TEACHING METHODS COMPARISON IN A LARGE INTRODUCTORY CALCULUS CLASS

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MOTIVATION

- Hake (1998). **Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses**. *American Journal of Physics.*

- Deslauriers, Schelew and Wieman (2011). **Improved Learning in a Large-Enrollment Physics Class**. *Science.*

- Can we do this for Calculus?

Setting

- Math 104: Differential Calculus for Business and the Social Sciences

- 1st Term, 1st Year Course

- 95% of students in this course have taken a calculus course prior to university.

- Two sections, 150 and 200 students, experienced and well-regarded instructors.

THE PLAN

1. Establish two comparable sections.
2. Junior instructor trained in research-based methods takes over for one topic (100-150 minutes of in-class time) in each section.
3. Compare student responses on quizzes, midterm and final exam questions for both topics.

EXPERIMENTAL DESIGN

Course weeks ➡

Section A								
A_1	A_2	$A_3 \ldots$	A_7	$\mathbf{X_8}$	A_9	A_{10}	A_{11}	A_{12}

Section B								
B_1	B_2	$B_3 \ldots$	B_7	B_8	B_9	B_{10}	$\mathbf{X_{11}}$	B_{12}

Assessments in common								
att	D			Q_{RR}	M_{RR}		Q_{LA}	att	FE

att: MAPS attitude survey, **D**: diagnostic pre-calculus and calculus tests, $\mathbf{Q_{RR}}$: Related Rates quiz, $\mathbf{M_{RR}}$: Midterm (Related Rates), $\mathbf{Q_{LA}}$: Linear Approx. quiz, **FE**: common final exam

INSTRUCTIONAL METHODS

Standard week: **Lecture with questions**
- Chalkboard lecture
- Clicker questions (1-2 per hour)
- Whole-class discussions led by instructor

"Intervention week": **Higher engagement**
- Pre-class assignment
- In class, students are much more active:
  - Structured handout
  - More clicker questions (5-8 per hour)
  - Small group tasks – thinking and doing

Captured by *Teaching Dimensions Observation Protocol*

TEACHING DIMENSIONS OBSERVATION PROTOCOL
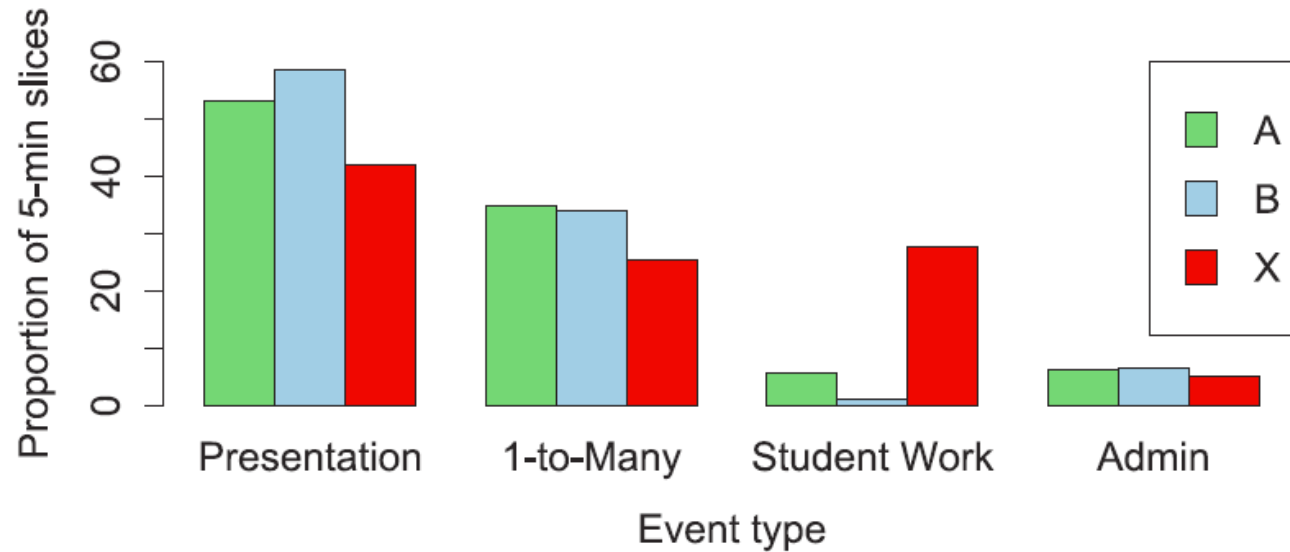
Classroom activity quantified by the Teaching Dimensions Observation Protocol (Hora & Ferrare, 2009) based on events during 5-min slices of lecture period; classified as Presentation, meaning lecture with no student interaction, 1-to-Many interaction which includes student questions and whole-class discussion led by the instructor, Student Work involving peer discussion and/or desk work, or Admin, non-content administrative events.

RESEARCH QUESTIONS

1. Will students demonstrate more sophisticated reasoning on an immediate test of learning?

2. Will any effects persist to later, more standard tests of learning in the course?

MEASUREMENT

Series of assessments:

- Quizzes in class at end of each topic.
- Common midterm problem (one topic).
- Common final exam problems.

Goals for the assessment:

- Problems typical in the course.
- Expose student thinking: concepts and computation.

Related Rates

Concepts
- Constant vs. changing quantities
- 3D shapes

Computation
- Implicit differentiation technique
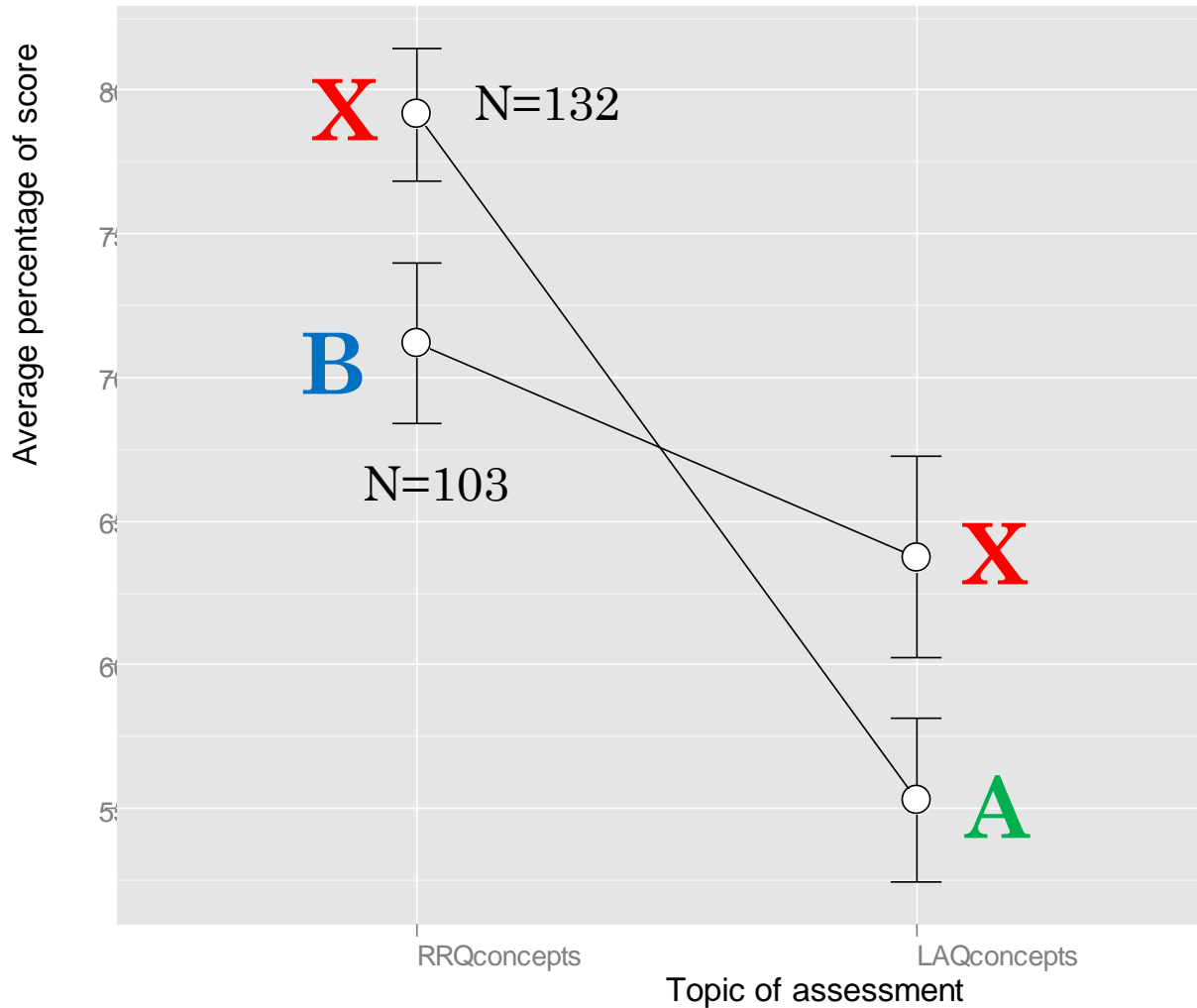- Derivative rules

LINEAR APPROXIMATION

Concepts
- Goal of the process
- Interpreting error
- Relate graph/picture to the formula

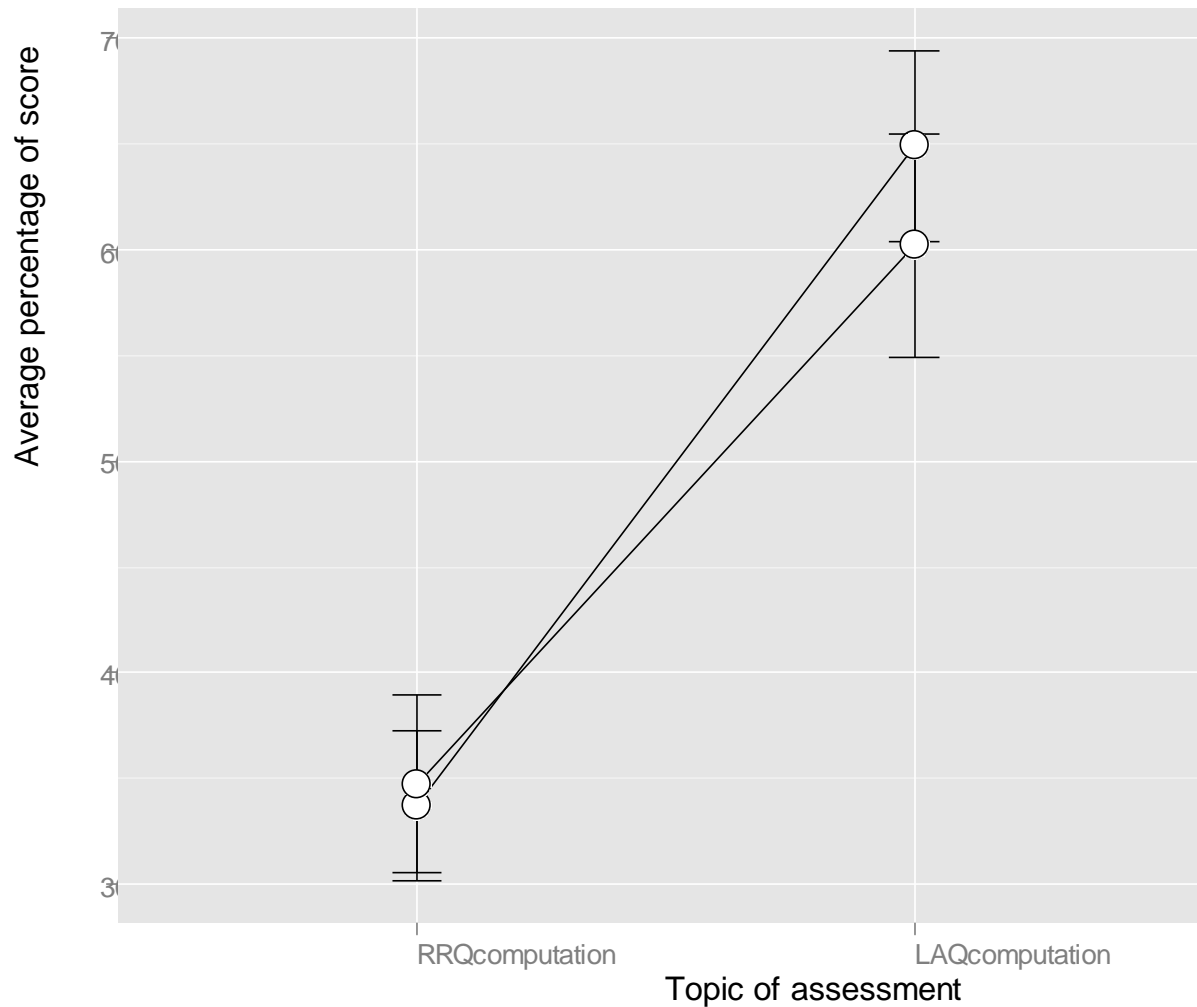Computation
- Use of the formula
- Derivative rules

QUIZ RESULTS FOR CONCEPTUAL ELEMENTS

High-engagement section students taught by Instructor X were stronger on conceptual elements of both quizzes.

This graph shows only students who wrote both quizzes. Dots are mean (%) scores, error bars are 95% confidence intervals.

Quiz Results for Computational Elements

No difference in performance was found for items categorized as "computational", which were much more dependent on student background earlier in the course and prior to the course.

Results were the same for separate tests if taken over all students who wrote each quiz.

MIDTERM: RELATED RATES (M_RR)

Compute the rate of change of height for each of an inverted cone and cylinder-shaped water tank of the same height and volume, given the same volume fill rate and initial water depth.
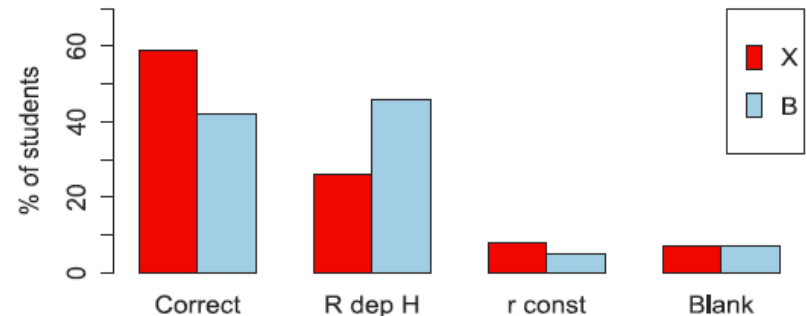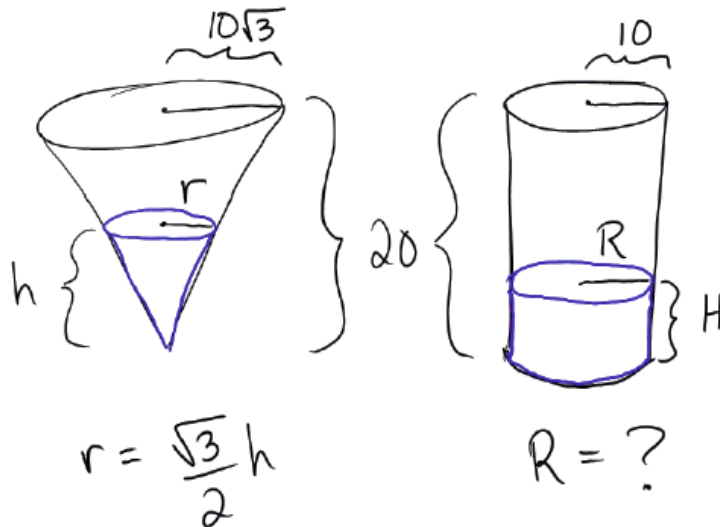
Radius relation for paired tanks midterm problem.

Many more students in Section B (N=127) applied the proportional relation formula for the radius and height of the cone directly to the cylinder ("R dep H", meaning they computed R to be a function of H instead of constant). Students treating both tank radii as constant ("r const") were a small minority. Section X (N=174) students were more likely to treat the radii correctly (p < 0.01).

Final Exam

Some marginal effects may have been observed on the final exam, which featured relatively standard assessment items, but there was no clear signal.

Conclusion

Though the real classroom is inherently a messy system to measure, we have observed better learning of introductory Calculus concepts with pre-class reading plus higher-engagement class time, where the instruction was developed according to evidence-based principles.