MichMATYC, October 15, 2016

Delta College, University Center, Michigan

# INVESTIGATIONS ON INSTRUCTION AND TEACHING IN POST-SECONDARY SETTINGS

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# INSTRUCTION VERSUS TEACHING

Are they synonyms?

Do they refer to the same phenomenon?

Is it worth making a distinction?

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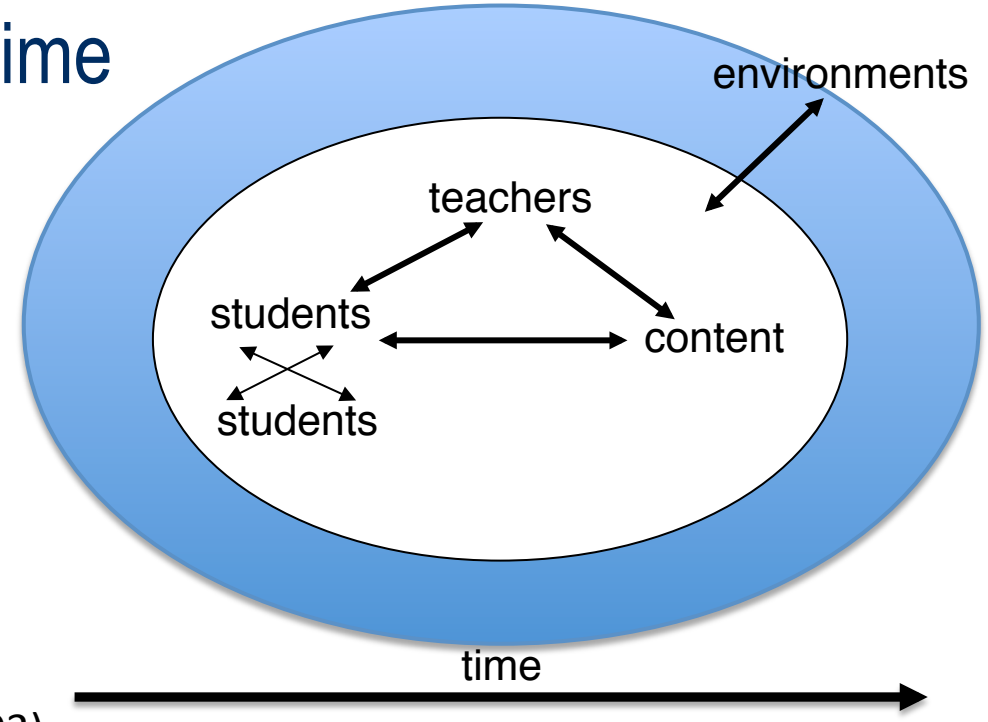
# INSTRUCTION – INITIAL DEFINITION

- The interaction between instructor, the student, and the content that occurs within an instructional situation and embedded in a particular environment.
- It changes over time

This definition has methodological advantages




(Cohen, Raudenbush, Ball, 2003)

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# TEACHING – INITIAL DEFINITION

The *work* instructors need to do to support instruction.

- Not very original, but it is a practical definition:
  - **Planning**: choose material, examples, tasks; decide on a sequence and relative emphasis of topics …
  - **Implementing**: present the day's topic, answer students' questions; ask students questions; correct mistakes, give hints and suggestions…
  - **Assessing/Evaluating**: decide how well the students demonstrate their learning; give feedback and suggestions; modify instruction…

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Attending to interaction allows me to identify regularities that can be critiqued and suggest changes in instruction that can support student learning.

Attending to teaching allows me to understand the complexity of the processes embedded in the work of the teacher, to situate them in a system of social activity, and to anticipate whether and how change can happen.

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# OVERARCHING RESEARCH QUESTIONS

- What are the characteristics of the **interaction** in mathematics classes in post-secondary education?

- Which areas of **teaching** present most difficulties when teachers seek to change instruction?

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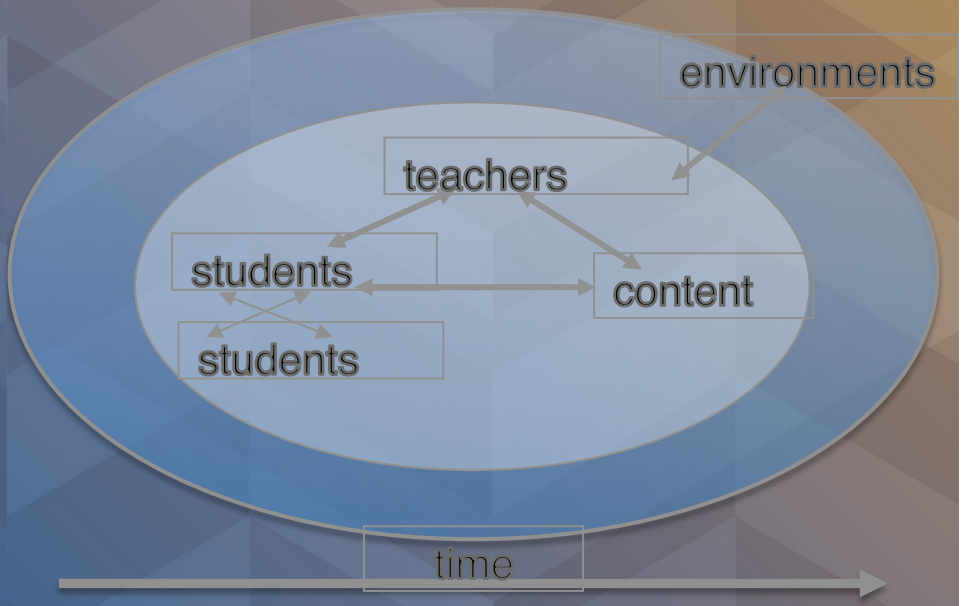
# DATA

| Project | Data |
|---|---|
| Community colleges CAREER | 72 Interviews, 10 focus groups, 33 classroom observations, 180 students surveyed on math content, 777 students surveyed on goal orientations, 500 problems in textbooks |
| MAA National Study of Calculus | 170 calculus coordinators, 660 calculus instructors and 14000 students surveyed; 18 institutions selected as case studies: 267 interviews, 45 focus groups, 70 classroom observations, 5,000 tasks analyzed |
| IBL (inquiry-Based Learning) | 41 interviews with faculty; 800 weekly logs from 74 instructors collected over a three-year period |

# INTERACTION

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# WHAT CAN BE OBSERVED?

- Frequency of the interaction
  - Number of *turns* by instructors and students
  - Length of *turns* (in words)
- Quality of the interaction
  - Types of questions asked
  - Cognitive demand of classroom tasks

→ Each requires different inference levels

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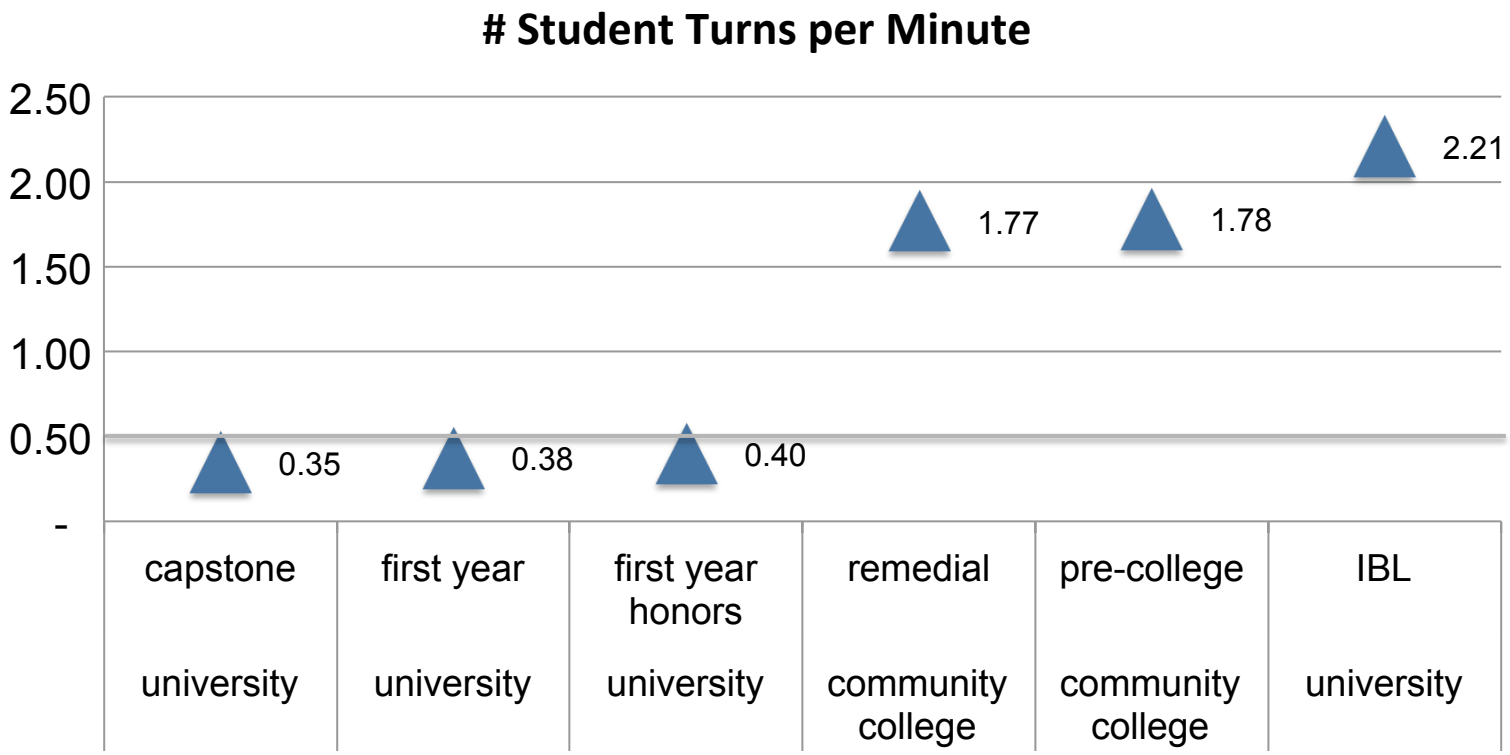
# FREQUENCY OF THE INTERACTION, 1

## 1. It varies by type of institution and course level




(Mesa, 2010; Mesa & Chang, 2010; Mesa, Celis, & Lande, 2014)

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# FREQUENCY OF THE INTERACTION, 2

2. Students participate but they do not say much:

- Average number of words in turns
  - By teachers: 40
  - by student : 4.5
- Percent of turns having one to three words:
  - In regular classes: 51%
  - In inquiry-based learning classes: <10%

(Mesa, 2010;2011)

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# QUALITY OF THE INTERACTION, 1

- **Routine Questions**: assume the students know the answer or the procedure they have to use.
- **Novel Questions**: require students to make new connections, re-invent processes, or use information that has not been discussed in class.

3. On average, percent of novel questions in…
   - regular classrooms: 20%
   - IBL classrooms: 80%

(Mesa, 2010; Mesa, Celis, & Lande, 2014; Mesa & Lande, 2014)

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# QUALITY OF THE INTERACTION, 2

**Knowledge**

**Factual**: basic units (facts) of a discipline, definitions

**Procedural**: how things are done

**Conceptual**: what relationships exists between facts, procedures, or other concepts

**Metacognitive**: how one thinks or organizes knowledge

**ALL ARE NEEDED**

**Cognitive Processes**

Remember

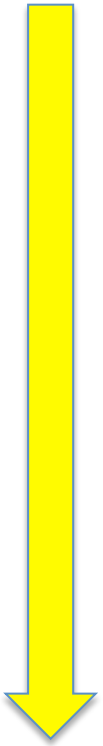
Apply

Understand

Analyze

Evaluate

Create



**INCREASE IN COMPLEXITY**

(Anderson et al, 2001)

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# QUALITY OF THE INTERACTION, 2

4. Most tasks emphasize basic cognitive processes with factual, procedural or conceptual knowledge. Low use of metacognition.

- Less than 2% of tasks require advanced processes: Analyze, Evaluate, Create

| (N=401) | Remember | Apply | Understand |
|---|---|---|---|
| Factual Knowledge | 41 (10%) | 18 (4%) | 46 (11%) |
| Procedural Knowledge | 38 (9%) | 109 (27%) | 59 (15%) |
| Conceptual Knowledge | 8 (2%) | 5 (1%) | 43 (11%) |

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# QUALITY OF THE INTERACTION, 3

5. The Initiation, Response, Evaluation (I-R-E) pattern predominates.

In 70 Calculus I lesson at post-secondary institutions…

| Type of interaction Pattern | Average time used in Class (min) | % |
|---|---|---|
| I-R-E | 1,309 | 33% |
| Lecture | 1,189 | 30% |
| Lecture with questions | 750 | 19% |
| Group or pairs | 614 | 16% |
| Discussion by students | 100 | 3% |

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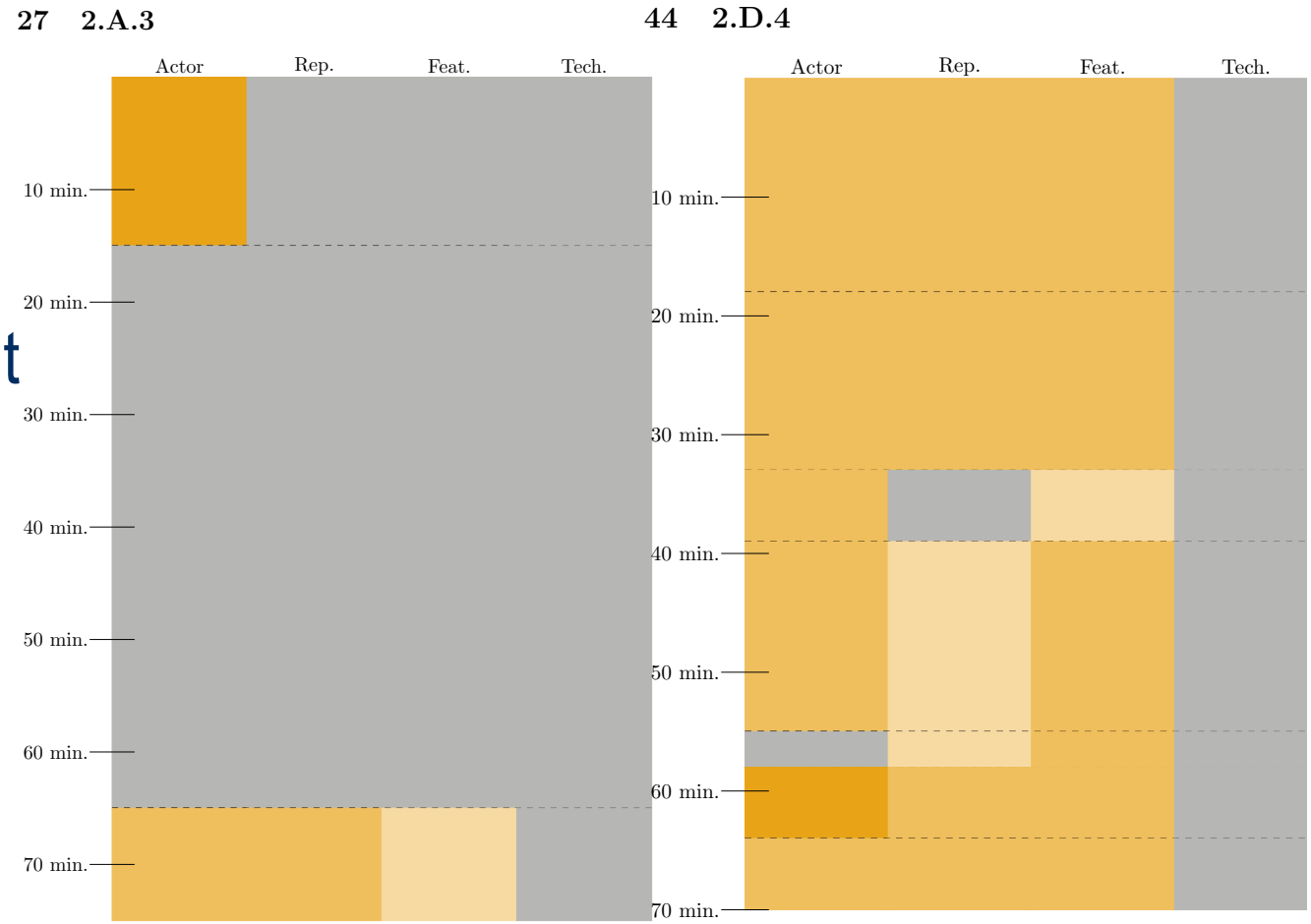
# QUALITY OT THE INTERACTION, 3

6. Weak correlation between lesson length and level of student involvement




(Mesa, White, Sobek & Burn, 2016; Mesa, White, Burn, in preparation)

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# SUMMARY

- There is variation in the quantity and quality of the interaction:
  - Less interaction in university math courses than in community college math courses
  - Higher interaction in IBL courses
- Even in cases with high interaction, the cognitive demand is not high. Instructors:
    - Focus on applying procedural knowledge
    - Show what to do
    - Ask questions students can answer
    - Solve problems in only one way

  →Except in IBL courses

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# HOW ARE THESE INSTRUCTOR ACTIONS JUSTIFIED?

## A psycho-social argument

The instructor has:

- Knowledge (math, pedagogy, curriculum)
- Beliefs, attitudes, expectations, motivations
- Working conditions

that are inadequate, incompatible, low, insufficient…

## A socio-technical argument

Individuals in specific roles respond to professional obligations established by:

- The institution
- The discipline (Math)
- The class as a whole
- Individual students

Individuals in roles of instructors respond to these demands depending on the instructional situation.

(Chazan, Herbst, & Clarke, 2016; Herbst & Chazan, 2015; Lande & Mesa, 2015; Mesa & Celis; 2014)

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# TEACHING

The *work* instructors need to do to support instruction

- Planning
- Implementing
- Assessing learning and Evaluating instruction

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# TEACHING WITH INQUIRY-BASED LEARNING

- Related to Project-Based Learning
- Quite spread out in school science
- Ample theoretical support from constructivism and social constructivism theories of learning.
- Not new!
- Hard to define... It is an approach that

  "invites students to work out ill-structured but meaningful problems… [and] construct, analyze, and critique arguments… present and discuss solutions alone at the board or via structured small-group work, while instructors guide and monitor this process"

  "It is not Lecture"

(Coppin et al, 2009, Laursen et al.; 2014, Renz, 1999)

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# WHAT IS IT?—PLANNING

| Non-IBL | IBL |
|---|---|
| **Before the course starts** | |
| Choose a textbook | There might not be 'a' textbook |
| Decide topics | Decide topics |
| Set a sequence | Set a sequence |
| Define problems for the students | Define problems for the students |
| Prepare lectures | Prepare worksheets/class problems |
| **While the course is being taught** | |
| Prepare daily lectures | Modify the worksheets daily |
| Solve problems assigned | depending on students' progress |
| **After the course ends** | |
| Repeat/modify as needed | Repeat/modify as needed |

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# WHAT IS IT—IMPLEMENTATION

| Non-IBL | IBL |
|---|---|
| **Instructor's role** | |
| Present material using clear explanations and examples | Organize students in groups to work on the worksheets |
| Answer students' questions | Walk around the groups to listen and observe as they work |
| Ask questions to establish level of understanding | Ask questions; give hints to help students move forward |
| | Solicit and give comments about presented work |
| Summarize key points | Summarize some key points |
| Provide correct and complete solutions | Do not provide solutions |
| **Students' role** | |
| Take notes | Work on the worksheets |
| Answer and ask questions | Present solutions on the board |
| | Comment on work done by other students |

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# WHAT IS IT—ASSESSMENT/EVALUATION

| Non-IBL | IBL |
| --- | --- |
| **Assessment** | |
| Ask questions during class or office hours<br>Assign and grade weekly homework | Ask questions during class or office hours<br>Assign, grade, and give detailed feedback to weekly and daily homework |
| **Evaluation** | |
| Quizzes, midterms, final exams with defined duration | Quizzes, midterms, final exams with defined and flexible duration<br>Daily presentations, weekly projects, portfolios, oral examinations to assess learning and performance |

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# BENEFITS

Students, specially those with below average representation in math (women, non-Caucasian or non-Asian) report:

- Larger gains in knowledge in IBL courses
- Higher satisfaction in their own mathematical competence
- Higher interest in continuing or pursuing a degree with mathematics

- Greater benefits when students work in groups

(Kogan & Laursen, 2014)

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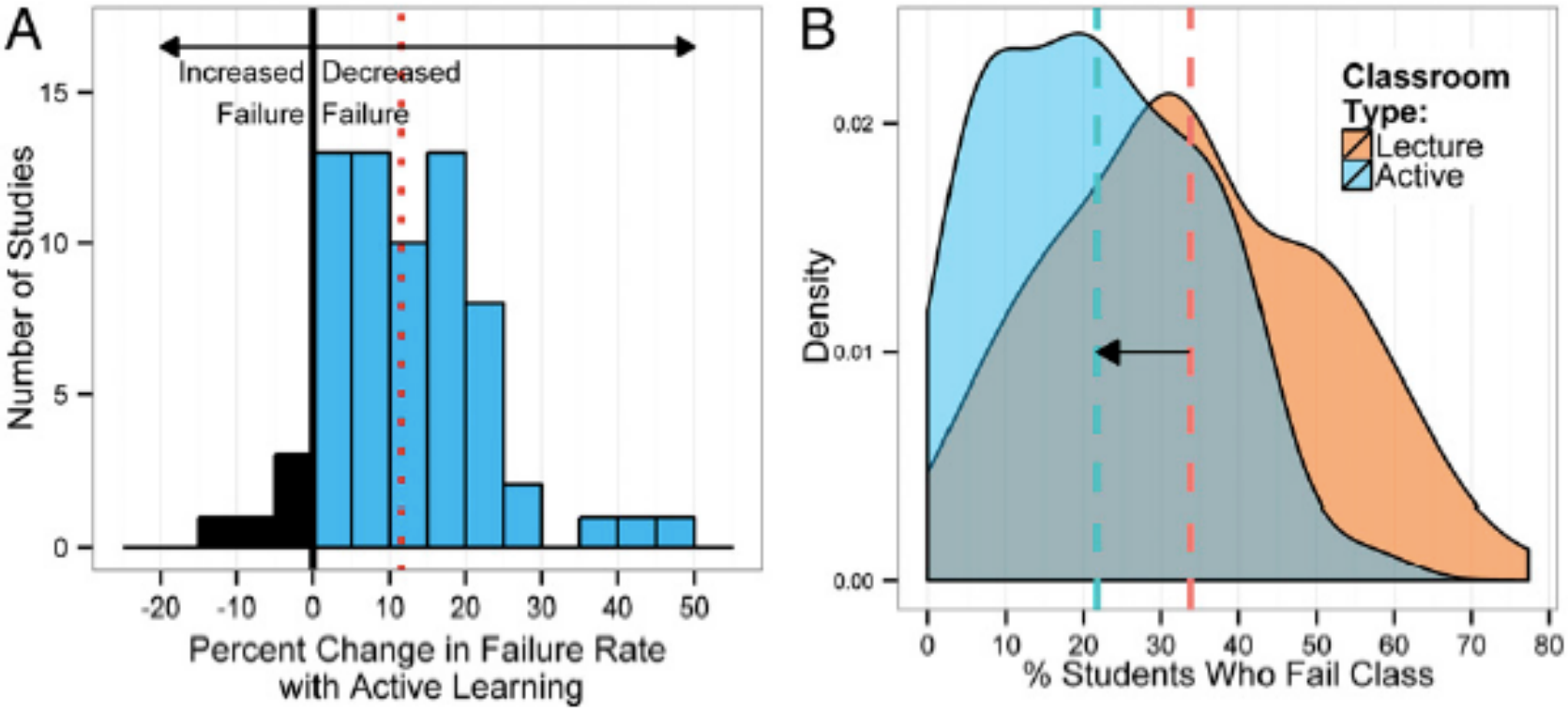
# META-ANALYSIS, 225 EXPERIMENTS IN STEM DISCIPLINES

The studies contrast courses using some version of active learning versus courses using lecture by the instructor (pass/fail, learning)




Fewer students fail the courses that use some version of active learning

(Freeman et al, 2014)

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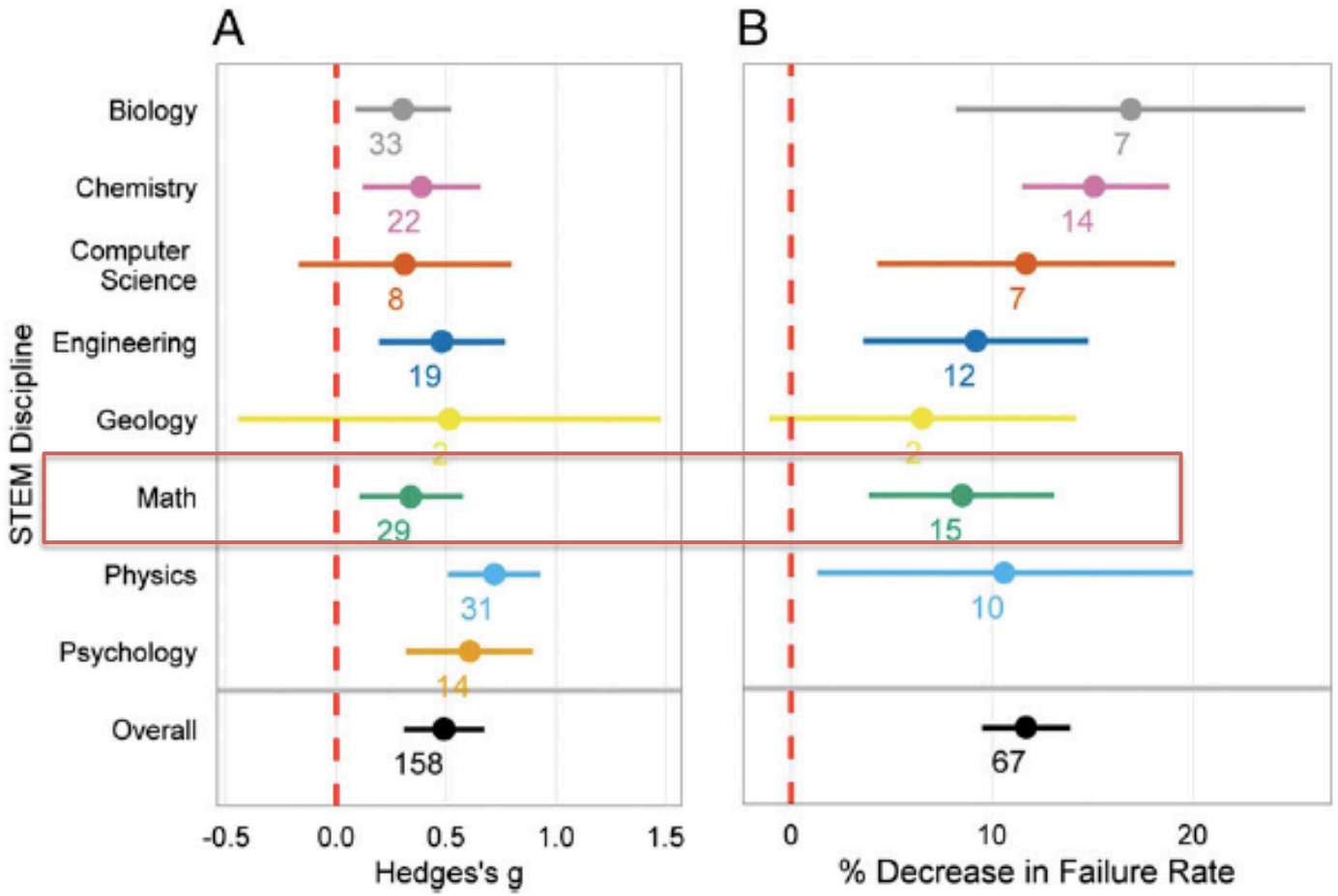
# EFFECTS BY DISCIPLINE




(A) Data on examination scores, concept inventories, or other assessments. (B) Data on failure rates. Numbers below data points indicate the number of independent studies; horizontal lines are 95% confidence intervals.

(Freeman et al, 2014)

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- A reduction of nearly 10% in failing teacher-made exams or concept inventories. The gains are larger with concept inventories
- Students scoring at the 50$^{th}$ percentile in a lecture-based class would score at 68$^{th}$ percentile in a class that uses some form of active learning
- A change of .47 standard deviations corresponds to a gain of about .3 in the students' final grade

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# CHALLENGES OF IMPLEMENTATION

- Faculty who choose to use IBL report difficulties in all areas of teaching:
  - Design, use, and management of group work
  - Management of student presentations
  - Design and use of assessments
- There are no differences in these challenges that depend on instructors' experience with IBL
- Challenges are solved 'locally': give hints, clarify or adjust expectations, re-work worksheets

(Jackson, Mesa, Huisinga, 2016; Mesa & Cawley, 2016)

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# SUMMARY

- IBL is a set of teaching practices that substitutes long periods of lecturing by in-class group work and student presentations
- It requires changes in all areas of teaching: planning, implementing, and assessing/evaluating
- It is equally difficult to implement for new and experienced instructors
- Students in courses that use some form of active learning in STEM perform better on teacher-made exams and concept inventories (after controlling for various features)
- Fewer students fail courses that used some form of active learning

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# IS IT WORTH THE EFFORT?

- If these experiments had been done in medicine, the group receiving the placebo (lecture) would have been switched to the treatment 'drug' (some form of active learning)
- The studies involved 29,300 students in the lecture groups. On average, 3,516 would have passed their courses if they had been in the other group → less expense to the students in terms of money and time and more students obtaining their college degree

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# THERE IS MORE TO INVESTIGATE!

- What is the connection of all these features with learning?
  - The existing research is mostly correlational
  - How does learning occur in these settings?
- Conditions of use
  - When is it appropriate to use IBL?
  - When is it better to use lecture?

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# CURRENT WORK

1. Impact of instruction on student gains in content knowledge and performance in intermediate and college algebra courses in six community colleges (AI@CC, NSF-156143)
2. Identification of community college programs that are successful in transitioning learners from Developmental Mathematics to Calculus II (TLC3, NSF-1625387)
3. Analysis of implementation of teaching with IBL in a linear algebra course at a research university (Sust-IBL, U-M)
4. Strategies of use of dynamic and static textbooks by teachers and students in linear and abstract algebra in 11 universities (UTMOST, NSF-1624634)

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# QUESTIONS?

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