From Lecture to Active Learning

Rewards for all, and is it really so difficult?

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Overview

- Thoughts about lecturing and classroom time
- Scientific evidence and reactions
- What is meant by “active learning”
- Alternatives (includes escaping the lecture/textbook trap!)
- Inertia
- Rewards
- Will this work?
- How much time does it take?
- Questions welcomed throughout
- Discussion

Lecturing Has Been Standard for 500 Years!

- Inspiration vs. Learning
  - Television
  - Videorecorded lectures
- "I understand perfectly when you lecture, but then I can't solve problems at home."

Learning Is Not a Spectator Sport!

I want my students to be

- Active in class ***and*** at home
- *DOING* [mathematics]
- Exploring and finding their own multiple ways to solve problems
- Creative and having fun
- Experimenting, conjecturing, proving, and generalizing

Classroom Time Is Precious

Do you want your students to spend it on

- First contact with new material

OR

- Higher level activity?

Scientific Evidence

- Calculus Concept Inventory (CCI): AMS Notices (2013)
- Physics ~1990: Force Concept Inventory (FCI)
- "The *most basic* conceptual comprehension of foundations of a subject"

Evidence

CCI example question:

If you know that a function *f(x)* is positive everywhere, what can you conclude from that about the derivative *f′(x)*?:

a) the derivative is positive everywhere
b) the derivative is increasing everywhere
c) the derivative is concave upward
d) you can’t conclude anything about the derivative

Evidence

Another CCI example question:

Figure 2.27 shows position as a function of time for two sprinters running in parallel lines. Which of the following is true?

(a) At time A, both sprinters have the same velocity

(b) Both sprinters continually increase their velocity.

(c) Both sprinters run at the same velocity at some time before A.

(d) At some time before A, both sprinters have the same acceleration.

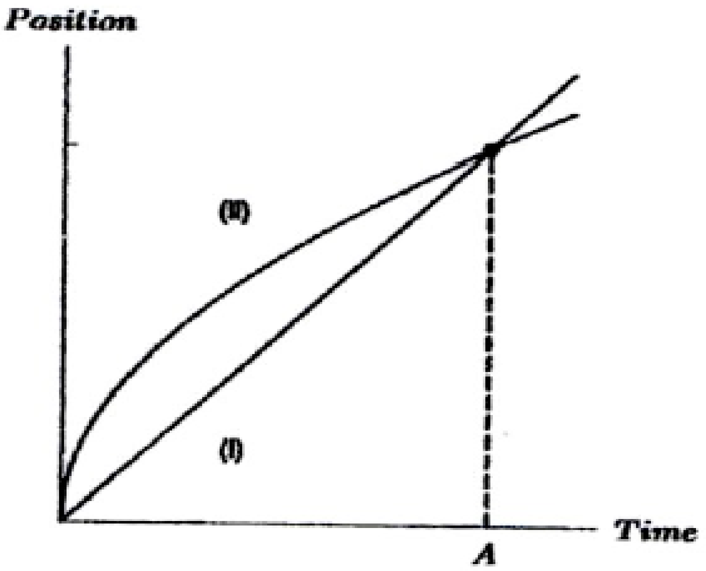


Figure 2.27

Evidence

CCI results

- Many thousands of students at hundreds of colleges in US, and many other countries
- “Traditional instruction (T) has remarkably little effect on basic conceptual understanding”

Evidence

- Interactive Engagement (IE): "students actively work on underlying concepts and problems during the class and receive feedback from the instructor or other students on their work in class"
- Versus Lecture (T)
- Dramatic differences (two standard deviations) in CCI gains between T and IE instruction, but no effect of instructor, class size, student preparation

Evidence

- "Evaluation of the Inquiry-Based-Learning Mathematics Project" (2013)
- 100 sections, 3200 students, 4 universities
- Courses: calculus, for majors, …, for teachers

Evidence

- “IBL” (Inquiry Based Learning): “Over 60% of class time spent giving and listening to student presentations, working in small groups, discussing ideas that generally arose from a group problem or student-presented solution”
- “Non-IBL”: “Over 87% of class time spent listening to their instructor talk”

Evidence

- "IBL students earned grades in subsequent courses that were as good or better than the grades of their non-IBL peers"
- "Because work was due nearly every class, the workload was steady rather than test-driven"

Evidence

- "Non-IBL courses tended to reinforce prior achievement patterns, helping the 'rich' to get 'richer.' In contrast, IBL courses seemed to offer an extra boost to lower achieving students, especially among pre-service teachers."

Evidence

- “No evidence of harm done to the strongest students. Indeed, high-achieving students may be encouraged by an IBL experience to take more mathematics courses, especially more IBL courses.”
- “Several lines of evidence indicate that IBL experiences were more powerful for students earlier in their college career.”

Evidence

IBL "benefited students in multiple, profound, and perhaps lasting ways. Learning gains and attitudinal changes were especially positive for groups that are often under-served by traditional lecture-based approaches, including women and lower-achieving students. First-year and less mathematically experienced students also benefited particularly."

Evidence

"Yet there was no evidence of negative consequences of IBL for men, high-achieving students, older and more experienced students: these groups too made gains greater than their non-IBL peers. The positive outcomes for students were linked to classroom practices that emphasized deep engagement with mathematical ideas and collaborative exploration of these ideas."

Evidence

- S. Freeman et al, Active learning increases student performance in science, engineering, and mathematics, *Proceedings of the National Academy of Sciences 111* (2014)
- Meta-analysis of 225 studies of undergraduate education across all STEM areas

Evidence

- Active learning improves grades, reduces failure among undergraduates in STEM areas
- 55 percent more students fail lecture-based courses than classes with at least some active learning

Recent Reactions

- C. Wieman, Large-scale comparison of science teaching methods sends clear message, *Proceedings of the National Academy of Sciences* 111 (2014)
- “most STEM courses are still taught by lecture---the pedagogical equivalent of bloodletting.”
- “… [A]ny college or university that is teaching its STEM courses by traditional lectures is providing an inferior education to its students.”

Recent Reactions

- National Science Foundation press release (2014): "Enough with the lecturing"
- "Active learning": Reduce or eliminate lecture, and devote substantial classroom time to student involvement in mathematical work that receives immediate feedback from other students and from the instructor.

Recent Reactions

CBMS, including presidents of AMS, MAA, and 12 other mathematics professional societies (2016):

“We call on institutions of higher education, mathematics departments and the mathematics faculty, public policy-makers, and funding agencies to invest time and resources to ensure that effective active learning is incorporated into post-secondary mathematics classrooms.”

Alternatives?

- My conclusion (evolution starting 25 years ago): Lecture is the least effective means of teaching
- Inefficient
- Obsolete (video)

Alternatives?

- We underestimate our students' abilities: Our job is to challenge in the right ways, to achieve potential.
- MAA Instructional Practices Guide (December 20, 2017); accepting reviewer comments to Dec. 1 https://www.maa.org/programs/faculty-and-departments/ip-guide

Inertia

- I-(We)-You
- We teach as we were taught (but we weren't typical, largely self-taught)
- Both instructors and students are extremely comfortable with lecture
- "How could I cover the material in the syllabus if I didn't lecture?" Trapped!
- We are not responsive to scientific evidence
- It takes effort to change (more work first time)
- Motivated more by personal reward, interest

Rewards for All

- Higher quality interactions with students; more rewarding in class
- Fewer exams to grade
- Less need for office hour time
- More rewarding homework marking
- No more time spent by me overall
- Syllabus less rushed; more coverage: students cover versus instructor covers; reduce cram-exam-forget; more even workload; less stress for all; avoid burnout
- Student responses

Case Studies

- 20 year evolution, started in Calculus I, II
- MATH 191,192,210,275,279,291,331, 332,411,430,452,453,455,459,541, 542,561
- Materials: Textbooks, projects, primary historical sources

Alternatives to lecture

- “Flipped/inverted classroom”?: video lecture, in-class group work (worksheets)?
- But still may be passive; still must make lectures and/or worksheets; still some first contact in class
- Instead: Eliminate lecture, replace with active student preparation for class

Alternatives to lecture

Goal:

1. Students read, and write responses
2. Students do preparatory work before class
3. In-class, group work and presentations build on top of preparation
4. Post-class harder homework, higher level

I-(We)-You $\rightarrow$ You-You-Y’all-We-You

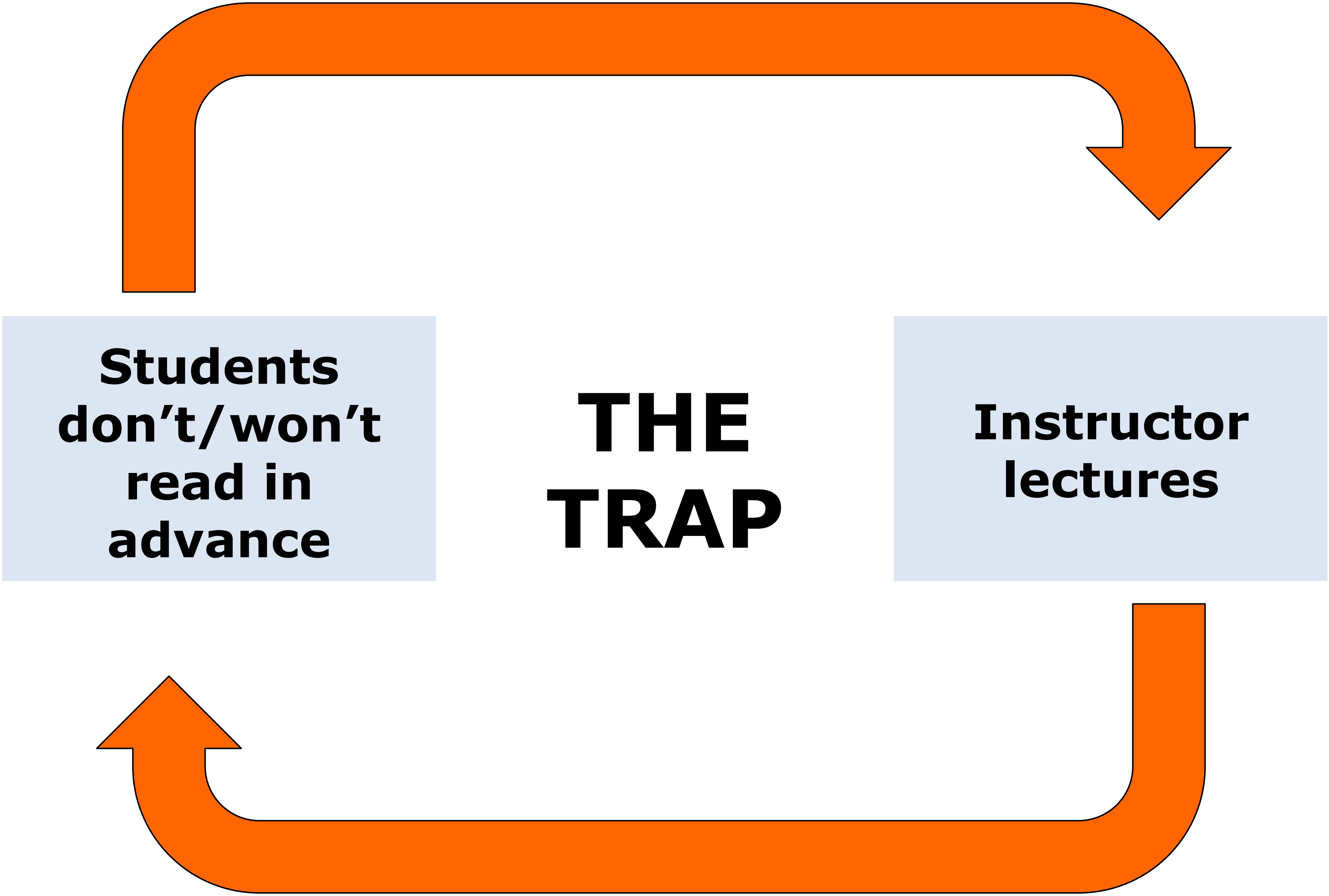
Alternatives to lecture

HW A,B,C rolling assignments

- A: Read, write responses to my questions for l.d. courses, write questions for l.d./u.d.; I read, mark quick +,✓,-, to prepare for class
- B: Prepare warm-up problems
- In-class: Briefly discuss reading responses; Gp. work on warm-ups, present, discuss. Hand in B: quick +,✓,-
- C: Post-class, a very few harder problems: grade A-F (*no points*)

Questions: Will this work?

Will students really read and write in preparation for class?


Students don’t/won’t read in advance
THE TRAP
Instructor lectures

Questions: Will this work?

- Will students really read and write in preparation for class?
- Students *will* read/write, hand it in. Part of grade; see value, become enthusiastic about it
- *Motto*: Never lecture on material students can read.

Questions: Will this work?

- Will students prepare warm-up problems before class?
- *Yes.* Part of grade, day one, peer and instructor pressure, presentations, see value
- Parts A,B,C *must* be a very large part of course grade (≥60%); *less* examining
- Harmony between learning and evaluation

Example assignments

(more on the web)

From Calculus I

HW 9A: Read §2.7.

Reading questions:

1. Explain in your own words what your understanding is of the idea of the derivative of a function.
2. What are the different mathematical and physical interpretations we know of for the derivative of a function?

HW 9B: §2.7: # 2,4,6,8,12,22,26

HW 9C: #28,32

Example assignments

(more on the web)

From a Discrete Mathematics & Intro to Proofs course

HW 10A: Read textbook Section 2.2.
Reading questions:

1. Make up two great examples of your own of multiply quantified statements, in which the meaning changes dramatically when the order of the quantifiers is changed as in Examples 2.2.1 and 2.2.2. Explain why this is the case for each.
2. Make a good example of your own of each of the two types (existential and universal) of multiply quantified statements discussed, and then write and explain their negations.

HW 10B: From the textbook, do §2.2, #6,8,14,17,19,32.
HW 10C: §2.2, #42,44 (careful, tricky!).

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Logistics

Homework parts are *assigned* in rolling trios

(*Described in more detail on my website*)

Day 4	•	•	**5A**				
Day 5		•	**5B**	**6A**			
Day 6			**5C**	**6B**	**7A**		
Day 7				**6C**	**7B**	•	
Day 8					**7C**	•	•