The Effect of Interactive Instruction in the Astro 101 Classroom: Report on a National Study

Alexander L. Rudolph
Department of Physics, California State Polytechnic University (Cal Poly Pomona)

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Please take a clicker!
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How can we all do research on the effectiveness of our instruction?

- Which instructional methods, strategies, activities and interventions work best in the classroom (in our case the Astro 101 classroom)?
- Do they work in all classrooms at all types of institutions, or only ones with certain characteristics?
- Do they work for all students equally well, or do some students benefit more (or less) from particular strategies?
- How can we easily evaluate the success of our instruction and measure how much our students learn as a result of my instruction?
The Bottom Line

Question: can interactive learning strategies have a positive impact on students’ conceptual learning of key ideas in Astro 101?

Answer: Yes! But...
Some Quotes to Frame Our Discussion
The best learners...often make the worst teachers. They are, in a very real sense, perceptually challenged. They cannot imagine what it must be like to struggle to learn something that comes so naturally to them.

Stephen Brookfield
Lecture has often been described as the process of taking the information contained in the teachers' notes and transferring them into the students' notes without the information passing through the brains of either.
A mind is a fire to be kindled, not a vessel to be filled

Plutarch
It's not what the teacher does that matters; rather, it is what the students do.
The fatal pedagogical error is to give answers to students who do not yet have questions.
Why study the Astro 101 classroom?

- Astro 101 is taken by 250,000 students each year!
- An amazing 10% of all college students will take an Astro 101 class at some point in their college career
- These students come from all backgrounds and majors (more on this later)
- 40% of students in an Astro 101 class plan to become licensed teachers
- Thus, in teaching Astro 101 classes, we are affecting the scientific literacy of many of our future citizens, as well as the teachers of the next generation
- Hence, it is in our interest to teach this class well
Outline of the presentation

- Introduction of clickers
- What is Interactive Learning? Why should we use it?
  - Think-pair-share (TPS) questions
  - Lecture Tutorials and Ranking Tasks
- Brief review of PER results
- A national study of student learning in Astro 101 classes
  - Participants
  - The instrument: the LSCI
  - Results
What are clickers?

Clickers are:

- A useful tool for engaging students in the classroom
- An increasingly simple technology to use
- Fun for both students and instructors

Clickers are *not*:

- The only way to engage students in interactive learning
Let’s try out clickers

Where are you coming from?

A) I am a student
B) I teach at a high school
C) I teach at a community college
D) I teach at a 4-year college or university
E) Don’t try to categorize me
Let’s try out clickers

Which statement best reflects your familiarity with Classroom Response Systems ("clickers")?

A) Classroom response what?
B) Heard of them.
C) Done some research into systems.
D) Have experience using systems in class.
E) I could be giving this talk.
Let’s try out clickers

Have you ever used or experienced Interactive Learning Strategies in a classroom?

A) I have used Think-Pair-Share (TPS) questions
B) I have used Lecture Tutorials and/or Ranking Tasks
C) I have used other Interactive Learning Strategies
D) I have used one or more of these
E) I haven’t yet used Interactive Learning Strategies
Why should you want to use Interactive Learning strategies?

And what are they anyhow?
Interactive Learning is a tool that can change the way students learn!
We’ve been teaching the same way for a long time...

2000 years ago

How effective are we?

Today
A Commonly Held Inaccurate Model of Teaching and Learning
“Students enter your lecture hall with *preconceptions* about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for the purposes of a test but revert to their preconceptions outside the classroom.”

A cautionary tale...

...about a violin

From Carl Weiman’s*
“Physics of Everyday Life”
class, Univ. of Colo.

*Nobel prize winner AND
good teacher
Teaching is not telling...
Learning is not listening

- Weiman reports the following example of trying to teach how a violin works—that the body of a violin is essential for amplifying the sound of the strings
- Most students have the preconception that the strings make all the sound
- Explaining about sound and how a violin works, he shows the class a violin and tells them that the strings cannot move enough air to produce much sound, so actually the sound comes from the wood in the back
- 15 minutes later in the lecture he asked students a question—the sound they hear from a violin is produced
  a. mostly by the strings, b. mostly by the wood in the violin back, c. both equally, d. none of the above
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What fraction of the students got the right answer?

A) 0%
B) 10%
C) 30%
D) 70%
E) 90%
B) Only 10% of students gave the correct answer.

*Fifteen minutes later in the same lecture!*
Teaching by telling is surprisingly ineffective...

...if you want student to master concepts.

Minds must be *active* to learn

*Clickers and “peer discussion” of conceptual questions forces students to talk and reason during class. Like this...*
What is Interactive Learning?

• Interactive Learning is a set of strategies to get students *actively involved* in their learning
  • Think-Pair-Share Questions
  • Lecture Tutorials and Ranking Tasks
  • Interactive Demonstrations

• Interactive Learning uses a *combination* of lecture, real-time assessment, and peer interaction and instruction

• Research (including our study) has shown that Interactive Learning strategies lead to significant improvement in conceptual understanding by students compared with lecture alone
Think-Pair-Share (TPS) Questions

- Short (10-20 minute) lecture on topic
- “Think-Pair-Share” Question posed
- Students given time to think
- Students record individual answers
- Students discuss with their neighbors
- Students record revised answers
- Instructor leads class discussion

Adapted from Eric Mazur, “Peer Instruction: A user’s manual”
This is Lunacy!

The Moon remains in its orbit around the Earth rather than falling to the Earth because

A. it is outside of the gravitational influence of the Earth
B. it is in balance with the gravitational forces from the Sun and other planets
C. the net force on the Moon is zero
D. none of these
E. all of these
“I think that I shall never see...”

Considering that a tiny acorn can grow into a mighty oak tree, which of the following contribute the majority of the mass of the tree?

A. soil
B. air
C. water
D. sunlight
E. minerals in the soil
Were you paying attention during ER?

If you breathe in O₂ and out CO₂, why does mouth-to-mouth CPR work?

A. Humans can convert CO₂ to needed O₂
B. It's the physical breathing action, not the O₂ that mouth-to-mouth actually provides
C. ☐ You exhale CO₂ and O₂
D. Mouth-to-mouth doesn't actually work except on TV
Peer Instruction Can Be Very Powerful

Before Peer Instruction
After Peer Instruction
Sometimes Further Teaching is Needed

Before Peer Instruction
After Peer Instruction

A
B
C
D
E
Other forms of Interactive Learning: Lecture Tutorials and Ranking Tasks

- These are activities are designed to be done in small groups.
- They typically require ~10-15 minutes and are designed for easy implementation in traditional lecture courses.
- **Lecture Tutorials** pose questions that lead students through a series of small cognitive steps guiding students to deeper scientific understanding than is possible with a single TPS question.
- **Ranking Tasks** use physical illustrations to portray variations of a physical situation and ask students to determine their order or ranking.

Cal Poly students enjoy working on a Lecture Tutorial.
Given the location marked with the dot on the star’s radial velocity curve, at which location would you expect to find the planet at this time?

A. Rank (from greatest to least) the strength of the gravitational force at positions A - E exerted by the Moon on the spacecraft

B. Rank (from greatest to least) the strength of the net (or total) gravitational forces at positions A - E exerted by both the Earth and the Moon on the spacecraft

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Development of the FCI

- Years of Physics Education Research has shown that lecture alone is not sufficient to maximize students’ conceptual understanding in introductory Physics classes.

- This was given a great push forward by the development of the Force Concept Inventory**, a 30-question multiple-choice survey on the basic concepts of Newton’s Laws.

- The FCI is now widely used as the standard measure of students’ learning in introductory Physics classes.


A National Study by Hake

• The biggest boost to the idea that interactive learning strategies stimulated measurable gains in students’ conceptual understanding came from the meta-study of Hake

• Hake’s study:
  – Focused on introductory Physics classes (primarily college level)
  – Included over 6000 students
  – Was national in scope
  – Used the FCI pre- and post-instruction to gauge the level of student learning
  – Compared traditional lecture-based courses to those incorporating interactive learning strategies (self-reported)


\[ g = \frac{\text{post\%} - \text{pre\%}}{100\% - \text{pre\%}} \]

- \( g > 0.7 \) "High"
- \( 0.3 < g < 0.7 \) "Medium"
- \( g < 0.3 \) "Low"
red = traditional, green = interactive engagement

This Study

- From Fall 2006 to Fall 2007, we conducted a national study to determine how instructional style affects student learning in Astro 101 (non-science major, GE astronomy) courses.

- The “Light and Spectroscopy Concept Inventory” (LSCI) was administered pre- and post-instruction.

- The LSCI was used to assess student learning in each course and these results help determine the effectiveness of various instructional styles in Astro 101 classes.

The Instrument: the LSCI

• The Light and Spectroscopy Concept Inventory consists of 26 multiple-choice questions designed to test students’ conceptual understanding of these topics in the context of astronomy

• The topics of light and spectroscopy were chosen because, light is the fundamental carrier of astronomical information, and they are common to all Astro 101 courses, regardless of their astronomy content

• All questions were extensively tested at the University of Arizona as part of a PhD thesis* to test for appropriateness and effectiveness at determining student conceptual understanding

Participants

- Almost 4000 students
- 31 institutions
- 36 instructors
- 69 different sections
  - Section sizes vary from <10 to 180
This was a truly national study
The Light and Spectroscopy Concept Inventory was accompanied by an additional 15 demographic questions to allow us to determine how such factors as

- Gender
- English as a native language
- Socioeconomic background (parental income, education, etc.)
- Overall GPA
- Major
- Number of prior science or astronomy courses
- Level of mathematical preparation

interact with instructional style to influence student conceptual learning

This survey also gave us a snapshot of who is taking Astro 101 courses in the US
$g > 0.7$ "High"

$0.3 < g < 0.7$ "Medium"

$g < 0.3$ "Low"
\[
g = \frac{\text{post\%} - \text{pre\%}}{100\% - \text{pre\%}}
\]

0.7 < \langle g \rangle < 1 \text{ “Un-ubtanium”}

0.3 < \langle g \rangle < 0.7 \text{ “Medium”}

0 < \langle g \rangle < 0.3 \text{ “Low”}
Instructor Surveys

- To assess the level of interactivity in each classroom, we asked each instructor to fill out a questionnaire, the “Interactivity Assessment Instrument” (IAI) detailing how they spend their class time.

- This survey was used to construct an “Interactivity Assessment Score” (IAS) based on what percentage of total class time is used for interactive activities such as:
  - Peer instruction activities such as think-pair-share (TPS) questions
  - Collaborative learning activities such as Lecture Tutorials or Ranking Tasks
  - Predictive activities such as interactive demonstrations
Rutherford’s attitudes are common among Physicists

- All science is either physics or stamp collecting
- The only possible conclusion that social sciences can draw is some do, some don't
- If your result needs a statistician then you should design a better experiment
Lower IAS (<25%)  
Higher IAS (>25%)  

Medium level $g > 0.30$
Lower IAS (<25%)

$g_{avg} = 0.13$

Higher IAS (>25%)

$g_{avg} = 0.29$
Who's taking Astro 101?

- Analysis of the student demographics showed that the students who take Astro 101 reflect the college population as a whole
  - Equal numbers of men and women
  - Native and non-native English speakers
  - All ethnicities
  - Students of all socioeconomic backgrounds
  - All majors
  - Students of all academic abilities
- 25% of students are declared education majors: we are teaching our future teachers
- Our findings reinforce the idea that, in teaching Astro 101 classes, we are affecting the scientific literacy of many of our future citizens and their future teachers

Multivariate modeling

- We conducted a full multivariate model of our data, with 13 independent variables (12 demographic variables and interactivity) to explain one dependent variable, *learning gain*
Multivariate modeling

• We conducted a full multivariate model of our data, with 13 independent variables (12 demographic variables and interactivity) to explain one dependent variable, learning gain.

• We found that, not surprisingly, a number of student characteristics (more years in college, more math and science background) led to higher gains.

• However, none of the ascribed characteristics, other than gender, had any affect on gain (men did slightly better than women, on average).

• Most importantly, we confirm that level of interactivity is the single most important variable in explaining the variation in gain, even after controlling for all other variables.

• In addition, testing for correlations between interactivity and student characteristics showed that interactive learning strategies equally benefit men and women, students of all ethnicities, native and non-native English speakers, as well as students of all academic ability, mathematical preparation and previous physical science coursework.

Implementation is Key

- Although there is clear evidence that interactive strategies have the potential to increase students learning, the wide range of gains seen for all classes suggests that implementation is key
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  - Training in the best pedagogic use of interactive learning strategies
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  • Training in the best pedagogic use of interactive learning strategies (CAE runs workshops - see astronomy101.jpl.nasa.gov/workshops/)
  • **Addressing students’ expectations** (interactive learning strategies contradict what students are used to in the majority of their classes)
Interactive Learning Techniques
Contradict Student Expectations

• Students in large lecture classes have certain expectations
  • If you want to interact, sit in front.
  • If you want to interact a lot, sit in front and raise your hand.
  • If you want to be anonymous, work on homework, read the paper, or sleep...sit in back

• Interactive Learning contradicts these expectations
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  • Addressing students’ expectations (interactive learning strategies contradict what students are used to in the majority of their classes)
  • Adequate preparation for a class using interactive learning strategies (it takes more time than you think... but it is worth it!)
Get Involved!

• Use the LSCI (or FCI) in your Astro 101 (or Physics) classroom to see how much the students are learning

• Try out interactive learning strategies in your classroom

• Attend a CAE or other professional development workshop

• Contribute your LSCI (or FCI) results to future studies of student learning (especially if you are not currently using interactive learning strategies)

• Become part of the Physics and Astronomy Education Research communities

• If you are department chair or senior colleague, support your junior colleagues in their professional development!
To learn more

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