Clickers in Upper-Division Courses

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What does it look like?

See the video running elsewhere in this room!
## Upper-div Clickers at CU

<table>
<thead>
<tr>
<th>Course</th>
<th># times w/clickers</th>
<th>Instructors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical Mechanics</td>
<td>6 (2004-2009)</td>
<td>PER, then non-PER</td>
</tr>
<tr>
<td>E&amp;M I</td>
<td>3 (2008-2009)</td>
<td>PER, then non-PER</td>
</tr>
<tr>
<td>E&amp;M II</td>
<td>1 (2009)</td>
<td>Non-PER</td>
</tr>
<tr>
<td>Quantum I</td>
<td>3 (2008-2009)</td>
<td>PER, then non-PER</td>
</tr>
<tr>
<td>Quantum II</td>
<td>1 (2008)</td>
<td>Non-PER</td>
</tr>
<tr>
<td>Graduate AMO</td>
<td>2 (2007, 2009)</td>
<td>Non-PER</td>
</tr>
</tbody>
</table>
Example Questions

- Conceptual
- Math/Physics connection
- Application of ideas
- Step in calculation, proof, derivation

In general, given Hermitian operators A and B, and a state $\psi$, (and with the usual notation $\langle A \rangle = \langle \psi | A | \psi \rangle$) what can you say about

$$\langle \psi | A \ B \ | \psi \rangle$$

A) $\langle AB \rangle$
B) $\langle BA \rangle$
C) $\langle B \rangle \langle A \rangle$
D) MORE than one of these is correct!
E) NONE of these is, in general, correct!

Could this be a plot of $|E(r)|$? Or $V(r)$? (for SOME physical situation?)

A) Could be $E(r)$, or $V(r)$
B) Could be $E(r)$, but can’t be $V(r)$
C) Can’t be $E(r)$, could be $V(r)$
D) Can’t be either
E) ???
What’s special about upper-div?

• Intellectually more sophisticated students
• Faculty and student investment & identity
• Complex physics
Active engagement and peer instruction is just as useful for juniors as for freshmen.

Students overestimate what they know.

If you have a misconception about some basic physical idea (yes, this does happen at the upper-division), it shows glaringly here.  -student

There is a time for telling (but not too soon!)
Arguments against upper-div clickers

- Chews up time
  *Ideas are complex*
- Discussion easy in small classes
  *Students can still hide*
- Students are sophisticated learners
  *Clickers used to aid learning*
- Students may resist
  *But perhaps only initially…*
- Extra effort for faculty
  *Question banks available if you want to try*
Students Find Clickers Useful

Q: How useful for your learning is the addition of clicker questions compared to pure lecture with no clicker questions?

- Lecture with clickers, much more useful: 79% of students
- Lecture with clickers, more useful: 26%
- Same: 5%
- Pure lecture, more useful: 0%
- Pure lecture, much more useful: 0%

Upper-div courses using clickers: 12 courses, 264 student responses
Students Recommend Clickers

Q: Would you recommend using clicker questions in upper-level physics courses?

- Highly Recommended: 73% of students
- Recommended: 27% of students
- Neutral: 0% of students
- Not recommended: 0% of students
- Definitely not recommended: 0% of students

Upper-div courses using clickers:
12 courses, 267 student responses
Example: Quantum Mech. I

3rd semester of PER-led reforms
With tri-phase co-teaching

Steven J. Pollock
PER researcher
Teaching: 15 years
Peer Instruction: 10 years
Expert clicker user

Oliver DeWolfe
String theorist
Teaching: 3 years
Clicker use: first year
Open-minded new user

Previous students didn’t recommend that Dr. DeWolfe add clickers to his Quantum Mech. course
Q: Would you recommend using clicker questions in upper-level physics courses?

- High Recommend
- Recommended
- Neutral
- Not recommended
- Definitely not recommended
Students’ recommendation for implementation

# of Qs per lecture: 2-5 [2-3 (62%); 4-5+ (21%)]

Timing: Interspersed with lecture (87%)

Peer-discussion: Allow and encourage (80%)

Preferred response mode:
- 93% prefer peer discussion as part of response
- 64% prefer some time for individual thinking prior to peer discussion

N=11 courses, 224 responses
Clicker Use in Upper-Level Courses

Preferred types of questions

N=4 courses, 66 students

How useful for learning?

% of students 0% 10% 20% 30% 40% 50% 60%

Types of clicker questions:
- Challenging conceptual
- Recalling a previous fact
- Recalling a recent fact
- Plugging numbers into equation

- Very useful
- Useful
- Somewhat useful
- Mostly useless
- Completely useless

91%    35%    36%    18%
Tips for Success

- Tell students why you’re using clickers
- Ask challenging questions
- Make environment comfortable to talk

It’s not the clicker that’s important, but the method of peer instruction! Peer instruction has been used successfully in upper-division astronomy, sans clickers.
• PER course materials for Quantum and E&M
  http://www.colorado.edu/sei/departments/physics.htm

• Clicker videos and this talk at
  STEMclickers.colorado.edu

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