Teaching, Fast and Slow:
Using Peer Instruction for Active Learning

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JMU CFI May Symposium 2016
Agenda

• Introduction
• Two systems model of thinking
• Heuristics and biases
• Why active learning?
• Peer Instruction
• Formative assessments and ConcepTests
• Practice time
Introduction

• Assistant Professor of Computer Science
  • Primary research focus is CS education
  • Misconceptions are central to my courses
• Started at JMU in 2011
  • Prior experience teaching mathematics for liberal arts majors at Purdue
Recommended reading

- **Thinking, Fast and Slow** by Daniel Kahneman
- **Peer Instruction** by Eric Mazur
- **Predictably Irrational** by Dan Ariely
Two systems model

LEFT
NOSE left
left sneeze
RIGHT FLU
RIGHTY
muddy left
RIGHT hands

upper
lower
LOWER
upper
UPPER
lower
LOWER
upper
Two systems model

SOUP

SOAP

WISH

WASH
Two systems model

**System 1**
- **Automatic** and quick
  - Language processing
- Little or no effort
- No sense of voluntary control
- Associative machine
- Substitutes easier questions

**System 2**
- **Effortful** mental activities
  - Calculations and critical thinking
- Depends on system 1 impressions
- Depletes self-control
- Lazy controller
  - Inhibited by stress, hunger, emotion
Two systems model

- Repeated Experience
- Clear Display
- Primed Idea
- Good Mood
- Feels Familiar
- Feels True
- Feels Good
- Feels Effortless

Cognitive Ease
Two systems model
Heuristics and biases

Which group can you make more words from?

- XUZONLCJM vs. TAPCERHOB

Which is a more common cause of death?

- Strokes or all unintentional accidents/poisonings combined

Which is more common?

- Words that start with “k” or words with “k” as the third letter

Available examples shape responses
Heuristics and biases

Write this number down on a piece of paper:

25
Heuristics and biases

About what percentage of African nations are in the UN?

(A) 20%
(B) 45%
(C) 73%
(D) 98%
Heuristics and biases

About what percentage of African nations are in the UN?

(A) 20%
(B) 45%
(C) 73%
(D) 98%

Numbers act as anchors that prime responses
Heuristics and biases

phlegm
NOSE

sneeze
FLU
FILTHY

muddy

clean

WASH

HANDS

SOAP
Heuristics and biases

Linda is thirty-one years old, single, outspoken, and very bright. She double majored in philosophy and criminal justice. As a student, she was deeply concerned with issues of discrimination and social justice, participated in protests against the 2003 invasion of Iraq, and served as a delegate to the National Black Student Union Conference.
Heuristics and biases

Which of the following is most likely?

(A) Linda is a corporate lawyer.
(B) Linda is an investment banker for Goldman Sachs.
(C) Linda is an elementary school teacher in a wealthy suburban district.
(D) Linda works two jobs as a fast food dishwasher and a custodian staff manager.
(E) Linda is a corporate lawyer who does pro bono work for the Black Lives Matter movement.
Heuristics and biases

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Representative examples suppress base rate statistics knowledge
Heuristics and biases

corporate lawyers

Not Linda

BLM advocates

Linda
Heuristics and biases

Which of these words do you associate more strongly with the passage about Linda?

old vs. liberal

The **halo effect** creates perceptions that match our emotions.
Heuristics and biases

**System 1 consequences**
- Availability heuristic
- Priming and anchors
- Representative samples & base rate bias
- Halo effect: emotionally coherent perceptions
Pedagogical implications

Think-pair-share activity

- Think of an instance or a topic that your students frequently miss on exams. Which biases, heuristics, or system 1/system 2 effects might be contributing to this?
Pedagogical implications

Pedagogical implications of system 1

Active learning and formative assessment train system 1
“Adopting instructional practices that engage students in the learning process is the defining feature of active learning.”

-Michael Prince
Why active learning?

Pre- vs. post- in physics

- Mechanics Diagnostic
- Force Concept Inventory
- 62 courses (14 trad.) at multiple institutions
- 6542 students (2084)


http://www.physics.indiana.edu/~sdi/ajpv3i.pdf
Why active learning?

Metaanalysis of 225 studies

- 158 studies: average 0.47 SDs better on CIs/exams
- 67 studies: average failure rate dropped from 33.8% to 21.8%

Why active learning?
### Table I. Force Concept Inventory

<table>
<thead>
<tr>
<th>Year</th>
<th>Method</th>
<th>FCI pre</th>
<th>FCI post</th>
<th>Absolute gain (post – pre)</th>
<th>Normalized gain $\langle g \rangle$</th>
<th>MBT</th>
<th>MBT quant. questions</th>
<th>$N$</th>
</tr>
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<tbody>
<tr>
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<tr>
<td></td>
<td><strong>Calculus-based</strong></td>
<td></td>
<td></td>
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<tr>
<td>1990</td>
<td>Traditional</td>
<td>(70%)</td>
<td>78%</td>
<td>8%</td>
<td>0.25</td>
<td>66%</td>
<td>62%</td>
<td>121</td>
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<td>1991</td>
<td>PI</td>
<td>71%</td>
<td>85%</td>
<td>14%</td>
<td>0.49</td>
<td>72%</td>
<td>66%</td>
<td>177</td>
</tr>
<tr>
<td>1993</td>
<td>PI</td>
<td>70%</td>
<td>86%</td>
<td>16%</td>
<td>0.55</td>
<td>71%</td>
<td>68%</td>
<td>158</td>
</tr>
<tr>
<td>1994</td>
<td>PI</td>
<td>70%</td>
<td>88%</td>
<td>18%</td>
<td>0.59</td>
<td>76%</td>
<td>73%</td>
<td>216</td>
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<tr>
<td>1995</td>
<td>PI</td>
<td>67%</td>
<td>88%</td>
<td>21%</td>
<td>0.64</td>
<td>76%</td>
<td>71%</td>
<td>181</td>
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<tr>
<td>1996</td>
<td>PI</td>
<td>67%</td>
<td>89%</td>
<td>22%</td>
<td>0.68</td>
<td>74%</td>
<td>66%</td>
<td>153</td>
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<td>1997</td>
<td>PI</td>
<td>67%</td>
<td>92%</td>
<td>25%</td>
<td>0.74</td>
<td>79%</td>
<td>73%</td>
<td>117</td>
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<td></td>
<td><strong>Algebra-based</strong></td>
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<td>1998</td>
<td>PI</td>
<td>50%</td>
<td>83%</td>
<td>33%</td>
<td>0.65</td>
<td>68%</td>
<td>59%</td>
<td>246</td>
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<tr>
<td>1999</td>
<td>Traditional</td>
<td>(48%)</td>
<td>69%</td>
<td>21%</td>
<td>0.40</td>
<td>…</td>
<td>…</td>
<td>129</td>
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<td>2000</td>
<td>PI</td>
<td>47%</td>
<td>80%</td>
<td>33%</td>
<td>0.63</td>
<td>66%</td>
<td>69%</td>
<td>126</td>
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</table>

*Fig. 3. Mechanics Baseline Test*

The findings of Thacker et al. in 1999 showed that students taught with PI substantially outperformed those taught traditionally. The improvement of the PI students over the traditional students corresponds to an effect size of 0.57. All measures indicate that our students' quantitative problem-solving skills are comparable to or better than those achieved with traditional instruction, consistent with results reported in Ref. 19.

The answers are categorized as correct both before and after discussion. The answers is around 50%.

In 1999 no pretest was given, so the average of the pretest and posttest for FCI is listed. In 1995 the 30-question revised version was introduced midsemester to all students enrolled in the second-semester course. Two months of instruction, except in 1998 and 1999, when it was administered the first week of the following semester.

The FCI pretest was administered on the first day of class; in 1990 no pretest was given, so the average of the MBT pretest and posttest was used. For years other than 1990 and 1999, scores are reported for matched samples for FCI pre- and posttest and MBT. No data are available for 1992.

Absolute gain (post – pre) = (post - pre) / (1 - pre)

$N$ represents the number of students.

These were NOT "worse" students
Peer Instruction

Class structure

• Daily or weekly reading quizzes to address basic definitions
• Minimum of 15 minutes per concept
  • 7-10 minutes of lecture
  • 5 - 8 minutes for ConcepTest
  • Vote first, discuss, vote again, debrief

Can be Canvas/JiTT

Graded but low-stakes
Peer Instruction

**Reading Quiz Question**
Without air resistance, an object dropped from a plane flying at constant speed in a straight line will
1. quickly lag behind the plane
2. remain vertically under the plane
3. move ahead of the plane
4. not covered in the reading assignment

**Exam Question**
Two stones are released from rest at a certain height, one after the other.  (a) Will the difference in their speeds increase, decrease, or stay the same?  (b) Will their separation distance increase, decrease, or stay the same?  (c) Will the time interval between the instants at which they hit the ground be smaller than, equal to, or larger than the time interval between the instants of their release?
Peer Instruction

ConcepTest

A person standing at the edge of a cliff throws one ball straight up and another ball straight down at the same initial speed. Neglecting air resistance, the ball to hit the ground below the cliff with the greater speed is the one initially thrown
1. upward.
2. downward.
3. neither—they both hit at the same speed.

Answer: 3. Upon its descent, the velocity of an object thrown straight up with an initial velocity \(v\) is exactly \(-v\) when it passes the point at which it was first released.
Peer Instruction

ConcepTest

Consider the following statement:

Bill should quit smoking because people who smoke get lung cancer.

What is the best interpretation of the premise?

1. Most people who smoke get lung cancer.
2. Everyone who smokes gets lung cancer.
4. People who smoke are more likely to get lung cancer than people who don’t smoke.

Answer: 4. This example illustrates the principle of charity by introducing the claim of likelihood into the speaker’s assertion.
Peer Instruction

Examples of Peer Instruction in the humanities

- Have students select the main idea in a text, audio, or video clip.
- Engage students in discussion about a key point in an image, text, audio, or video clip that may have more than one valid answer.
- Solicit views on contentious points and explain their perspectives to peers.

Peer Instruction Blog
https://blog.peerinstruction.net/2013/06/10/3-easy-ways-to-use-clickers-and-peer-instruction-in-the-arts-and-humanities/
ConcepTests

Guidelines for writing ConcepTests

• Focus on a single concept
• Require conceptual understanding, not solvable with just equations or facts
• Use unambiguous language
• Use students’ wrong answers from old exams as options
• Avoid converging answers
• Un-situate concepts with near and far transfer
• Be aware of intrinsic, germaine, and extraneous cognitive load
  • Provide worked examples, not just solutions
Far transfer

Apply the Pythagorean theorem to the above triangle to find the value of \( x \).

In a baseball diamond, the distance between each base is 90 ft. Which of the following is true about the shortest distance between 1st and 3rd bases (the red line shown above)?

1. It is less than 90 ft.
2. It is between 90 and 180 ft.
3. It is greater than 180 ft.
Work time

**ConcepTest writing**

- **Recall** the learning objective that you identified as challenging for students in the think-pair-share
- **Construct** a stem for that objective
- **Write** a misconception or two that students have about the topic
- **Rephrase** the misconception as an answer
- **Test** your ConcepTest on a peer from a different discipline
Backup slides
The Force Concept Inventory (FCI) is a validated test to measure learning in physics. Students take the FCI on the first and last day of class. In one study, women scored an average of 60% on the pretest; women in traditional lectures scored an average of 70% on the posttest, whereas women in interactive classrooms scored an average of 85% on the posttest. Men scored an average of 70% on the pretest; men in traditional lectures scored an average of 80% on the posttest, compared with 87% in interactive classrooms.
Which statement best summarizes the pre- vs. post-test gender performance gap in the physics courses studied?

(A) In both traditional and interactive classrooms, the gender performance gap increased on the post-test.
(B) The gender performance gap increased in traditional lectures but stayed constant in interactive classrooms.
(C) The gender performance gap stayed constant in traditional lectures but decreased in interactive classrooms.
(D) The gender performance gap increased in traditional lectures but decreased in interactive classrooms.
ConcepTests

Cooperative learning closes the gender gap

- Pre-test scores were 10% points higher for men
- Gap persisted with lecture alone
- Post-test results for cooperative classes were almost equal
- Requires more than just interactive lecture

T: traditional lectures
IE: interactive lectures
IE+: interactive assignments, lectures, tutorials

E. Mazur, “The scientific approach to teaching: Research as a basis for course design,” keynote/plenary talk at the International Computing Education Research Conference (ICER), 2011.
http://mazur.harvard.edu/search-talks.php?function=display&rowid=1712
ConcepTests

The evidence supporting active learning suggests that passive engagement with information can contribute to reinforcing misconceptions. One study examined how effective in-class physics demonstrations were in helping to understand concepts. All students began with a reading assignment. Some students then took part in an in-class demonstration; the control group did not observe or take part in a demonstration. The students completed a short test to conclude the experiment. Which group did the worst on the post-test, missing the most points?
ConcepTests

Which group did the **worst** on the post-test, missing the most points?

(A) Students who did not observe a demo (control group)
(B) Students who only observed the demo
(C) Students who predicted the outcome before it occurred by writing down a guess
(D) Students who discussed the outcome with peers after observing what occurred

<table>
<thead>
<tr>
<th>mode</th>
<th>correct</th>
<th>incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td>no demo</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>observe</td>
<td>18%</td>
<td>82%</td>
</tr>
<tr>
<td>predict</td>
<td>29%</td>
<td>71%</td>
</tr>
<tr>
<td>discuss</td>
<td>30%</td>
<td>70%</td>
</tr>
</tbody>
</table>
Two systems model

Christopher Chabris and Daniel Simons

*The Invisible Gorilla*

http://www.theinvisiblegorilla.com/videos.html