SFU SIMON FRASER UNIVERSITY
ENGAGING THE WORLD

Active Learning in Large Classes

get ready for audience participation:

b.socrative.com ⟶ room: sfumath

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Download on the App Store

ANDROID APP ON Google play

Jamie Mulholland
Department of Mathematics
Simon Fraser University

CMS
June, 2015

There are no proofs in mathematics education.

Henry Pollak

Overview

- introduction
- what is active learning?
- example of active learning
- next steps...

audience poll

b.socrative.com

room: sfumath

#1 Think about something you are really good at—perhaps a skill you are proud of, maybe one that advanced your career.
Now, think of how you became good at it.
Was it by...

HOW'D WE DO? **0/0** students answered

A ... trial and error

B ... mentorship (one-on-one guidance)

C ... attending lectures

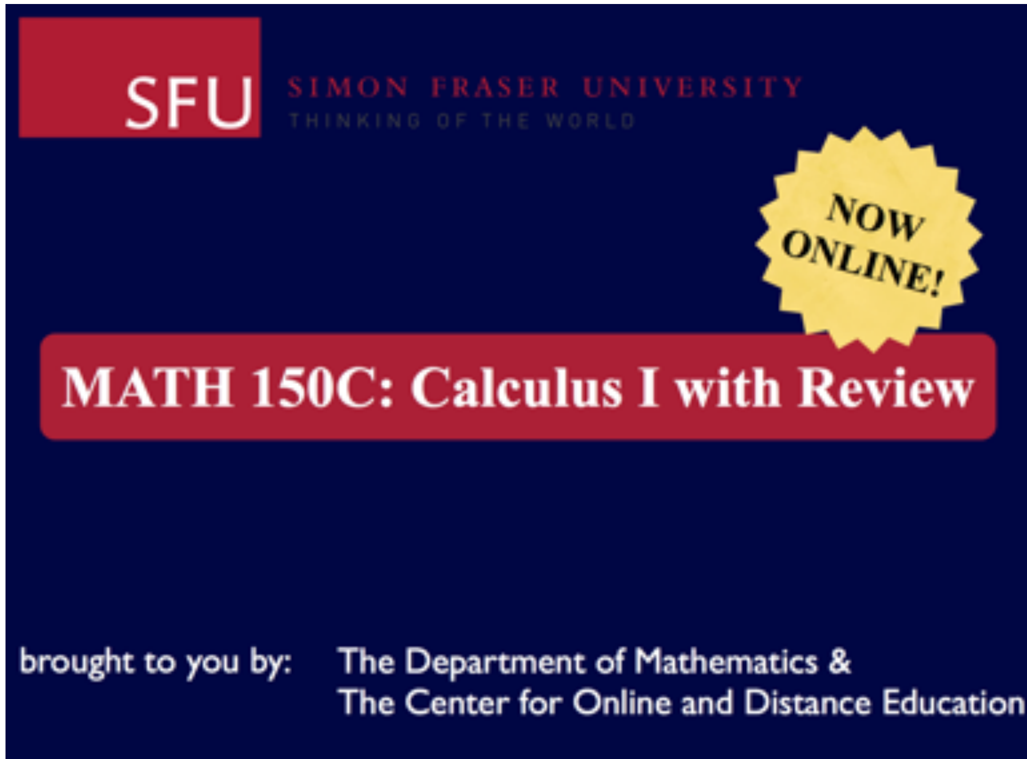
D ... familiy and friends

E ... practicing

Simon Fraser University

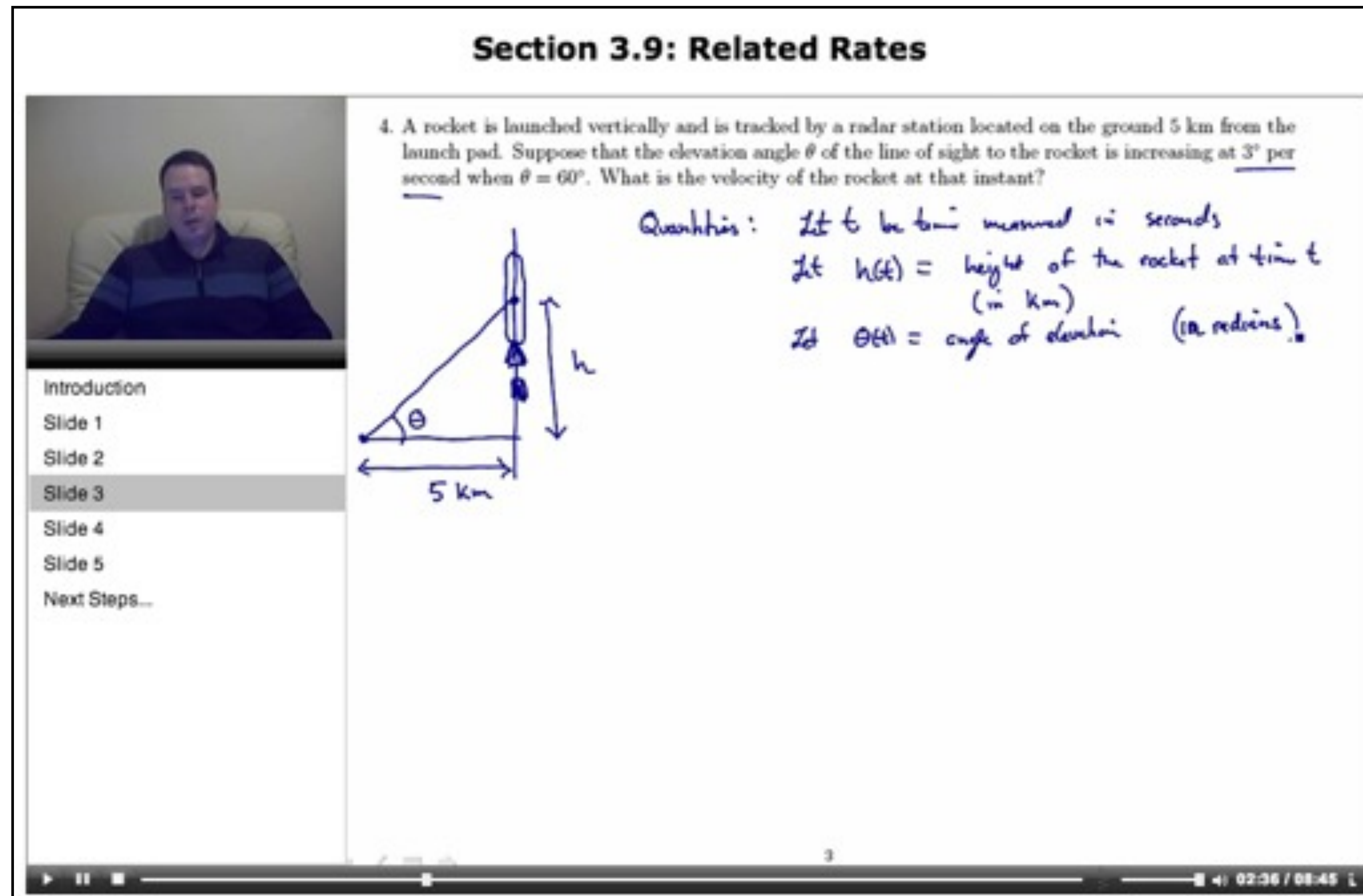
- 25,000 undergraduate students
- SFU is a commuter campus - 90% of students live off campus
- first year calculus: 100 - 550 students per section (large classes)

Seeds of change...



2008

- created online/distance ed. version of Calculus I
- featured pre-recorded video lectures



2010

- Eric Mazur
  - *Confessions of a Converted Lecturer*
  - peer instruction

Seeds of change...

Two phases of learning:

classroom → ***1) Acquisition of information***

home → ***2) Assimilation of information***

Seeds of change...

Two phases of learning:

home → ***1) Acquisition of information***

classroom → ***2) Assimilation of information***

What is Active Learning?

Active learning **is any instructional method that engages students in the learning process <u>inside the classroom</u>.**

peer instruction

class response systems

turn to your neighbour

individual problem solving

group discussions

3-points summary

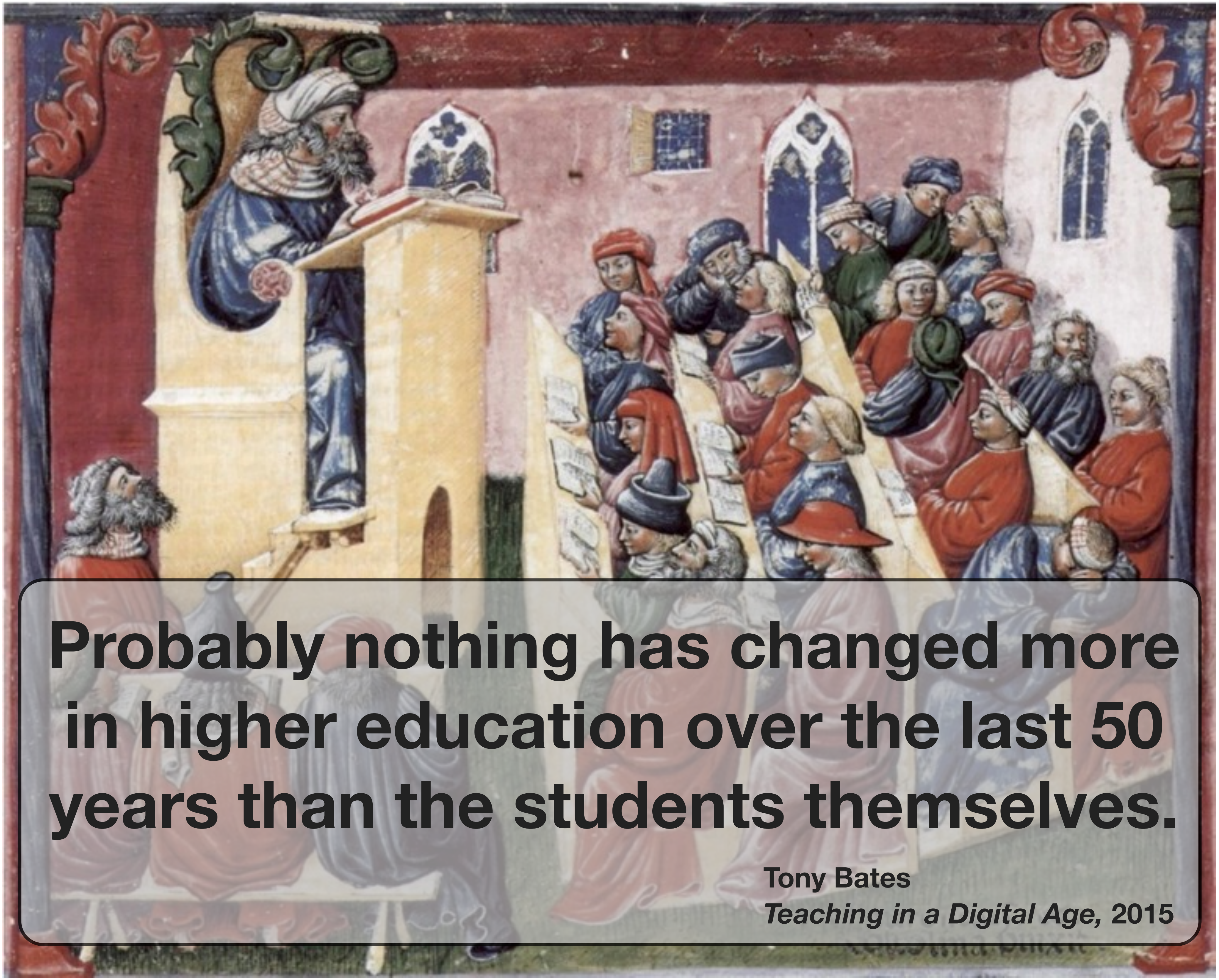
Active Learning

3-points summary

Henry of Germany delivering a lecture to university students in Bologna, Italy, in 1233

A medieval lecture
Artist: Laurentius de Voltolina;
Liber ethicorum des Henricus de Alemannia; Kupferstichkabinett SMPK, Berlin/Staatliche Museen Preussiischer Kulturbesitz, Min. 1233

Henry of Germany delivering a lecture to university students in Bologna, Italy, in 1233



Probably nothing has changed more in higher education over the last 50 years than the students themselves.

Tony Bates
***Teaching in a Digital Age*, 2015**

A medieval lecture
Artist: Laurentius de Voltolina;
Liber ethicorum des Henricus de Alemannia; Kupferstichkabinett SMPK, Berlin/Staatliche Museen Preussiischer Kulturbesitz, Min. 1233

Change is in the air...

- Simon Fraser University: TLC, Task Force on Flexible Education
- University of British Columbia: Flexible Learning Initiative
- University of Alberta awards for adopting blended learning approaches
- University of Calgary: Vision & Strategy Report
- University of Ottawa: E-Learning Working Group
- University of Ottawa and McMaster University:
  Invest in blended learning approaches.
- SFU, UofA, UofC, Mount Royal, UofS, UofR, UofM, York, Guelph, Waterloo, Memorial: Contributed to a Report on Blended Learning
- MIT: Institute-Wide Task Force on the Future of MIT Education

We may be reaching a potential tipping point in higher education, which challenges universities to improve substantially the value of the learning interaction.

UBC Flexible Learning
2014

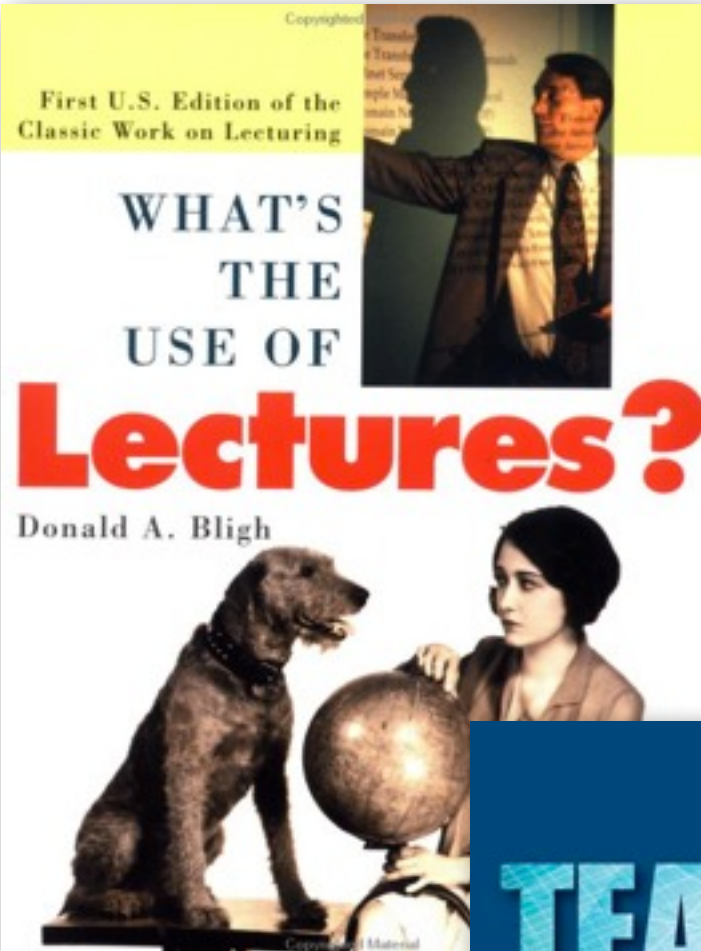
A Look at the Lecture

People have nowadays…got a strange opinion that everything should be taught by lectures. Now, I cannot see that lectures can do as much good as reading the books from which the lectures are taken…Lectures were once useful, but now, when all can read, and books are so numerous, lectures are unnecessary.

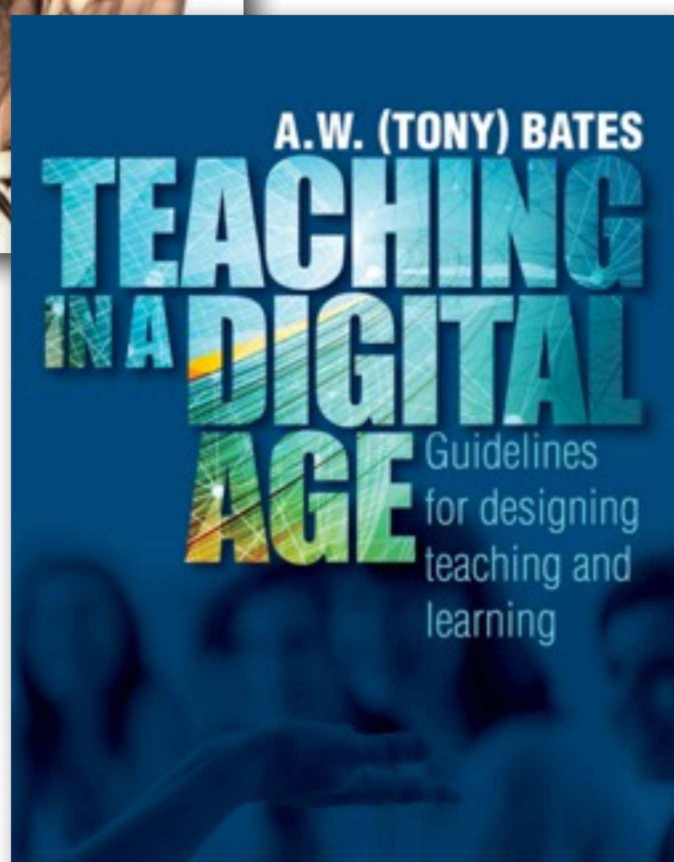
Samuel Johnson
1709-1784

Boswell, J. (1791), The Life of Samuel Johnson, New York: Penguin Classics (edited by Hibbert, C., 1986)

A Look at the Lecture



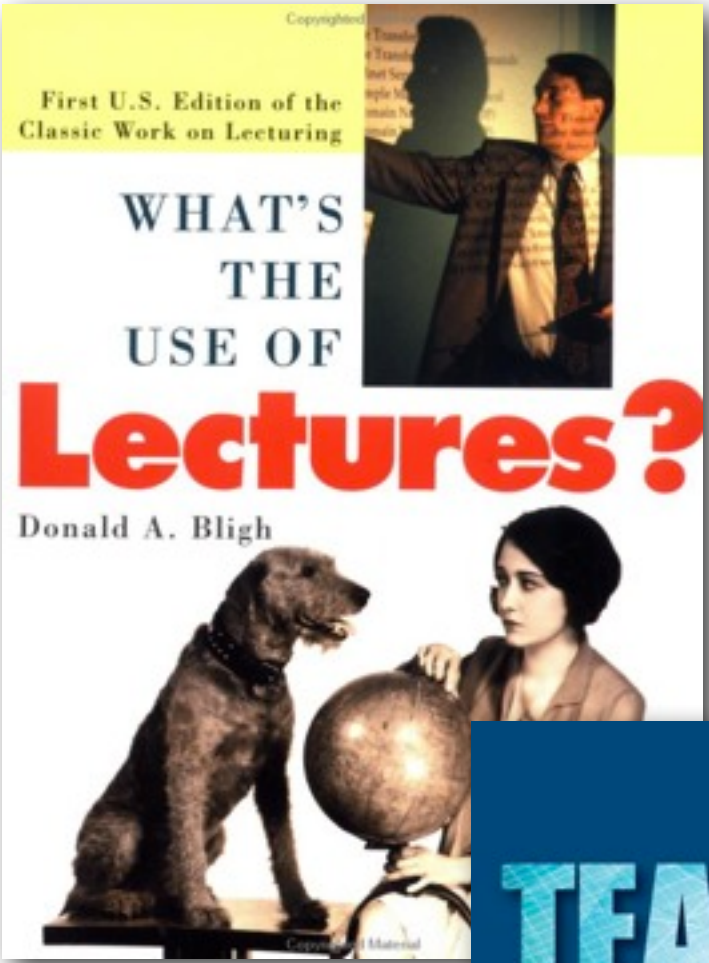
1972, 2000



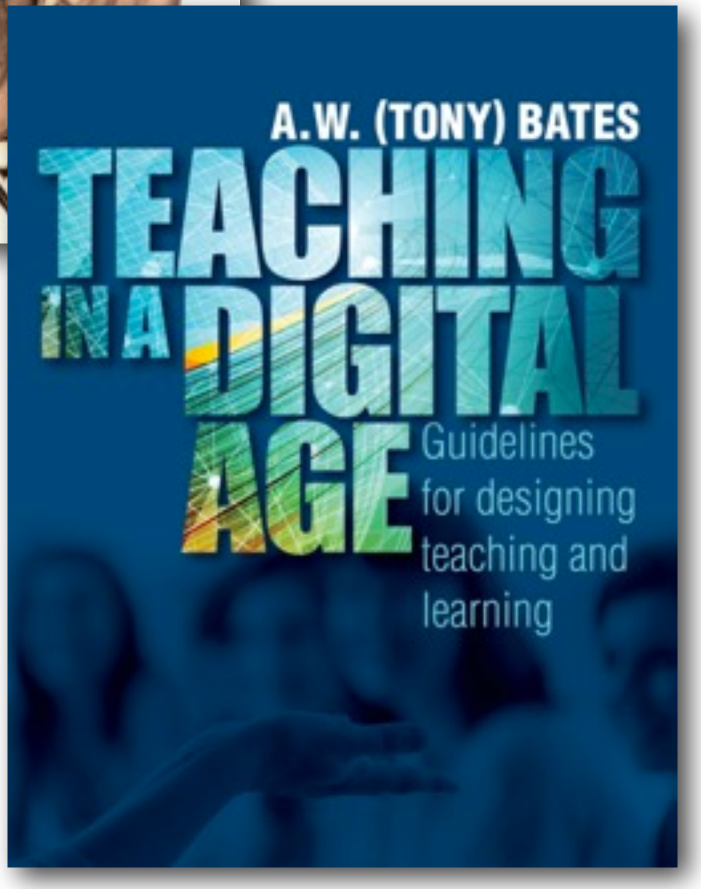
2015

A *lecture* is a continuous exposition by a speaker who wants the audience to learn something.

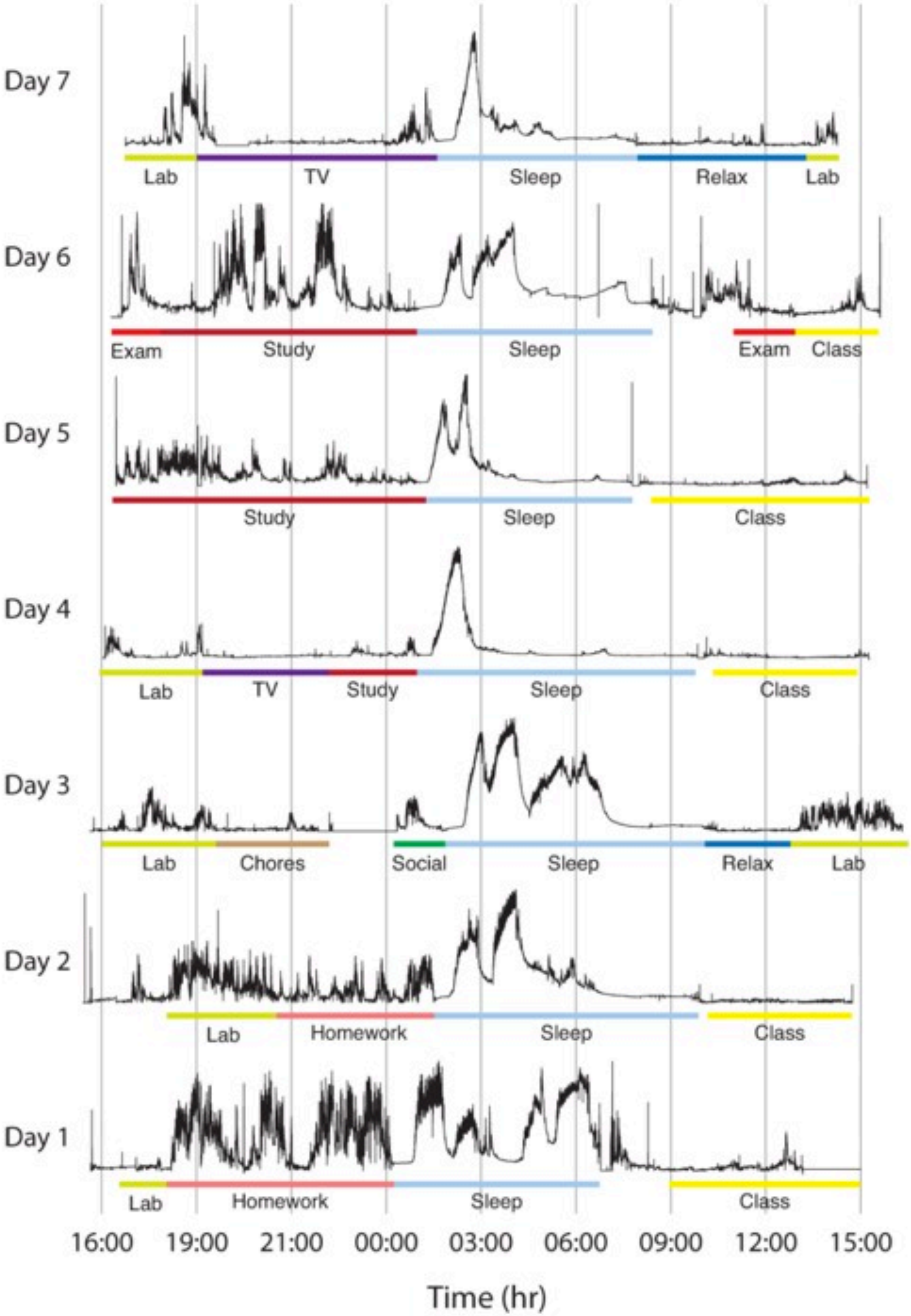
A Look at the Lecture



1972, 2000



2015



Poh, M,, Swenson, N., Picard, R. W. *A wearable sensor for unobtrusive, long-term assessment of electrodermal activity,* IEEE Transactions on Biomedical Engineering. vol 57, no 5, pp 1243-1252. May 2010.

A Look at the Lecture

Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses

Richard R. Hake[a)]
Department of Physics, Indiana University, Bloomington, Indiana 47405

(Received 6 May 1996; accepted 4 May 1997)

A survey of pre/post-test data using the Halloun–Hestenes Mechanics Diagnostic test or more recent Force Concept Inventory is reported for 62 introductory physics courses enrolling a total number of students $N=6542$. A consistent analysis over diverse student populations in high schools, colleges, and universities is obtained if a rough measure of the average effectiveness of a course in promoting conceptual understanding is taken to be the average normalized gain $\langle g \rangle$. The latter is defined as the ratio of the actual average gain (%⟨post⟩ − %⟨pre⟩) to the maximum possible average gain (100 − %⟨pre⟩). Fourteen "traditional" (T) courses ($N=2084$) which made little or no use of interactive-engagement (IE) methods achieved an average gain $\langle g \rangle_{T\text{-ave}} = 0.23 \pm 0.04$ (std dev). In sharp contrast, 48 courses ($N=4458$) which made substantial use of IE methods achieved an average gain $\langle g \rangle_{\text{IE-ave}} = 0.48 \pm 0.14$ (std dev), almost two standard deviations of $\langle g \rangle_{\text{IE-ave}}$ above that of the traditional courses. Results for 30 ($N=3259$) of the above 62 courses on the problem-solving Mechanics Baseline test of Hestenes–Wells imply that IE strategies enhance problem-solving ability. The conceptual and problem-solving test results strongly suggest that the classroom use of IE methods can increase mechanics-course effectiveness well beyond that obtained in traditional practice.

I. INTRODUCTION

There has been considerable recent effort to improve introductory physics courses, especially after 1985 when Halloun and Hestenes[1] published a careful study using massive pre- and post-course testing of students in both calculus and non-calculus-based introductory physics courses at Arizona State University. Their conclusions were: (1) "...the student's initial qualitative, common-sense beliefs about motion and...(its)... causes have a large effect on performance in physics, but conventional instruction induces only a small change in those beliefs." (2) "Considering the wide differences in the teaching styles of the four professors... (involved in the study)... the basic knowledge gain under conventional instruction is essentially independent of the professor." These outcomes were consistent with earlier findings of many researchers in physics education (see Refs. 1–8 and citations therein) which suggested that traditional passive-student introductory physics courses, even those delivered by the most talented and popular instructors, imparted little con-

cent con[11] and pro[12] arguments as to whether a high FCI score indicates the attainment of a unified force concept. Nevertheless, even the detractors have conceded that "the FCI is one of the most reliable and useful physics tests currently available for introductory physics teachers" [11(a)] and that the FCI is "the best test currently available... to evaluate the effectiveness of instruction in introductory physics courses." [11(b)] While waiting for the fulfillment of calls for the development of better tests[11] or better analyses of existing tests,[12] the present survey of published[1(a),8(a),9(a),13,14] and unpublished[15(a),(b)] classroom results may assist a much needed further improvement in introductory mechanics instruction in light of practical experience.

II. SURVEY METHOD AND OBJECTIVE

Starting in 1992, I requested that pre-/post-FCI test data and post-test MB data be sent to me in talks at numerous colloquia and meetings and in e-mail postings on the PHYS-L and PhysLrnR nets.[16] This mode of data solicitation

A Look at the Lecture

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Richard R. Hake[a)]

PNAS

CrossMark

Active learning increases student performance in science, engineering, and mathematics

Scott Freeman[a,1], Sarah L. Eddy[a], Miles McDonough[a], Michelle K. Smith[b], Nnadozie Okoroafor[a], Hannah Jordt[a], and Mary Pat Wenderoth[a]

[a]Department of Biology, University of Washington, Seattle, WA 98195; and [b]School of Biology and Ecology, University of Maine, Orono, ME 04469

Edited* by Bruce Alberts, University of California, San Francisco, CA, and approved April 15, 2014 (received for review October 8, 2013)

To test the hypothesis that lecturing maximizes learning and course performance, we metaanalyzed 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning. The effect sizes indicate that on average, student performance on examinations and concept inventories increased by 0.47 SDs under active learning (n = 158 studies), and that the odds ratio for failing was 1.95 under traditional lecturing (n = 67 studies). These results indicate that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. Heterogeneity analyses indicated that both results hold across the STEM disciplines, that active learning increases scores on concept inventories more than on course examinations, and that active learning appears effective across all class sizes—although the greatest effects are in small ($n \leq 50$) classes. Trim and fill analyses and fail-safe n calculations suggest that the results are not due to publication bias. The results also appear robust to variation in the methodological rigor of the included studies, based on the quality of controls over student quality and instructor identity. This is the largest and most comprehensive metaanalysis of undergraduate STEM education published to date. The results raise questions about the continued use of traditional lecturing as a control in research studies, and support active learning as the preferred, empirically validated teaching practice in regular classrooms.

constructivism | undergraduate education | evidence-based teaching | scientific teaching

Lecturing has been the predominant mode of instruction since universities were founded in Western Europe over 900 y ago

225 studies in the published and unpublished literature. The active learning interventions varied widely in intensity and implementation, and included approaches as diverse as occasional group problem-solving, worksheets or tutorials completed during class, use of personal response systems with or without peer instruction, and studio or workshop course designs. We followed guidelines for best practice in quantitative reviews (*SI Materials and Methods*), and evaluated student performance using two outcome variables: (*i*) scores on identical or formally equivalent examinations, concept inventories, or other assessments; or (*ii*) failure rates, usually measured as the percentage of students receiving a D or F grade or withdrawing from the course in question (DFW rate).

The analysis, then, focused on two related questions. Does active learning boost examination scores? Does it lower failure rates?

Results

The overall mean effect size for performance on identical or equivalent examinations, concept inventories, and other assessments was a weighted standardized mean difference of 0.47 (Z = 9.781, P << 0.001)—meaning that on average, student performance increased by just under half a SD with active learning compared with lecturing. The overall mean effect size for failure rate was an odds ratio of 1.95 (Z = 10.4, P << 0.001). This odds ratio is equivalent to a risk ratio of 1.5, meaning that on average, students in traditional lecture courses are 1.5 times more likely to fail than students in courses with active learning. Average failure rates were 21.8% under active learning but 33.8% under traditional lecturing—a difference that represents a 55% increase (Fig. 1 and Fig. S1).

Significance

A Look at the Lecture

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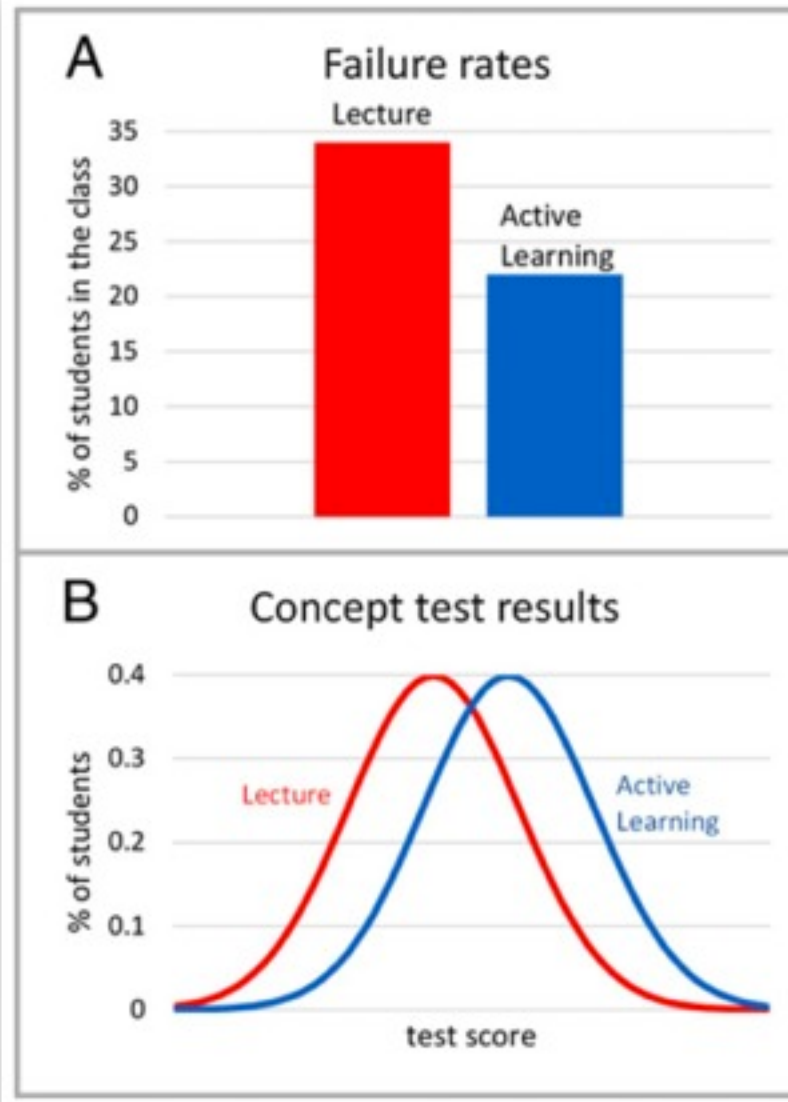
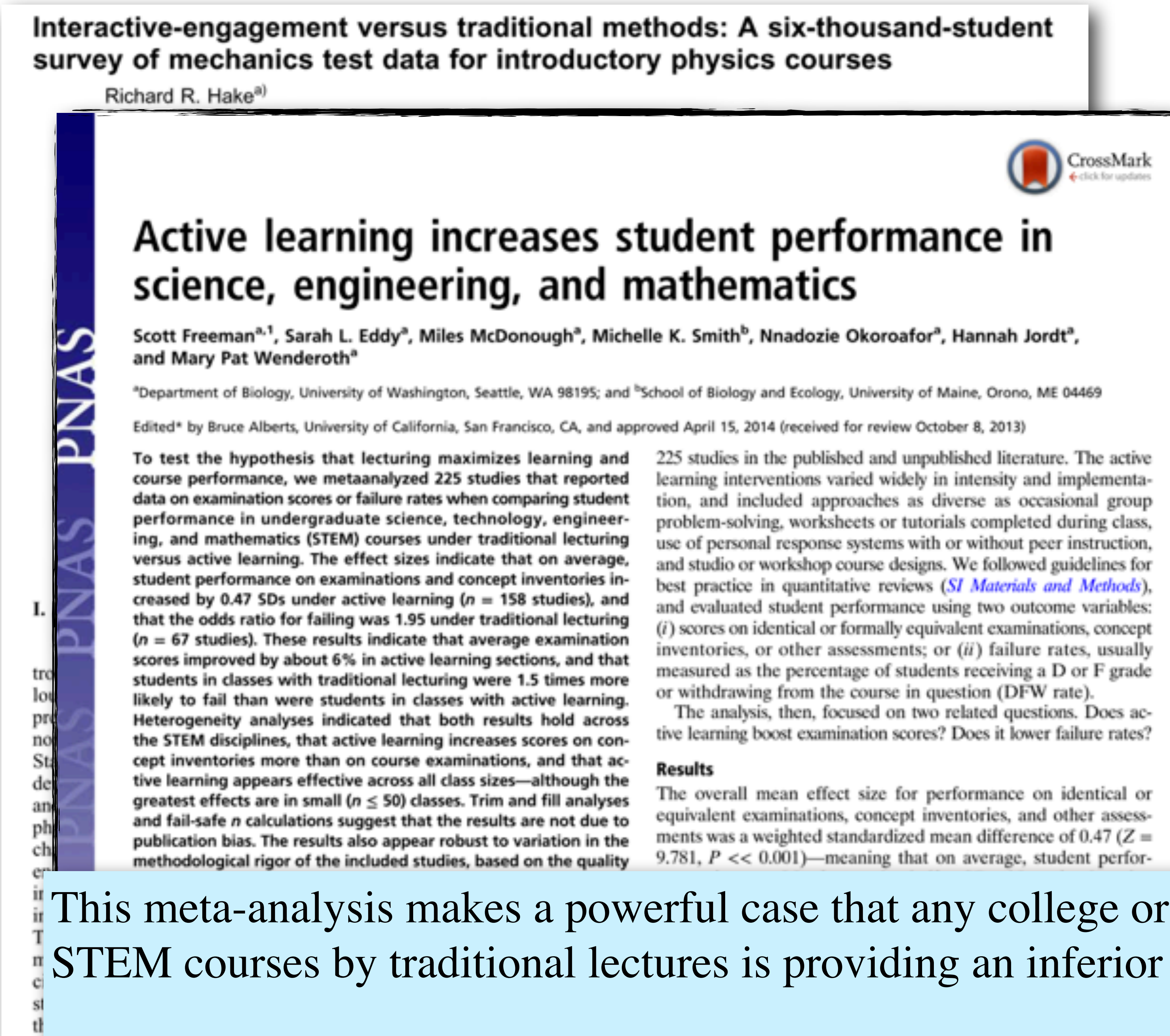


Fig. 1. Comparisons of average results for studies reported in ref. 3. (*A*) Failure rates for the active learning courses and the lecture courses. (*B*) Shift in distribution of student scores on concept inventory tests.

A Look at the Lecture



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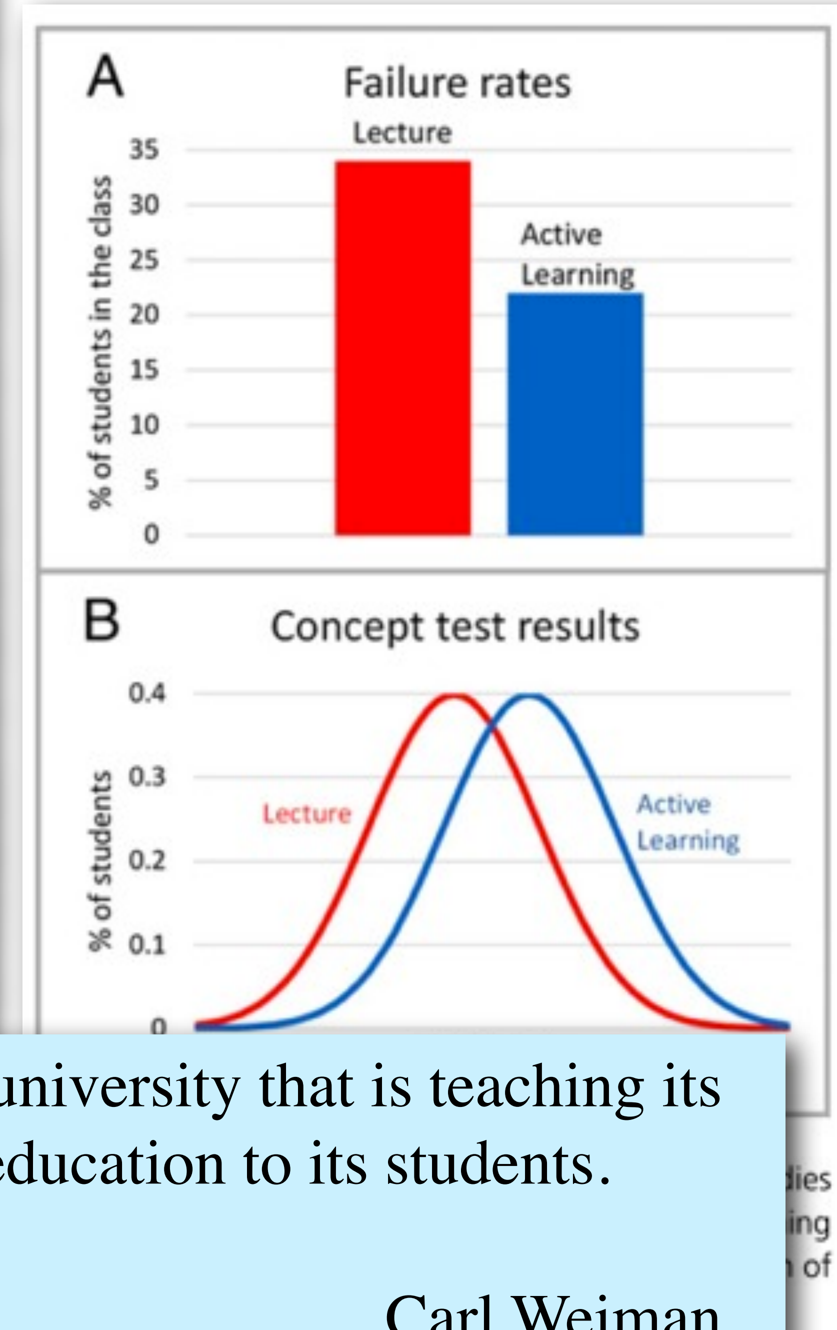

This meta-analysis makes a powerful case that any college or university that is teaching its STEM courses by traditional lectures is providing an inferior education to its students.

Carl Weiman

Wieman, C. E. (2014). Large-scale comparison of science teaching methods sends clear message. PNAS, 111(23): 8319–20.

IN THIS ISSUE
DANS CE NUMÉRO

CMS NOTES de la SMC

June juin 2015

Vice-President's Notes /Notes du Vice-président

Mark Lewis, *University of Alberta, Vice-President -Western Provinces and Territories*

Calculus that delivers

With two calculus-aged students at home and a recent foray into teaching freshman students under my belt, I have been reflecting on the way we deliver calculus in bigger, research-intensive universities. I know many

Des cours de calcul qui donnent des résultats

Ayant deux jeunes en âge d'apprendre le calcul différentiel et intégral à la maison et une expérience récente d'enseigner à des étudiants de première année d'université à mon actif, je réfléchis depuis un certain temps à la façon d'enseigner cette matière dans les grandes universités de recherche.

2015 CMS Summer Meeting. 20

CMS NOTES de la SMC

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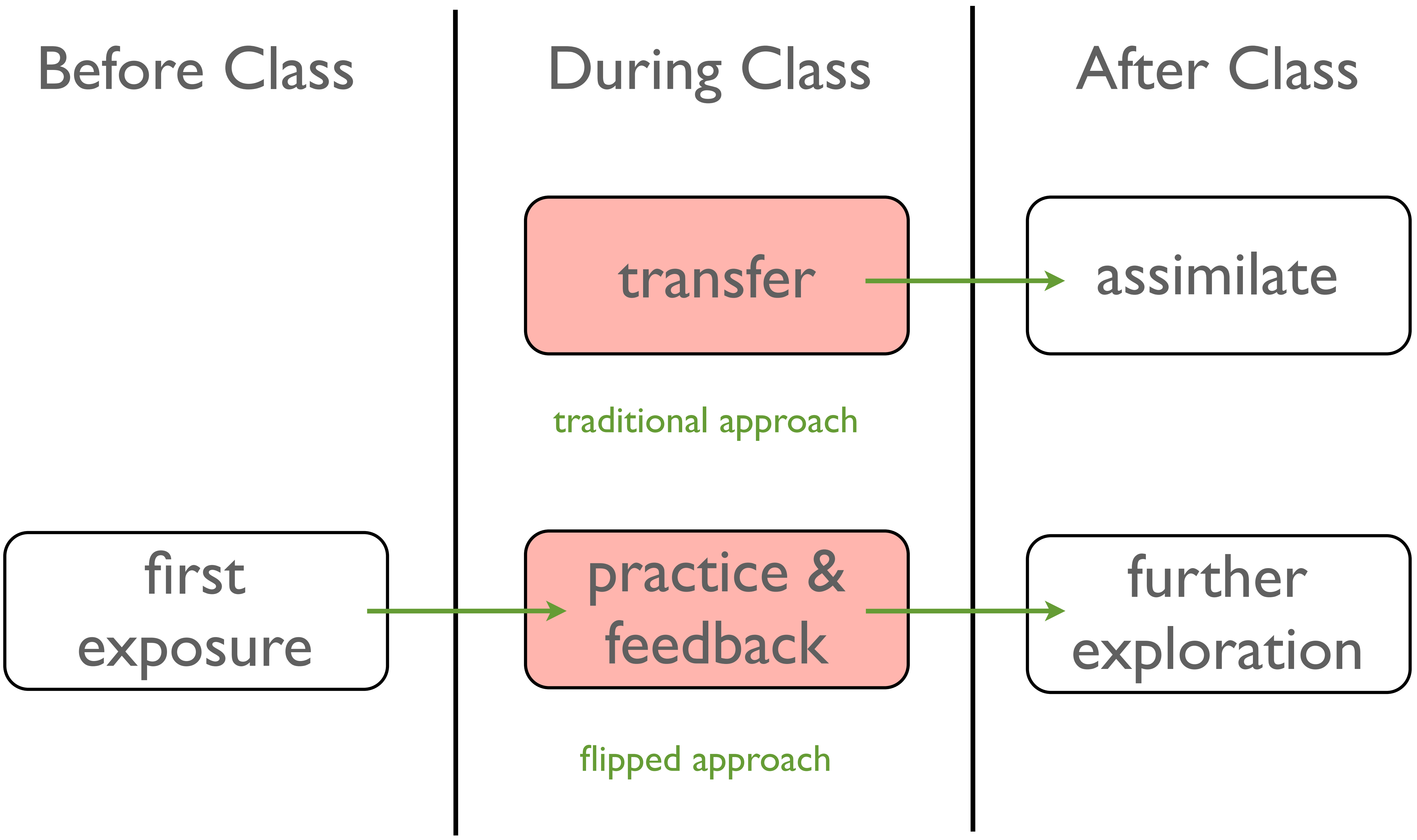
Flip

Example of Active Learning



Derek Bruff: Class time reconsidered

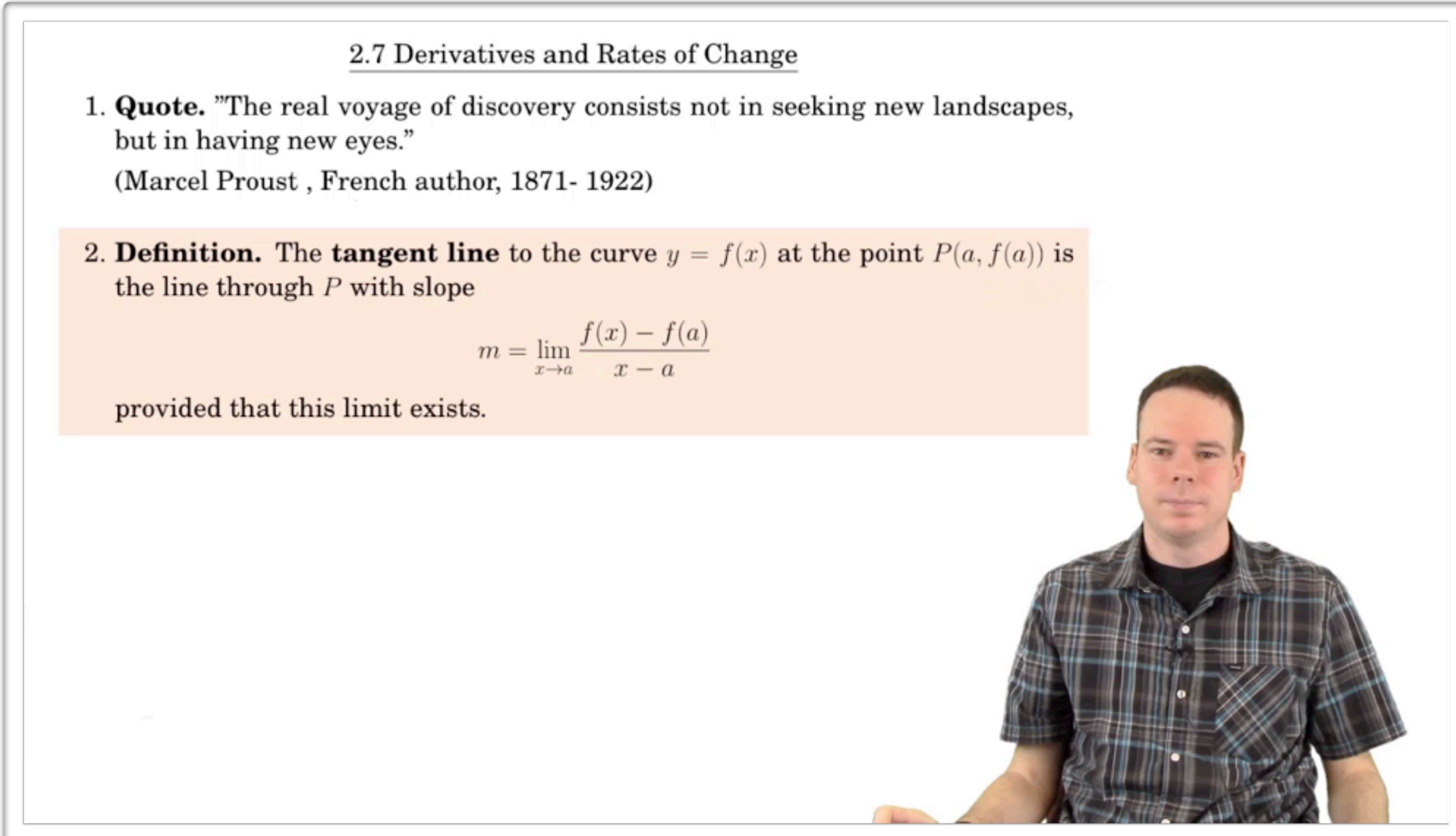
Example of Active Learning

course	title	enrollment	instructor	semester
Math 150	Calculus I: Differential Calculus with Review	150	Mulholland	Spring 2015
Math 152	Calculus II: Integral Calculus	288	Mulholland	Fall 2014
Math 150	Calculus I: Differential Calculus with Review	110	Mulholland	Spring 2014
Math 151	Calculus I: Differential Calculus	342	Mulholland	Fall 2013
Math 150	Calculus I: Differential Calculus with Review	220	Jungic	Fall 2012
Math 152	Calculus II: Integral Calculus	246	Mulholland	Fall 2012

The Script

- **Phase 1: information acquisition (at home)**
  - students watch video lecture or read textbook
- **Phase 2: preliminary assessment (at home)**
  - students complete an online quiz
- **Phase 3: information assimilation (in class)**
  - students work through problems individually and in groups (clickers, peer instruction, just-in-time teaching)
- **Phase 4: further exploration (at home)**
  - students continue to make sense of information by working on the weekly homework assignment

Video Demo


2.7 Derivatives and Rates of Change
1. Quote. "The real voyage of discovery consists not in seeking new landscapes, but in having new eyes."
(Marcel Proust , French author, 1871- 1922)
2. Definition. The tangent line to the curve $y = f(x)$ at the point $P(a, f(a))$ is the line through P with slope
$$m = \lim_{x \to a} \frac{f(x) - f(a)}{x - a}$$
provided that this limit exists.

Pre-Class Questions

Question 1 1 pts

If $\lim_{x \to a} f(x) = 0$ and $\lim_{x \to a} g(x)$ does not exist then $\lim_{x \to a} f(x)g(x)$

(A) is 1

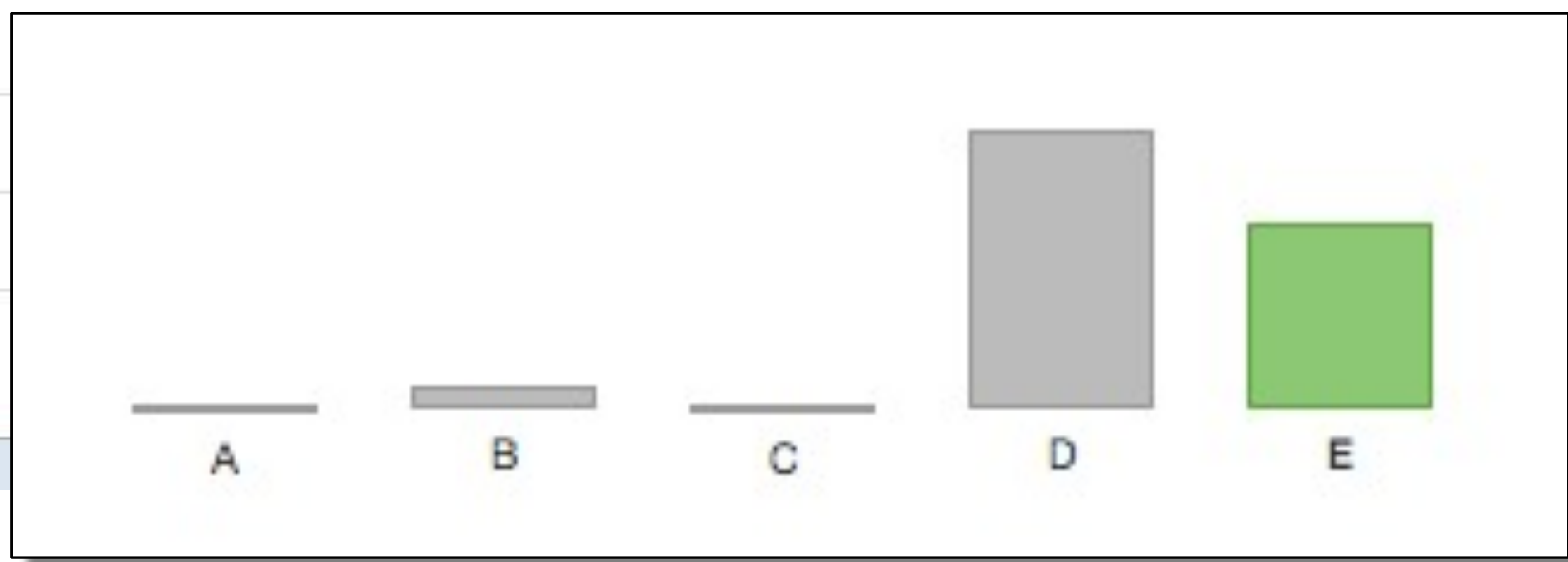
(B) is 0

(C) is ∞

(D) does not exist (and isn't ∞)

(E) not enough information is given

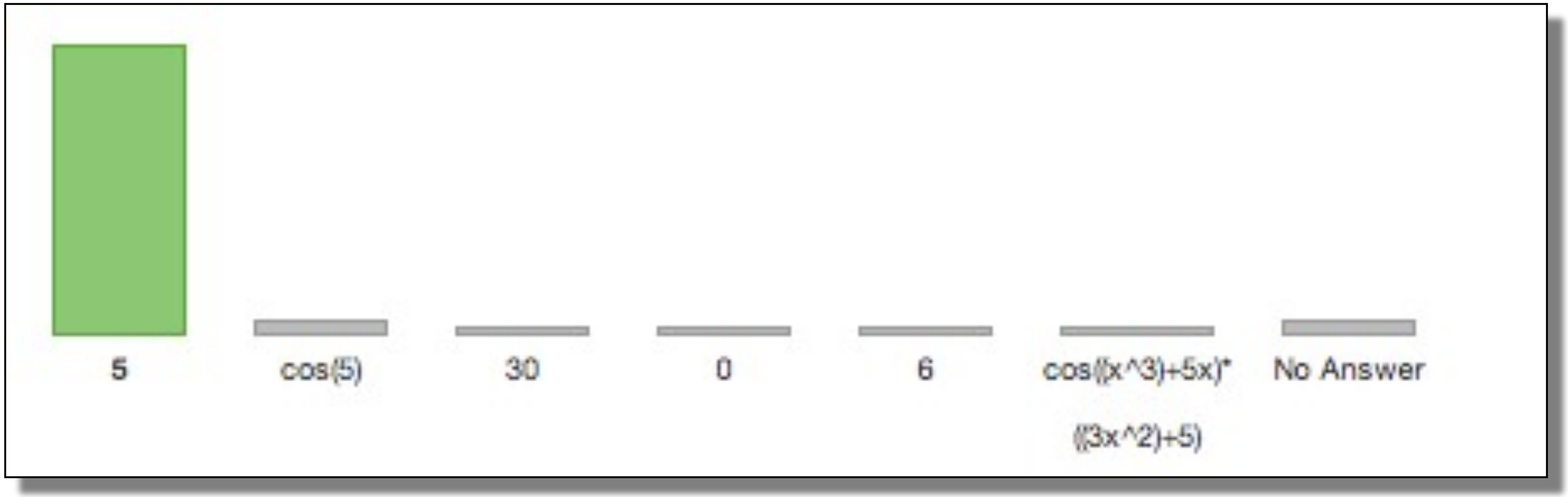
- A
- B
- C
- D
- E



Pre-Class Questions

Question 1 1 pts

For the function $f(x) = \sin(x^3 + 5x)$ determine the derivative $f'(0)$.



Inside the Classroom

i>clicker

Determine $\frac{A-1}{B}$

A: 7 = **D** in a W

in the

12 = A in the **L** S with J C

3 = B in the L of the R: T F of the R, T **T** T, and T R of the K

29 = D in the **M** of F in a L Y

of the

525,600 = M in a **Y**

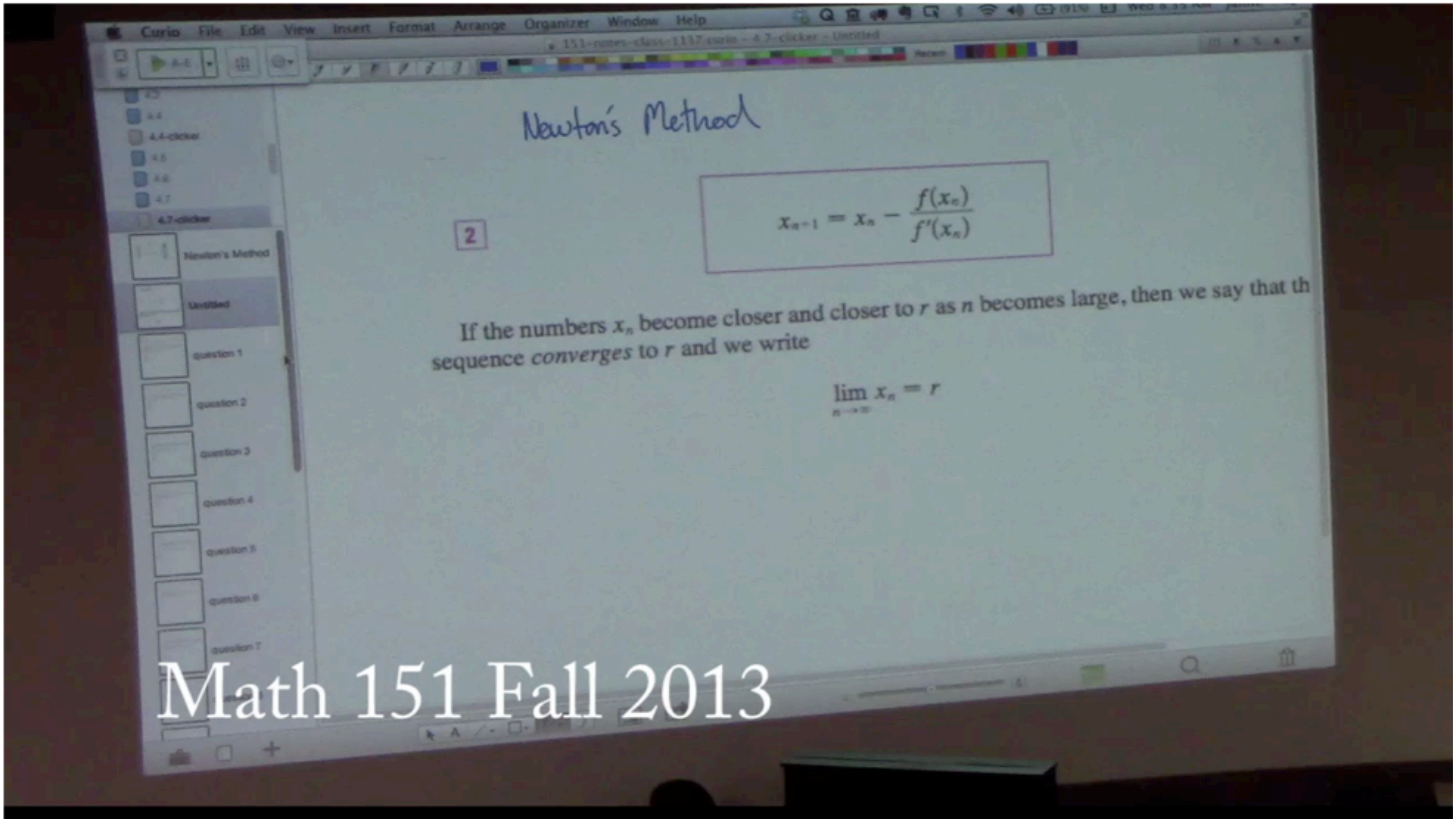
B: 150,000,000 = K between the S and the **T** P of the S S

2 = the only E **P** N

99 = W G's J **N**

answer at: b.socrative.com room: sfumath

Inside the classroom



Inside the Classroom

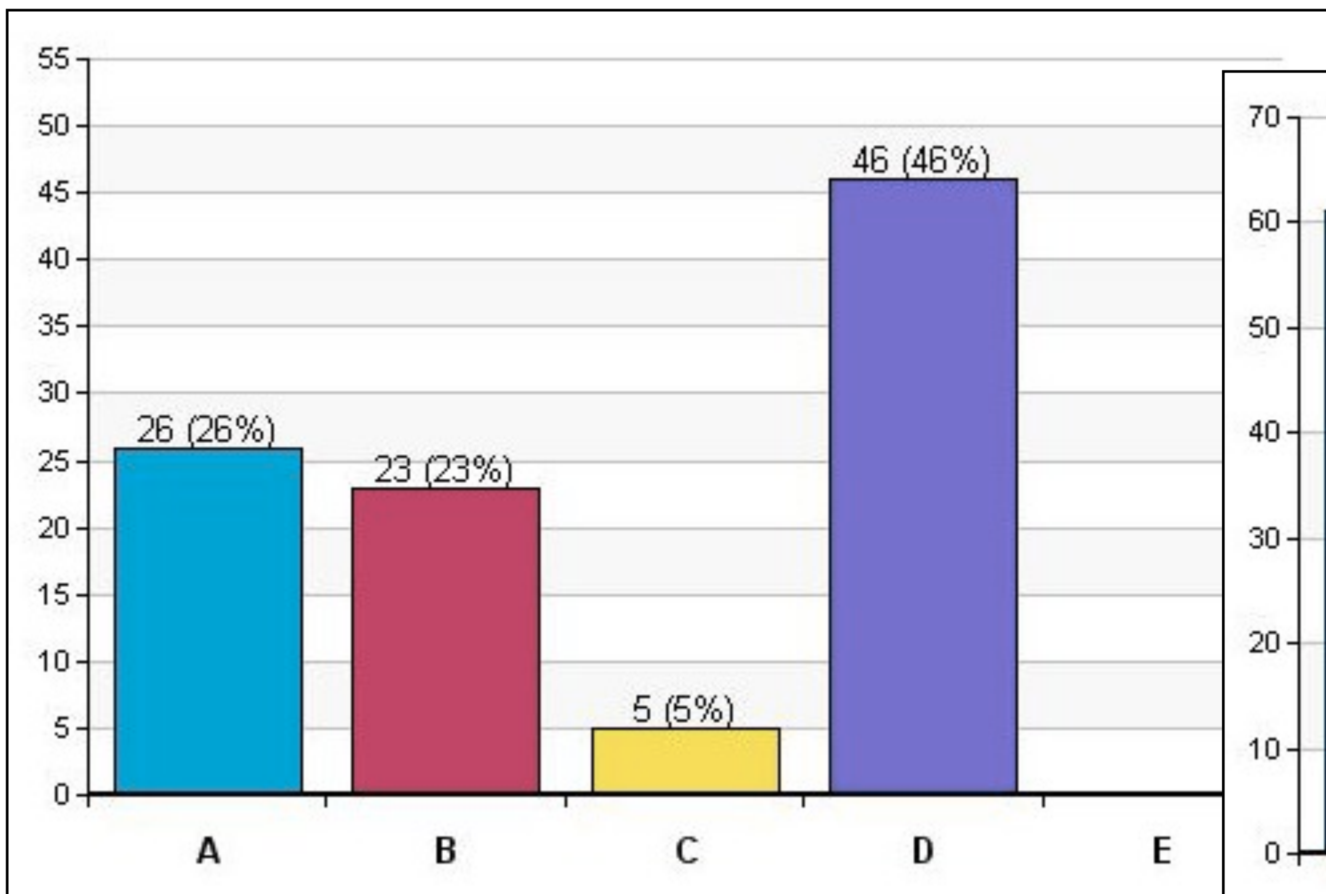
The derivative of $f(x) = x|x|$ at $x = 0$

(A) is 0.

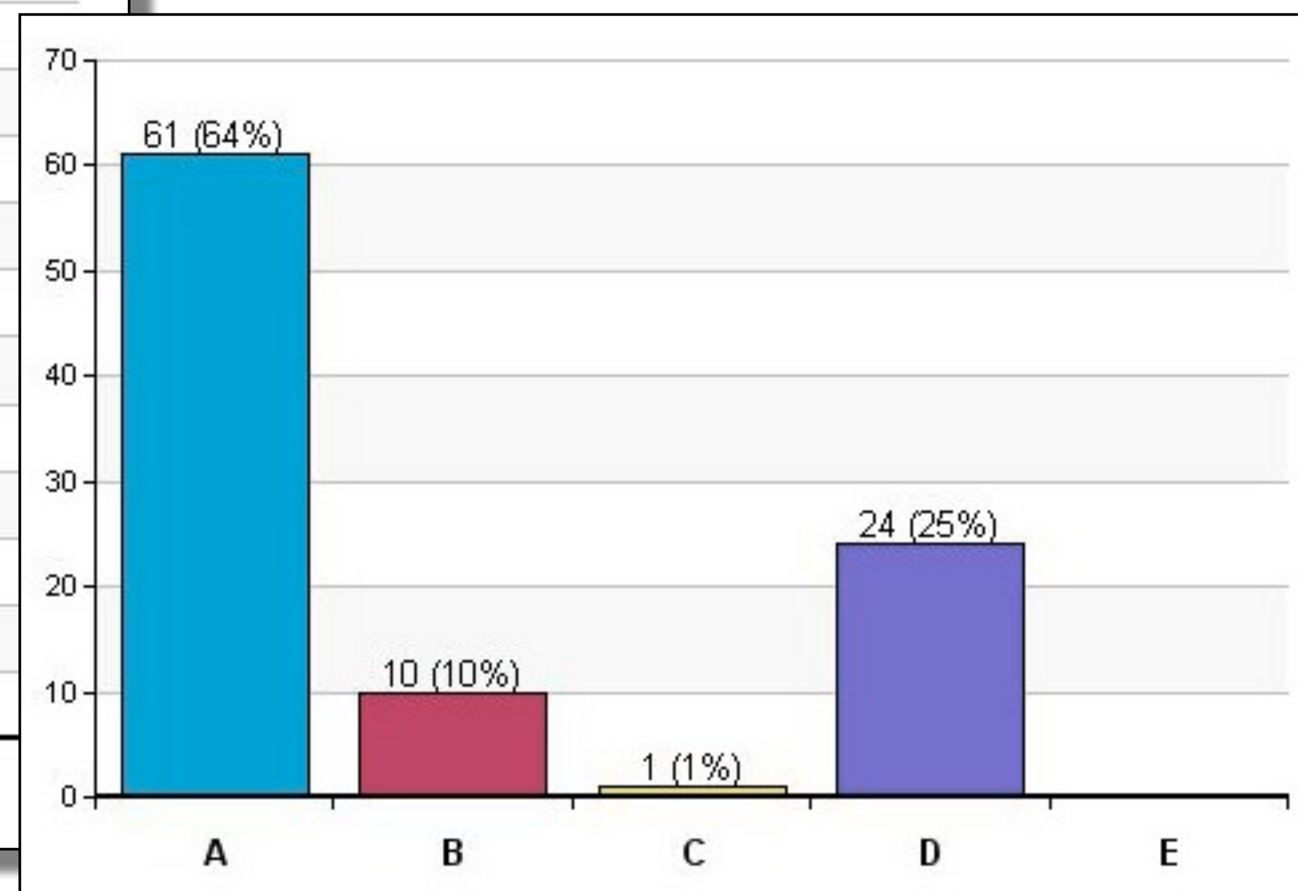
(B) does not exist, because $|x|$ is not differentiable at $x = 0$

(C) does not exist, because f is defined piecewise

(D) does not exist, because the left and right hand limits do not agree.



first round
individual



second round
group

Inside the Classroom

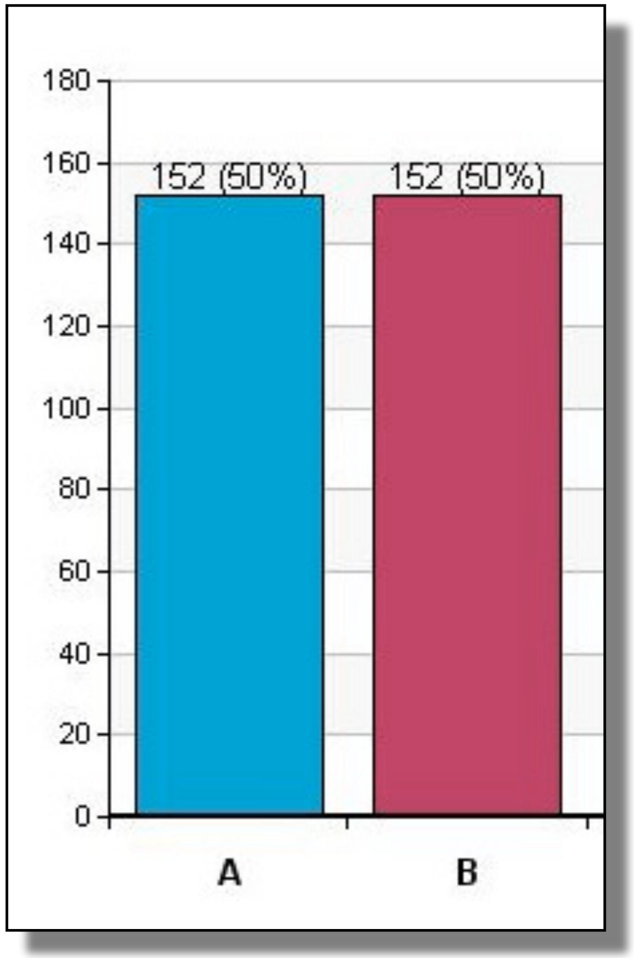
True or **False**.
$\lim_{x \to a} f(x) = L$ **means that if** x_1 **is closer to** a **than** x_2 **is, then** $f(x_1)$ **will be closer to** L **than** $f(x_2)$ **is.**

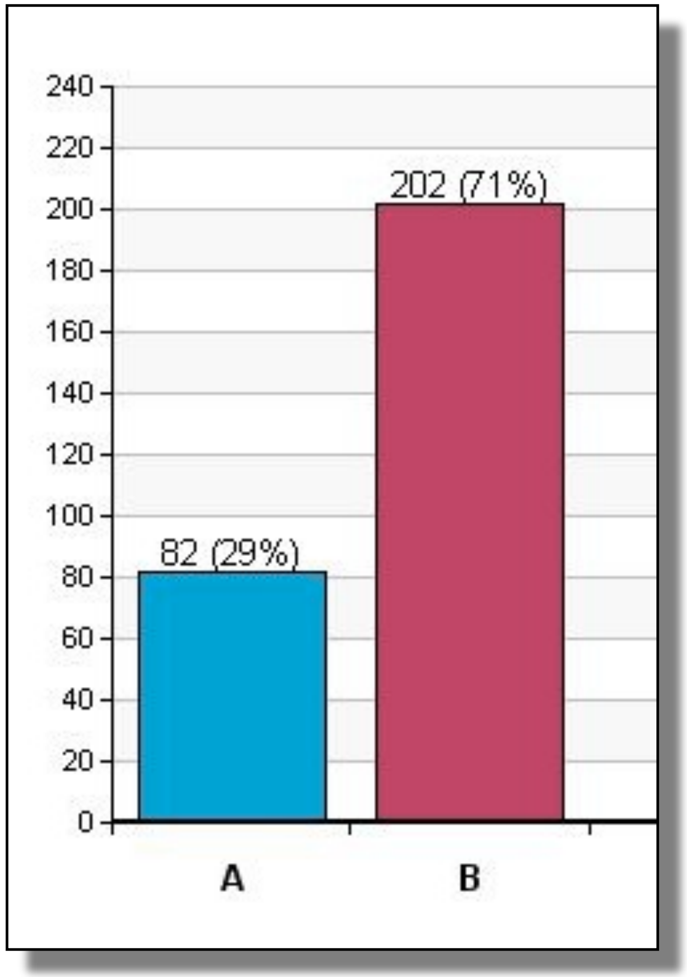
Be prepared to justify your answer with an argument or counterexample.

(A) True

(B) False

first round individual

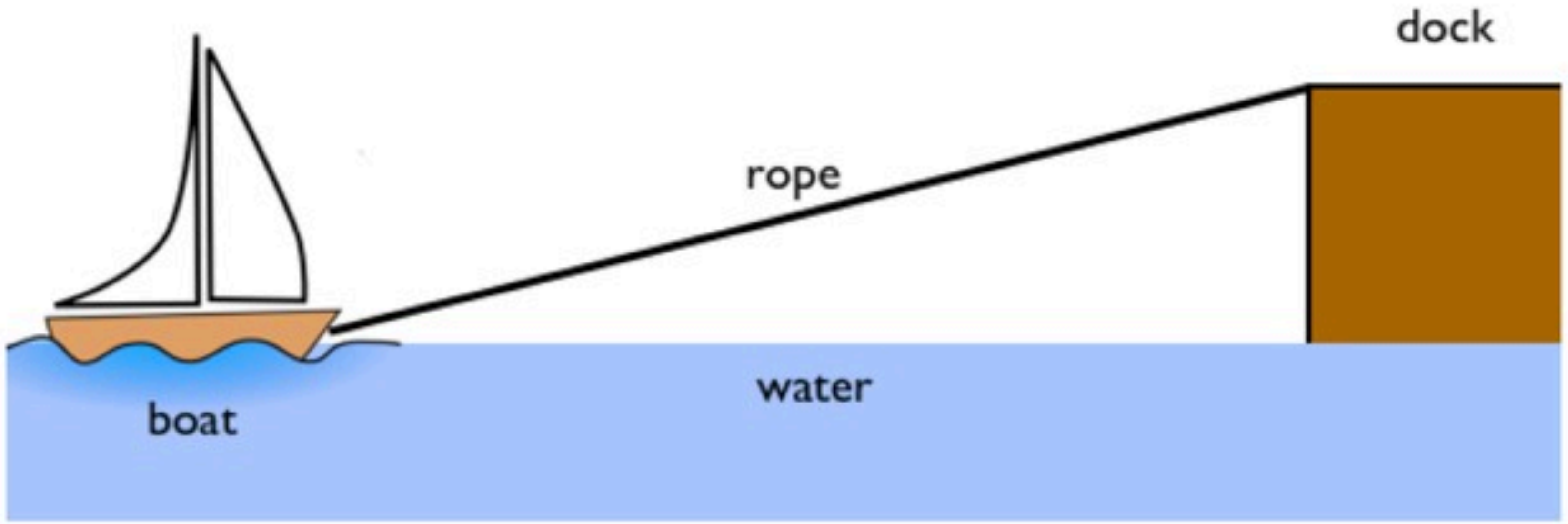




second round group

Inside the Classroom

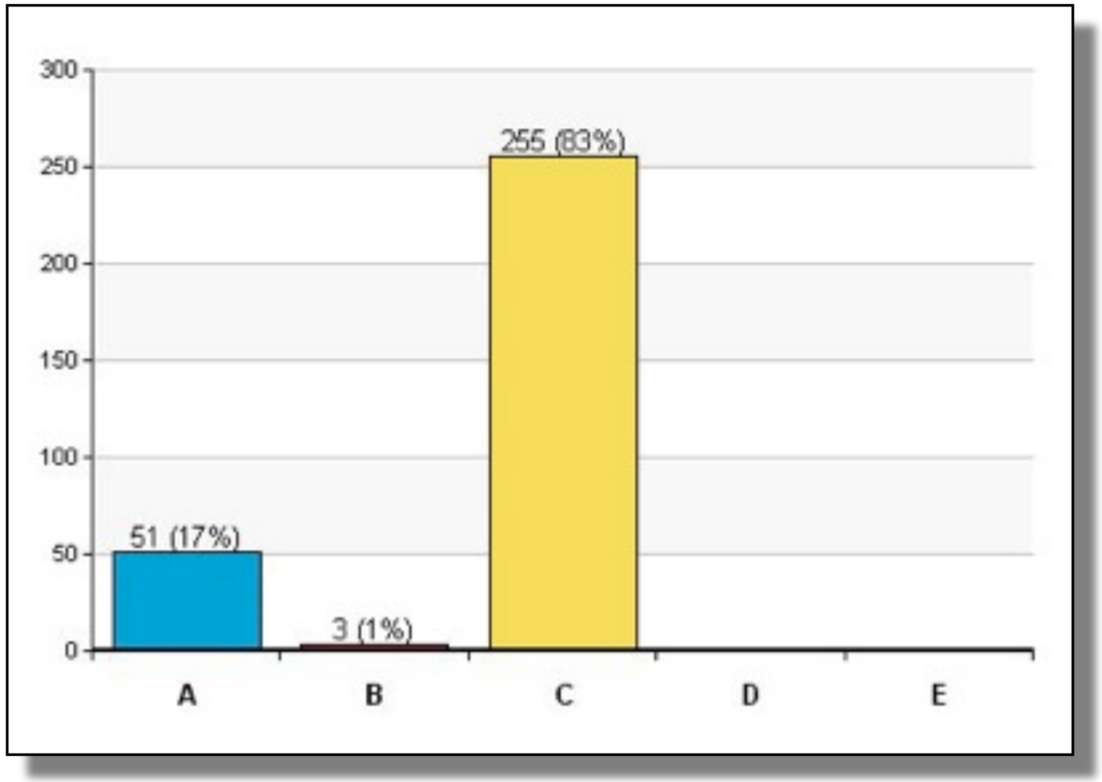
A boat is drawn close to a dock by pulling in a rope as shown. How is the rate at which the rope is pulled in related to the rate at which the boat approaches the dock?



(A) One is a constant multiple of the other.

(B) They are equal.

(C) It depends on how close the boat is to the dock.



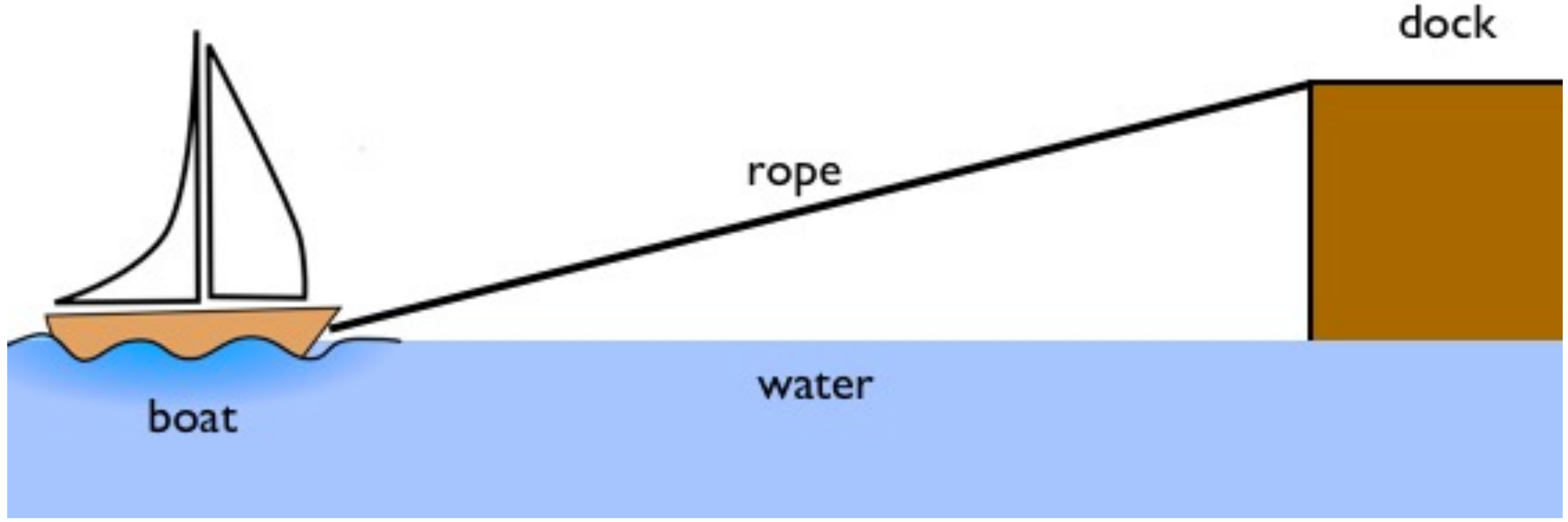
Inside the Classroom

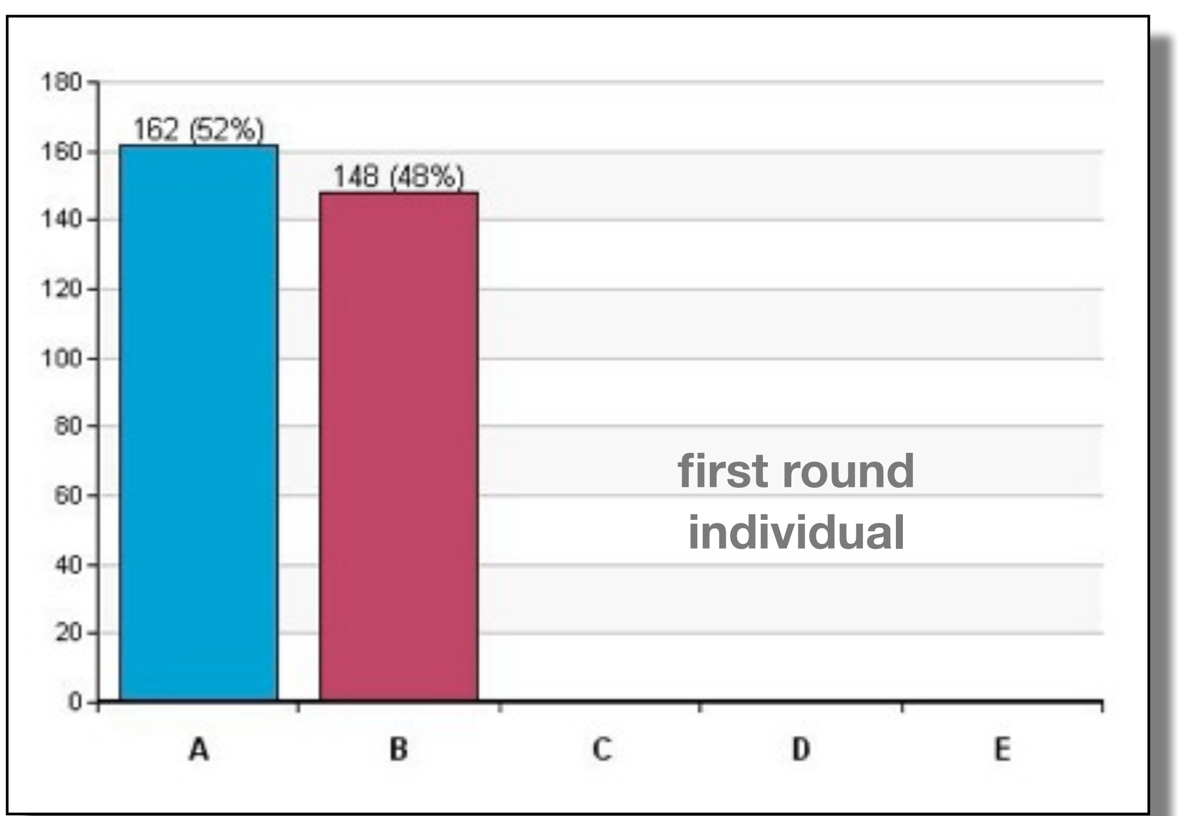
A boat is drawn close to a dock by pulling in the rope at a constant rate.

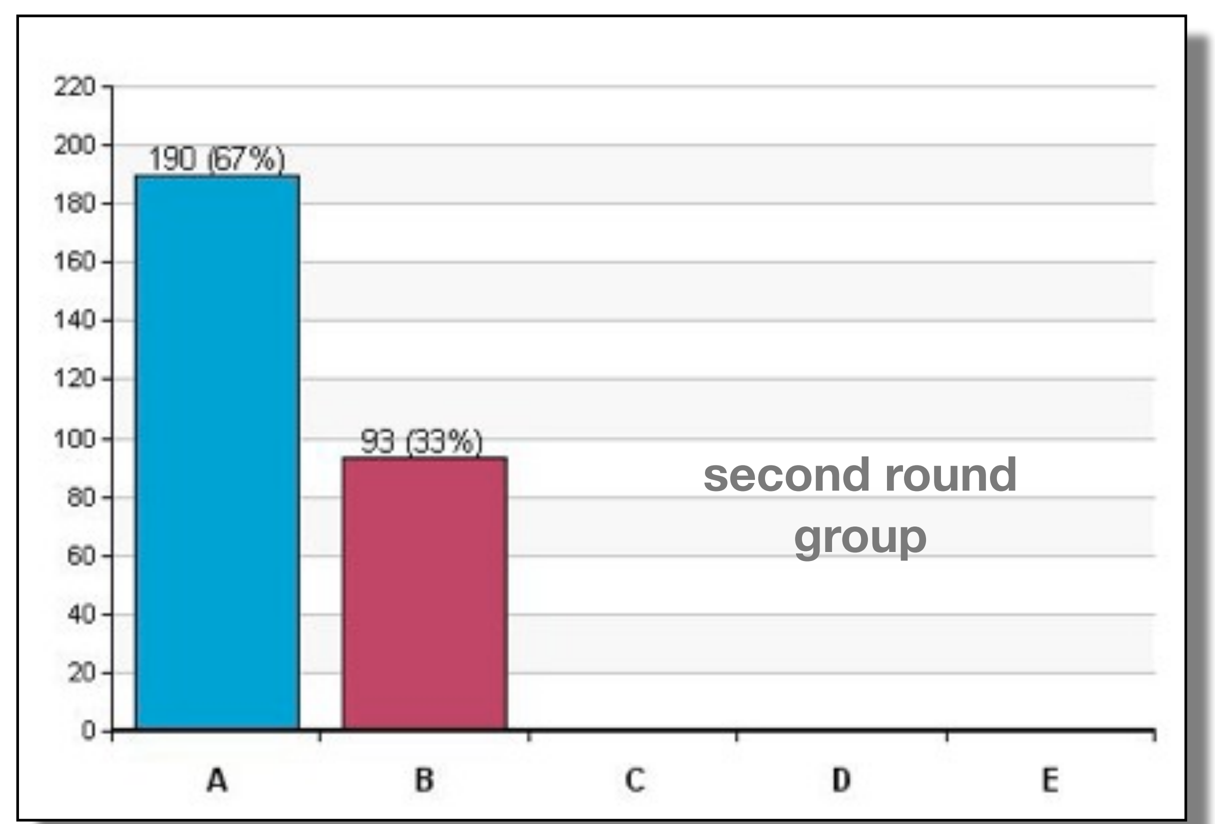
True or **False**. The closer the boat gets to the dock, the faster it is moving.

(A) True

(B) False







Student Feedback

I also loved your usage of the flipped classroom learning style. I thought it was extremely conducive to learning the material. I had heard of it before this course, but I had never experienced it, and the way it was set up I thought it greatly enhanced the lessons.

Math 151 student, Fall 2013

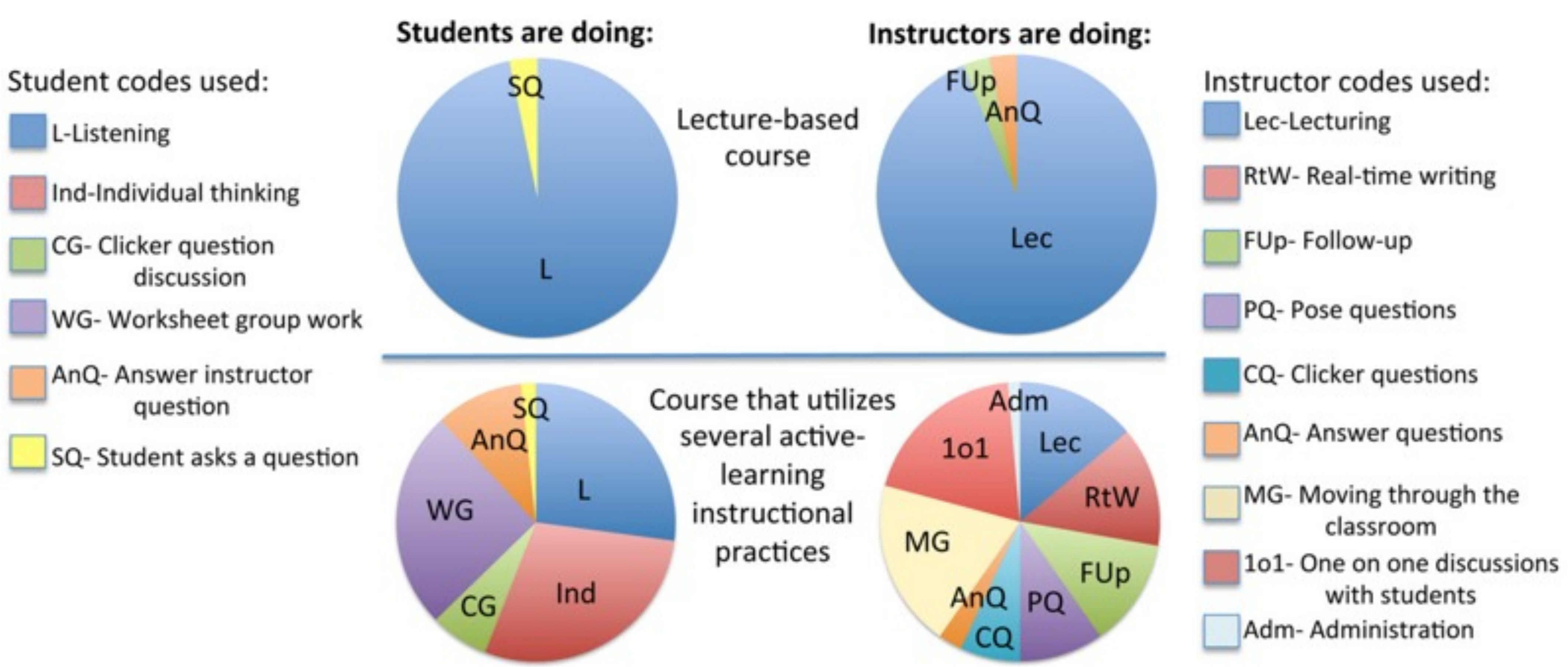
Barriers to Active Learning

- resistance to change
- workload
- suitability of teaching spaces
- content coverage
- loss of control in the classroom

Evaluating Teaching Approaches

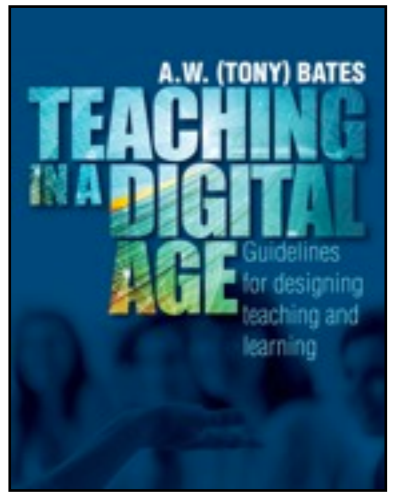
- concepts inventory
  - pre test given at the beginning of the term (plain language questions)
  - post test (exactly the same test) given at the end of the term
  - measure students gain

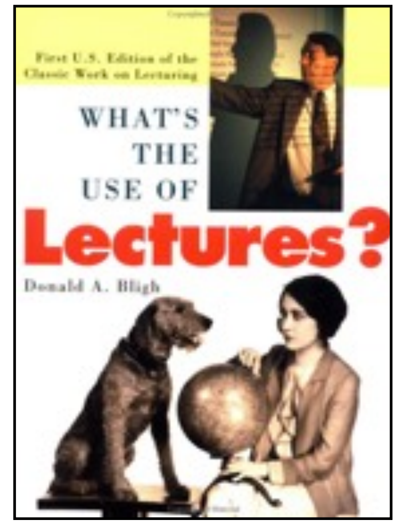
- Classroom Observation Protocol for Undergraduate STEM (COPUS)

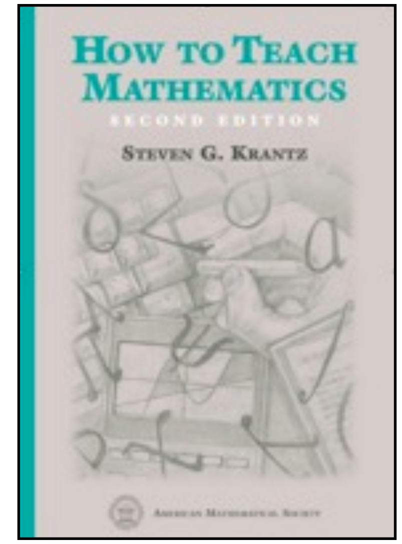


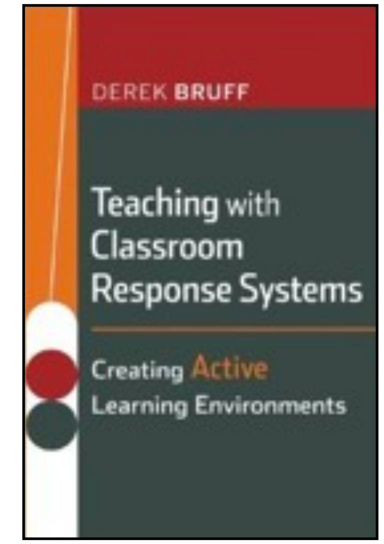
Thank You!

References









Books:

Teaching in the Digital Age. T. Bates (2015)

What's the Use of Lectures? D. Bligh (2000)

How to Teach Mathematics. S. Krantz (2000)

Teaching with Classroom Response Systems: Creating Active Learning Environments. D. Bruff (2009)

Twenty Terrible Reasons for Lecturing. G. Gibbs (1981)

Articles:

Freeman, et al. *Active learning increases student performance in science, engineering, and mathematics.* Proceedings of the National Academy of Sciences. (2014)

Weiman, C. *Large-scale comparison of science teaching methods sends clear message.* Proceedings of the National Academy of Sciences. (2014)

Other resources:

Classroom Observation Protocol for Undergraduate STEM (COPUS)
http://www.cwsei.ubc.ca/resources/COPUS.htm

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ENGAGING THE WORLD

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