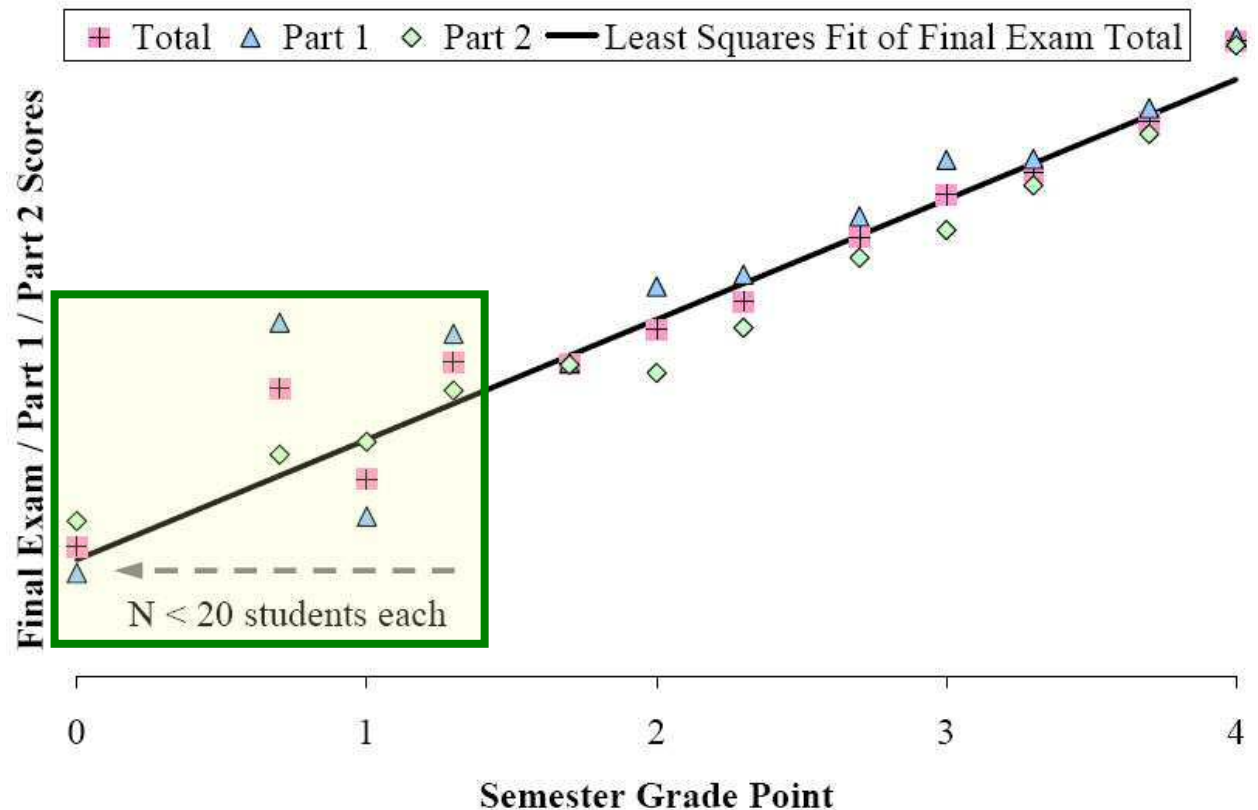
Methodology

- Investigate whether, pedagogically speaking, concept questions are easier than multi-step calculation-based working problems
  - o Examine whether the junior-year Propulsion course final exam, which utilizes both types of questions, correlates with semester grade

- Determine how the Statics final exam, which has concept questions and short answer calculation-based problems, correlate against the semester grade for both 50- and 75-minute classes

- Investigate whether class GPA correlates with prerequisite testing, which measures incoming student capability and knowledge
  - o Determine what conclusions can be drawn about the capability of 50- and 75- minute classes based on prerequisite testing

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Junior-year Propulsion Course Final Exam Format

- Junior-year Propulsion course has a 110-minute comprehensive final exam weighted as 30% of the semester grade
- Final consists of two parts, each worth 50% of the final exam:
  - 1st part – concept questions (2/3 of the points) plus single step calculation-based short answer questions (1/3 of the points)
  - 2nd part – four multi-step calculation-based working problems
- Determine the correlation of the two parts with the semester grade
- Pearson correlation coefficient ranges between +1 and -1
  - It is +1 when it is perfectly correlated
  - It is 0 when there is no correlation at all
  - It is -1 when increase in one variable leads to a decrease in other
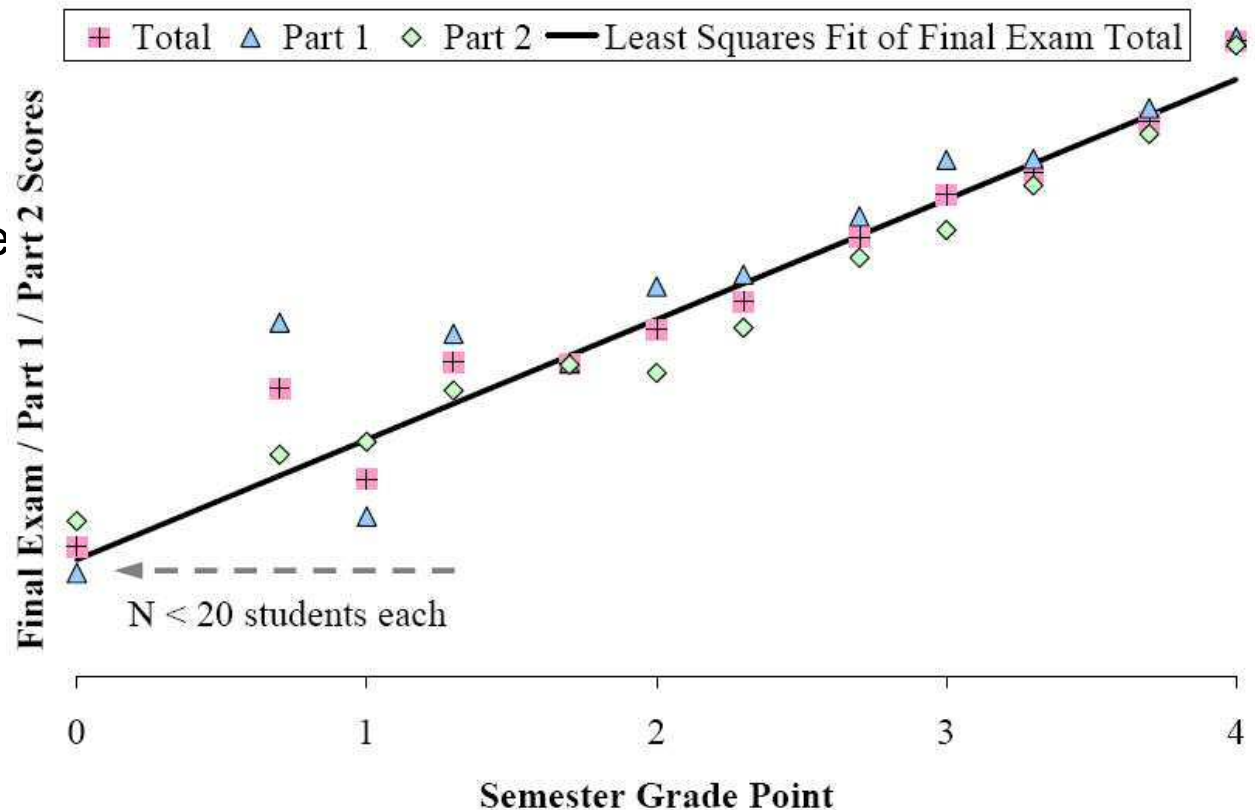 - Less scattered when the correlation coefficient approaches +/-1

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Propulsion Final Exam Results

- **Pearson correlation coefficient of +0.805**
  - o Highly correlated
- **Graph of Propulsion final exam score correlated against semester grade (N=350 students)**
- **Generally limited scatter with the exception of D's**
  - o Arises due to limited data (N<20 students)

Legend: + Total △ Part 1 ◇ Part 2 ── Least Squares Fit of Final Exam Total

Y-axis: Final Exam / Part 1 / Part 2 Scores
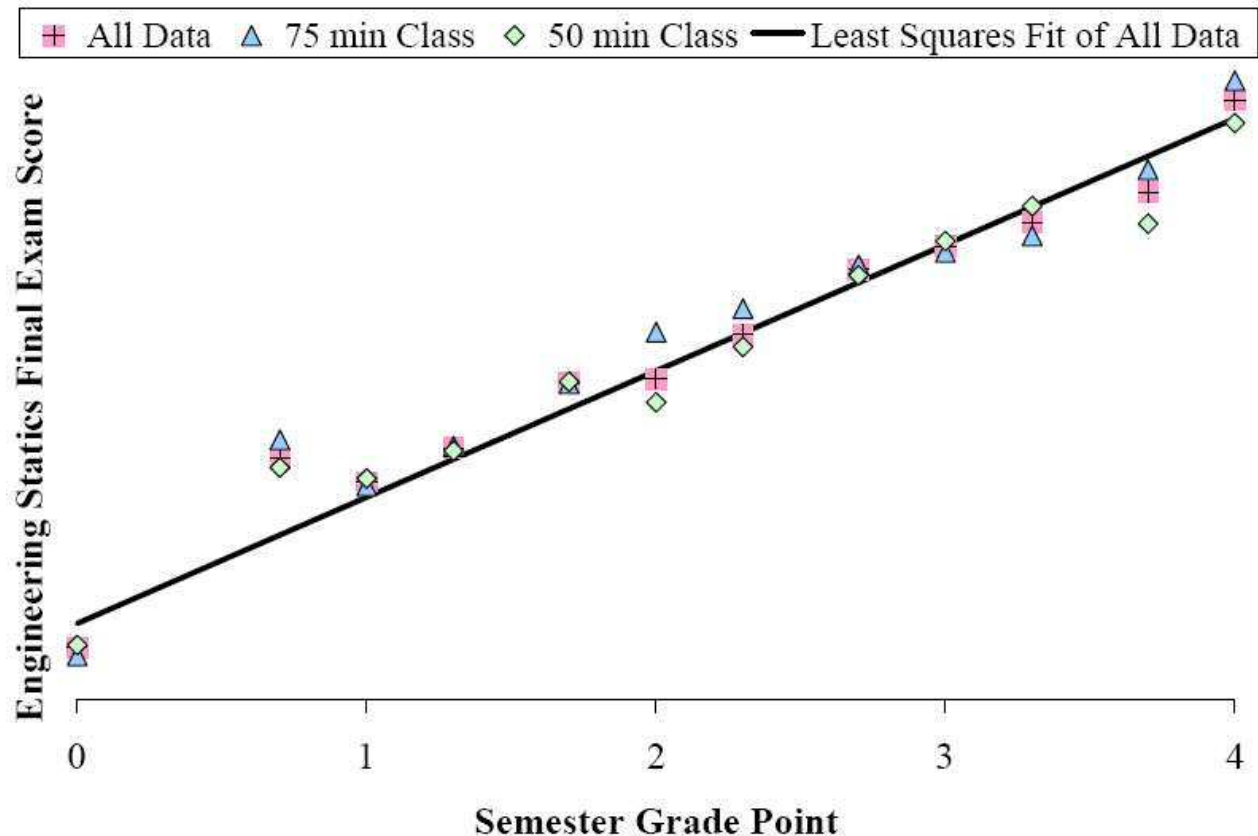X-axis: Semester Grade Point

N < 20 students each

Propulsion Final Exam Results

- Least squares fit to total of 1st & 2nd parts (■ data and line –)

- 1st part (▲) lies above least squares fit line → slightly harder

- 2nd part (♦) lies below least squares fit line → slightly easier

- Conclusion: concept questions are of comparable difficulty level, so **unlikely** to cause increased GPA

+ Total   △ Part 1   ◇ Part 2   —— Least Squares Fit of Final Exam Total

Final Exam / Part 1 / Part 2 Scores

N < 20 students each

Semester Grade Point

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Examine Student Performance in Common Format Statics Final Exam

- Graph of Statics final correlated against semester grade (N=241 students)

- Pearson correlation coefficient of 0.861
  - Highly correlated

- Pearson=0.858 for 75-min class (△, N=109)

- Pearson=0.856 for 50-min class (♦, N=132)

Legend: + All Data △ 75 min Class ◇ 50 min Class — Least Squares Fit of All Data

Y-axis: Engineering Statics Final Exam Score
X-axis: Semester Grade Point

- Very little difference in correlation between 75min & 50min classes for final

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Examine Student Performance in Common Format Statics Final Exam

- Students perform similarly irrespective of 50- or 75-min class for the same type of final exam

- Graph does not show how many students are at each grade → this is main affecter of class GPA

- Thus, this graph cannot answer the question about student capability
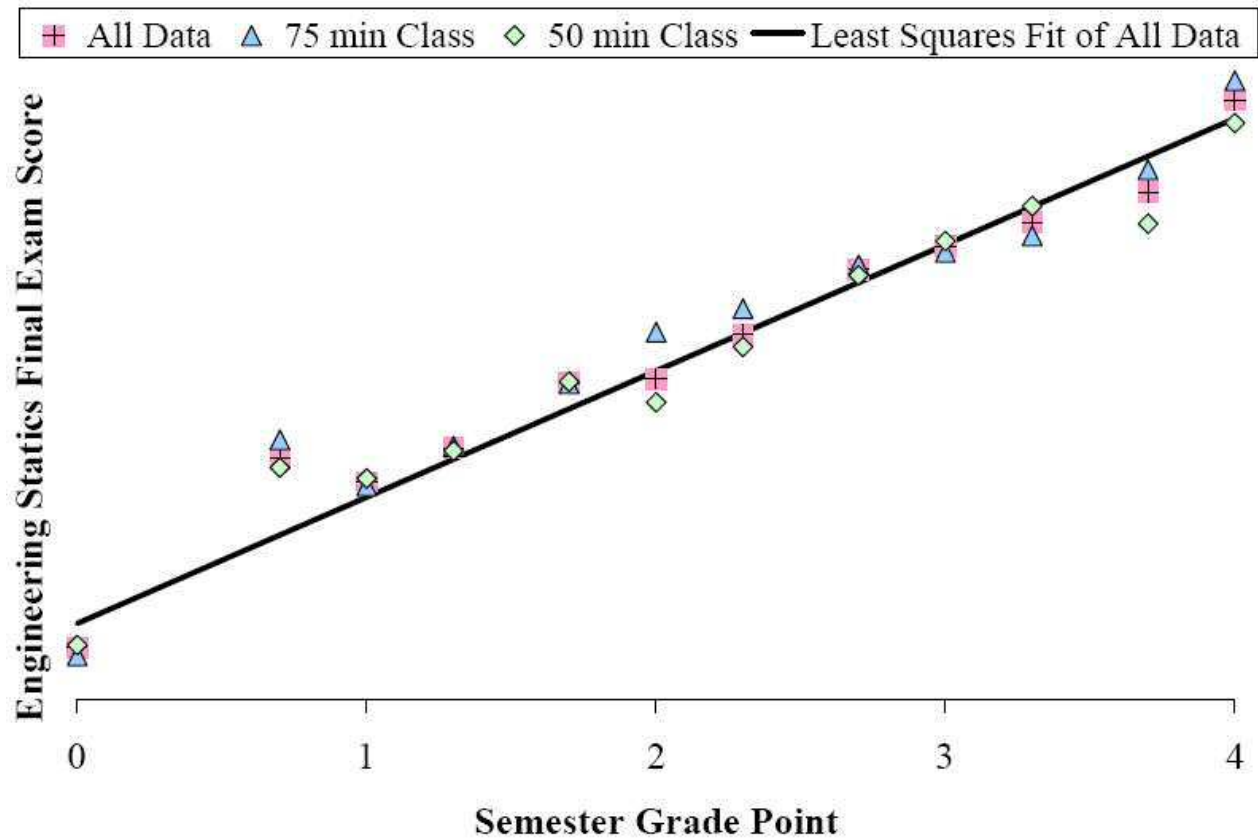
Statics Prerequisite Test to Measure Student Capability and Knowledge

- Prerequisite test at **<u>start of semester</u>** covers Physics and Math topics: 1) vector magnitude, 2) vector resultant, 3) friction, 4) dot product, 5) torque (i.e., moment), and 6) force equilibrium

- Question types: multiple choice concept questions and single-step calculation-based short answer problems

- Prerequisite testing began at WSU in 2012 – preliminary results were reported in 2014* with ~750 students in database
  - Prerequisite testing & database expansion has continued – today ~1760 students
  - No substantive difference in results with increased database size

*Reference: Myose *et al*., "Correlating Engineering Statics Student Performance with Scores of a Test over Pre-requisite Material…," *2014 ASEE Midwest Conference*

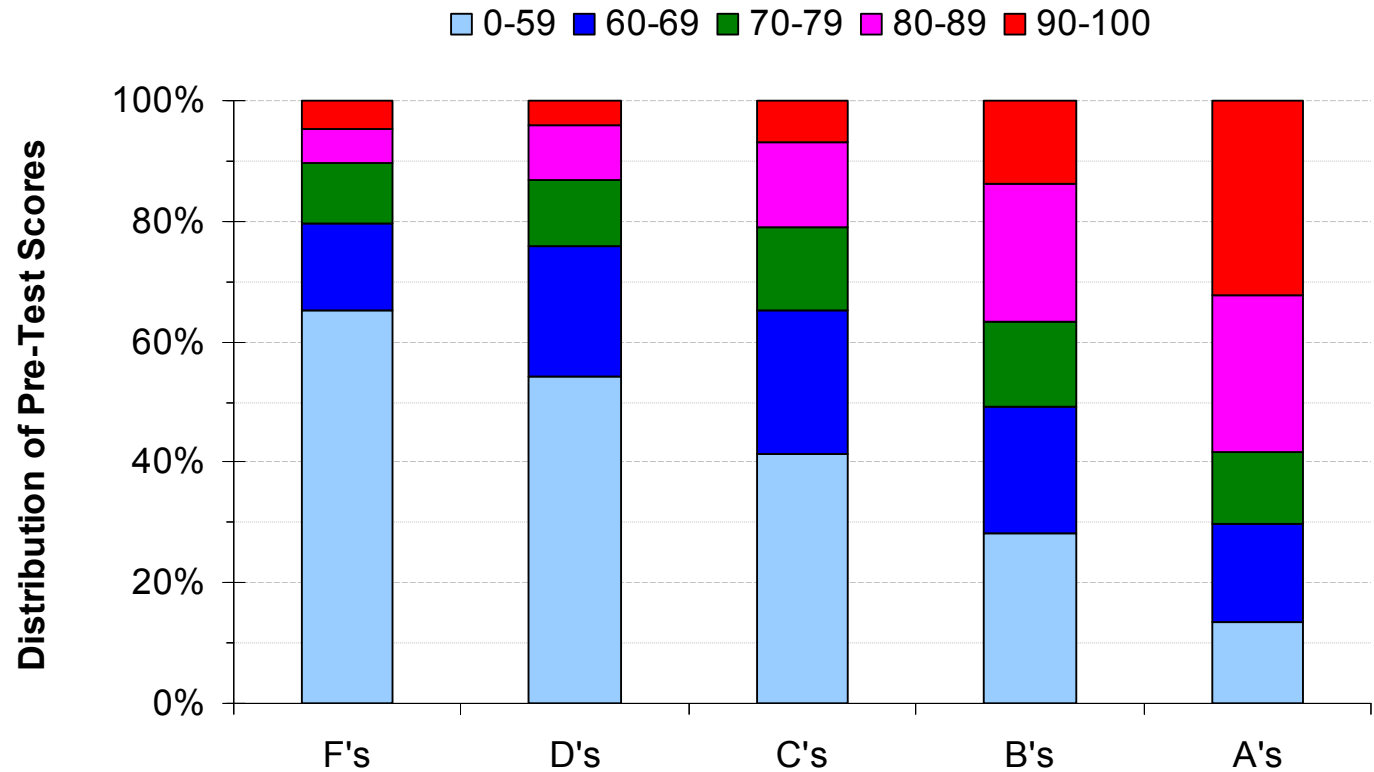# Statics Prerequisite Knowledge Test Score vs. End of Semester Grade Point

- Results shown for grade vs. pre-test score

- Data set (■) of 1760 students taught by six instructors with least squares fit line (– ● –)

- Also shown is least squares fit (solid) line for 1st author's (50-, 60-, & 75-min) classes
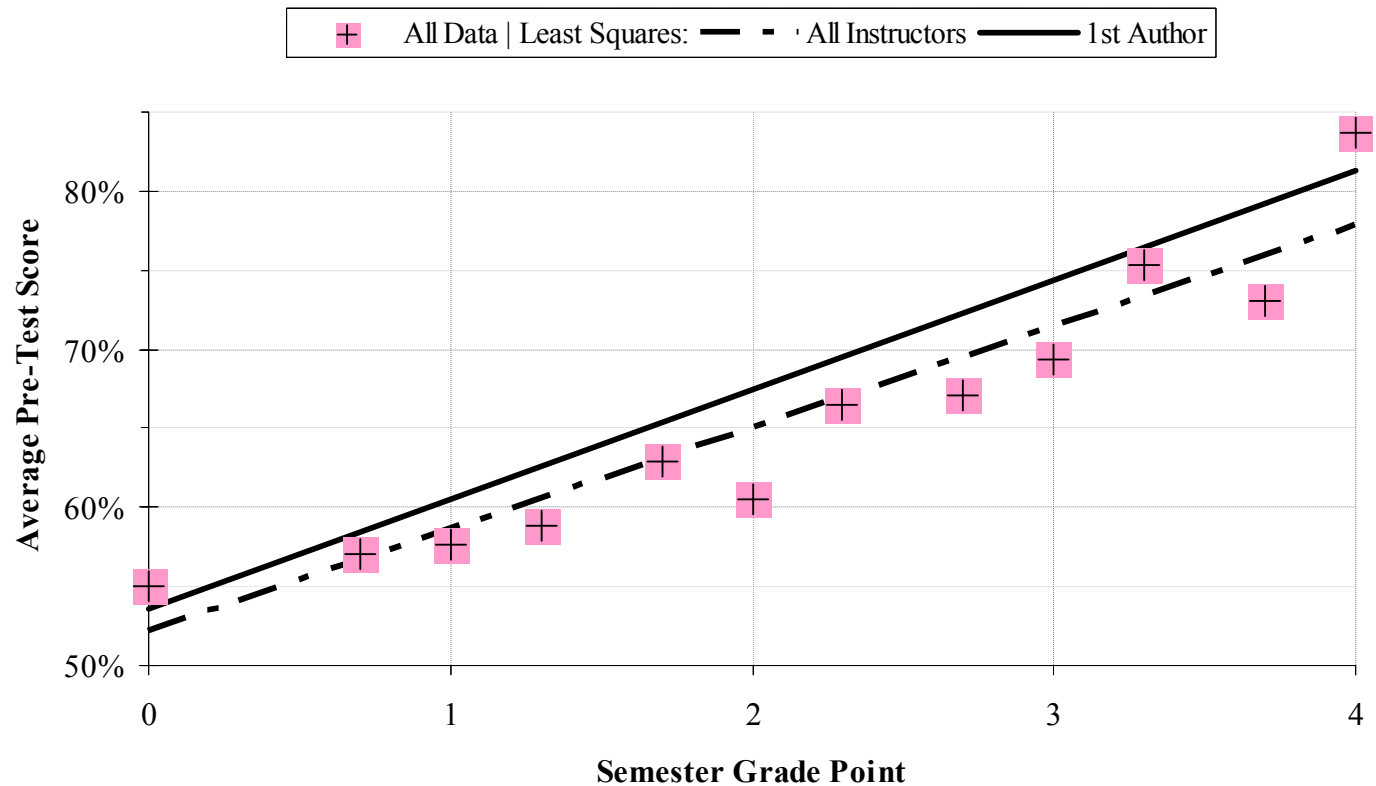
- Moderate correlation (Pearson = 0.440) between start of semester pre-test and grade at end for all instructors
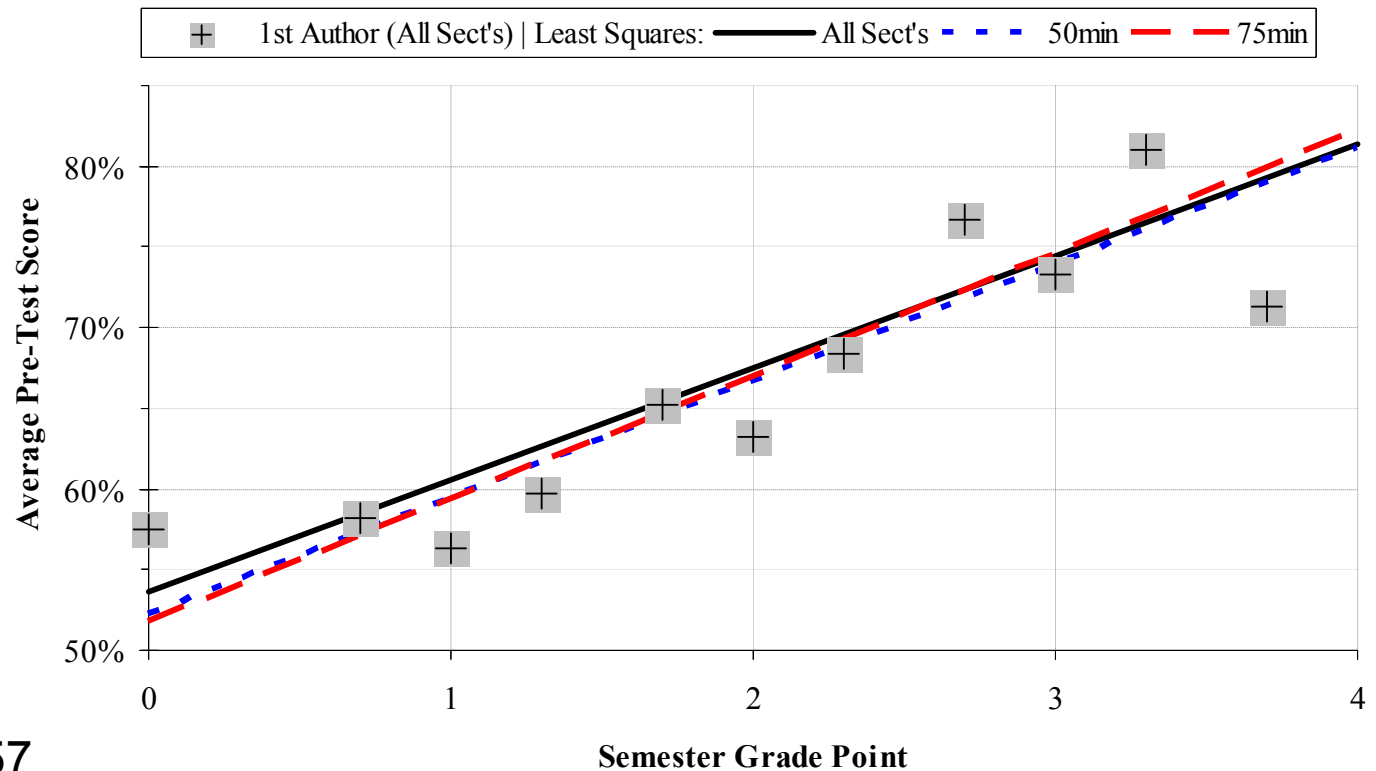
Statics Prerequisite Knowledge Test Score vs. End of Semester Grade

- Correlating pre-test scores to grades is not possible with individual students
- Example: ~5% of students who receive an F scored in 90s on pre-test
- Also, ~14% of students who receive an A scored below 60 in pre-test

Legend: □ 0-59 ■ 60-69 ■ 70-79 ■ 80-89 ■ 90-100

Y-axis: Distribution of Pre-Test Scores (0% to 100%)

X-axis categories: F's, D's, C's, B's, A's

Statics Prerequisite Knowledge Test Score vs. End of Semester Grade Point

- Data set (■) of 298 students taught by 1st author with least squares fit (solid) line

- Also shown are least squares fit for 75-min (– –) & 50-min (- - -) classes

- Correlation for:
  All classes = 0.457
  75-min = 0.503
  50-min = 0.491

Legend: + 1st Author (All Sect's) | Least Squares: —— All Sect's - - - 50min – – 75min

Average Pre-Test Score (y-axis: 50%, 60%, 70%, 80%)

Semester Grade Point (x-axis: 0, 1, 2, 3, 4)

- Eq for least squares fit: Score = Slope x Grade+Intercept
  Inverted eq to predict: Grade = (Score – Intercept)/Slope

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Statics Prerequisite Knowledge Test Score vs. End of Semester Grade Point

Two prediction versions:

- A = use average pre-test score in the eq

- B = use individual pre-test scores in the eq, then average predicted grades

Results for class GPA:

- A predicted class GPAs to within 0.1 grade points

- B underestimated class GPA by 0.1 to 0.2 grade points

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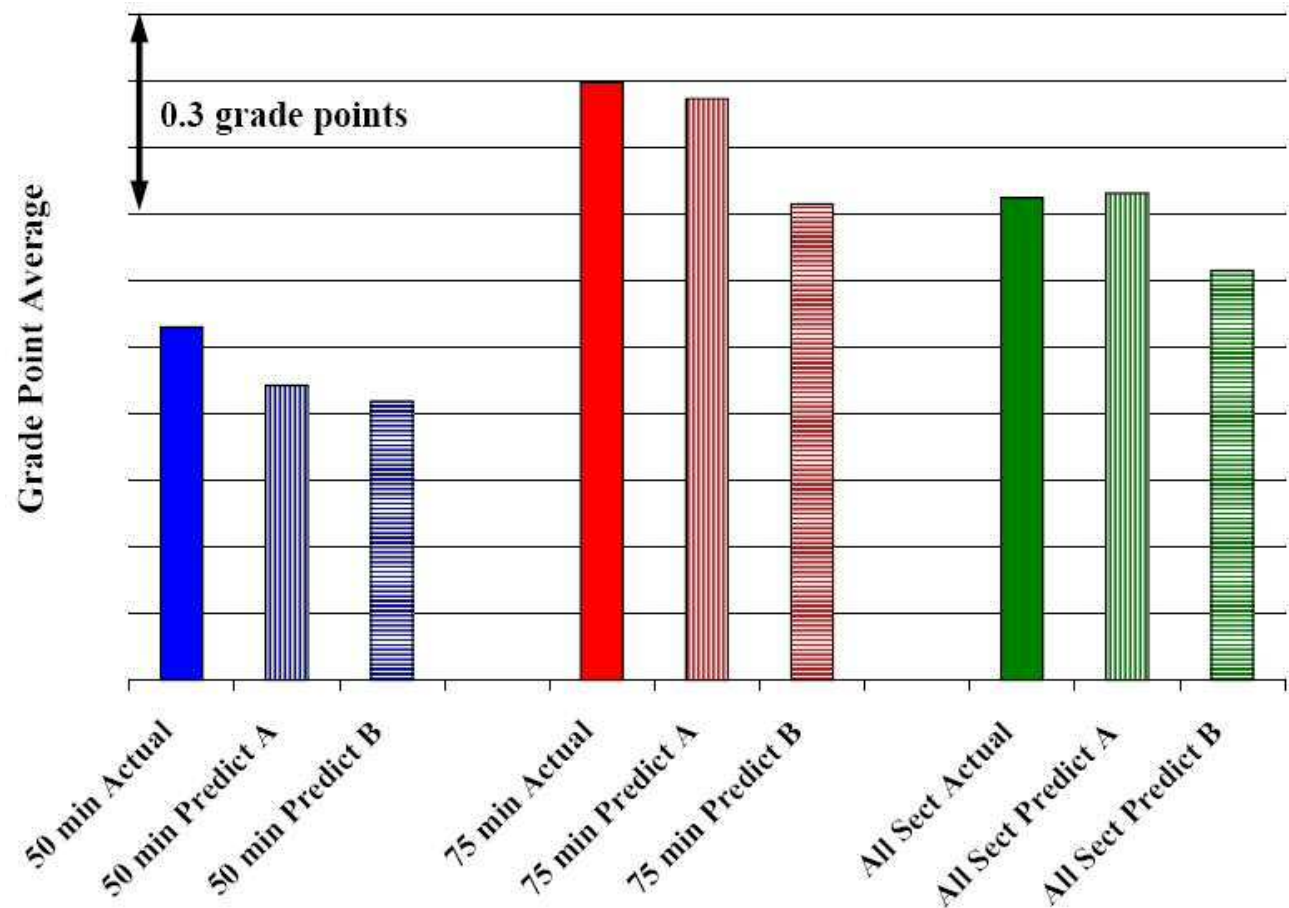
Statics Prerequisite Knowledge Test Score vs. End of Semester Grade Point

- 3.2% higher pre-test score for 75-minute class compared to 50-minute class

- **0.37** higher GPA for 75-minute class than 50-min class

- Version A predicted **0.43** higher GPA

- Version B predicted **0.29** higher GPA

- Conclusion: GPA difference caused by difference in student capability

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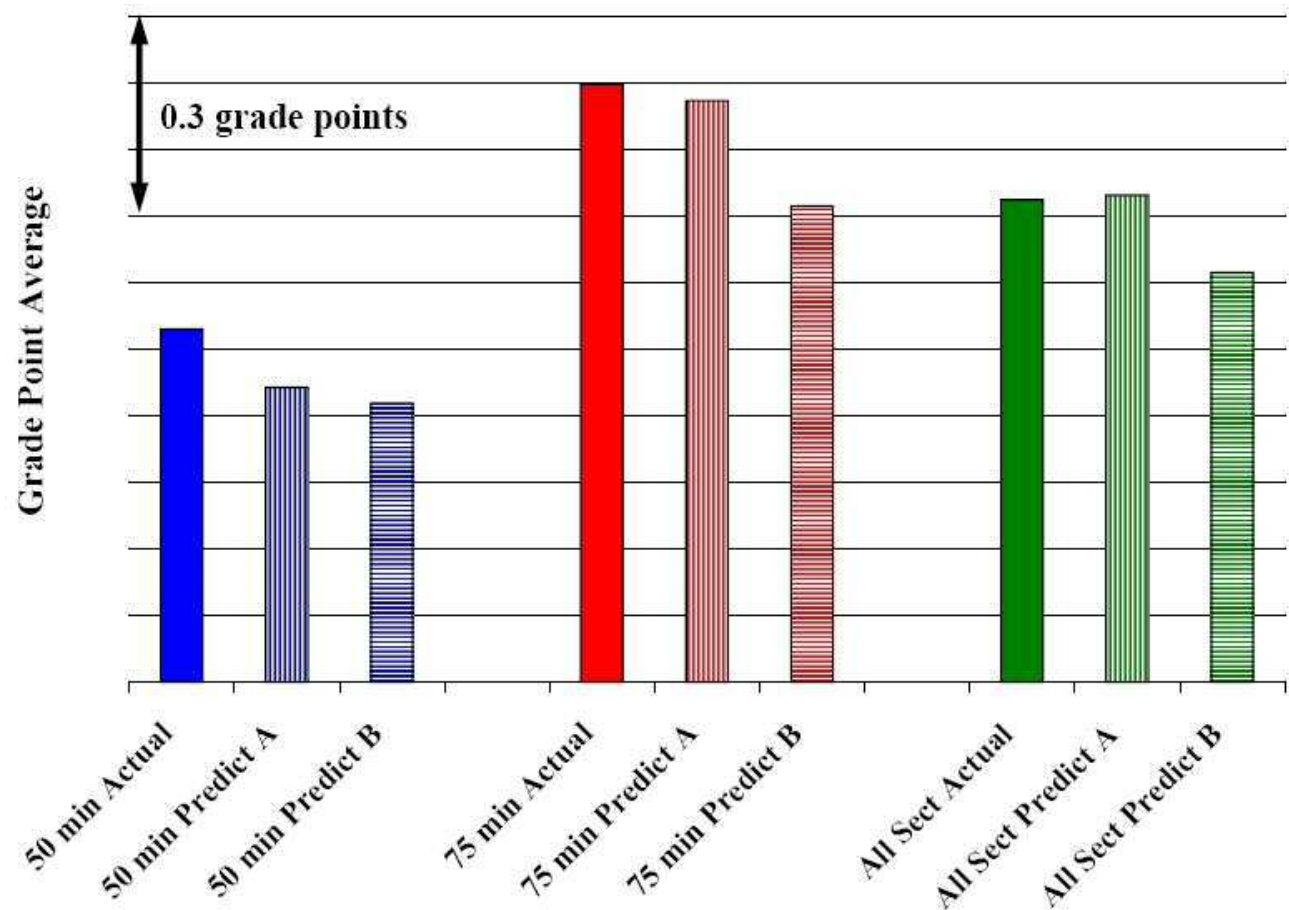
Summary

- A prerequisite test given at the start of the semester was used to gauge incoming student capability and knowledge

- Pre-test is moderately well-correlated with grade even though it is given before any substantive teaching of new material occurs

- Students in the first author's 75-minute classes, compared to 50-minute classes, had 3.2% higher pre-test scores with a resulting 0.37 grade point higher GPA

- This suggests that the pre-test can be used as a tool to gauge incoming student capability and knowledge

- In the future, the pre-test can be used to see if changes in student performance are due to incoming student capability or changes in teaching method