Have you ever used clickers in a class?

A) Yes, lots
B) Yes, occasionally
C) I’m familiar with them, but haven’t used them
D) No, and I’m not really familiar with them
E) Other/NA

Take a clicker & turn it on
If the green light flashes, your vote has been counted
Clickers in Upper-Division Courses

Stephanie V. Chasteen
Steven Pollock
Kathy Perkins

Physics Dept. and Science Education Initiative
University of Colorado at Boulder
Physics faculty:
- Michael Dubson
- Noah Finkelstein
- Kathy Perkins*
- Steve Pollock
- Carl Wieman*

*Science Education Initiative
- Wendy Adams
- And 12 Teaching Fellows in 5 departments

Ph. D. students:
- Lauren Kost
- Chandra Turpen
- Ben Spike
- Charles Bailey

Postdocs:
- Stephanie Chasteen*
- Steven Goldhaber*
- Rachel Pepper*
- Noah Podolefsky

Non-PER participating faculty
- Paul Beale (chair)*
- Edward Kinney
- Oliver DeWolfe
- + working groups
Outline

• Step into our classroom…
• Why use clickers in upper-division?
• What does it look like?
• Tips for success
What is your teaching role?

A) Science teacher (University level)
B) Non-science teacher (University level)
C) Informal educator
D) Teacher (other)
E) Administrator/support/other (not teaching students)
STEP INTO OUR CLASSROOM...
# Upper-div Clickers at CU

## Course Usage

<table>
<thead>
<tr>
<th>Course</th>
<th>Sp04</th>
<th>Sp09</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mech &amp; Math I</td>
<td>★★★★</td>
<td>★★★★</td>
</tr>
<tr>
<td>Mech &amp; Math II</td>
<td>★★★</td>
<td>★★★★</td>
</tr>
<tr>
<td>EM I</td>
<td>★★★★</td>
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</tr>
<tr>
<td>EM II</td>
<td>★★★★</td>
<td>★★★★</td>
</tr>
<tr>
<td>QM I</td>
<td>★★★★</td>
<td>★★★★</td>
</tr>
<tr>
<td>QM II</td>
<td>★★★★</td>
<td>★★★★</td>
</tr>
<tr>
<td>Solid State</td>
<td>★★★</td>
<td>★★★★</td>
</tr>
<tr>
<td>Stat Mech</td>
<td>★★★</td>
<td>★★★★</td>
</tr>
<tr>
<td>Optics</td>
<td>★★★</td>
<td>★★★★</td>
</tr>
<tr>
<td>Grad AMO</td>
<td>★★★★</td>
<td>★★★★</td>
</tr>
</tbody>
</table>

- ★: 12 non-PER faculty
- ★★: 2 PER faculty

Collected by COLTT CU 2009

Clicker Use in Upper-Level Courses

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PER@C
Example: Quantum Mech. I

3 semesters of transformed course
With PER + non-PER co-teaching

Steven J. Pollock
PER researcher

10 years clicker user

Oliver DeWolfe
String theorist

Open-minded new user

Video:
Upper division use
Example: Quantum Mech. 1
WHY USE CLICKERS IN UPPER DIVISION?
What’s the most important aspect of clickers?

A) Attendance/quizzes
B) focus on the concept
C) peer discussion
D) feedback to the teacher
E) something else
What’s special about upper-div?

- Intellectually more sophisticated students
- Faculty and student investment & identity
- Complex physics
Why use clickers in upper-div?

Active engagement and peer instruction is just as useful for juniors as for freshmen.

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
Why use clickers? Students Learn More

Electricity & Magnetism: Compared
Traditional (no clickers) and
Transformed classes (with clickers)

• Traditional Exams
• Conceptual test (CUE)
Assessing transformations: the CUE

CU Trad

CUE IE

Development (PER-1)

Team teaching (PER-2 + 3)

Average Score (%)

Trad  IE1  IE2  IE3

IE/transformed courses
Students Find Clickers Useful

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

Upper-div courses using clickers:
- Lecture with clickers: 79% of students find it much more useful
- Lecture with 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: 79% "if used as suggested"
- Neutral
- Not recommended
- Definitely not recommended

Upper-div courses using clickers:
12 courses, 267 student responses
What’s the most important *impact* of clickers?

A) Increases attendance
B) feedback to the teacher
C) feedback to the students
D) keeps students paying attention
E) something else
What do upper-division students think?

<table>
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<tr>
<th>Code</th>
<th># of responses* (out of 70)</th>
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</tr>
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<tbody>
<tr>
<td>Positives</td>
<td>64</td>
<td>91%</td>
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<tr>
<td>Improved mastery</td>
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<td>50%</td>
</tr>
<tr>
<td>Type of Activity</td>
<td>31</td>
<td>44%</td>
</tr>
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For the clicker questions and discussion in this course, please explain why you felt they were particularly useful or not useful for your learning

Coded 70 responses over range of courses.
“Clicker questions encourage me to **pay attention** in class as well as help me to come to firm **understanding of material** through **argument**.”

“They were useful because they were **challenging** but used the knowledge we **just learned** in the lecture portion. They are a great way to go from hearing the information to actually **using the information**.”

“It helps a lot to be able to **check your understanding** of the concepts **before moving on** to the next, especially when we’re going over **complex topics** that we may not have seen before. Also, **discussing** the topic with others, as we did when a clicker question was posed, is a great way to **develop intuition** and **stay focused**.”
## What do upper-division students think?

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<tr>
<td>Active processing/activity</td>
<td>44</td>
<td>63%</td>
</tr>
<tr>
<td>Discussion with others</td>
<td>20</td>
<td>29%</td>
</tr>
<tr>
<td>Feedback to students</td>
<td>20</td>
<td>29%</td>
</tr>
<tr>
<td>Time/pause to think, OR Immediacy</td>
<td>18</td>
<td>26%</td>
</tr>
<tr>
<td>Engagement</td>
<td>16</td>
<td>23%</td>
</tr>
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</table>
Quantum Mech: Before clickers

They are quite time consuming, and there is a lot of material to be covered.

The class is small enough that if you don’t understand something you can ask the professor to clarify.

-students in non-clicker QMII course
Q: Would you recommend using clicker questions in upper-level physics courses?

- Highly Recommend
- Recommended
- Neutral
- Not recommended
- Definitely not recommended

- In highly rated pure lecture, No clickers (QM II, n=17)
- Add Clickers (QM I, n=30)
- Missing clickers? (EM II, n=16)
WHAT DOES IT LOOK LIKE?

We are solving the equation
\[ \frac{\hbar^2}{2m} \frac{d^2u}{dr^2} + \left( \frac{-ke^2}{r} + \frac{\hbar^2(l+1)}{2mr^2} \right)u = Eu \]

What, then, is the full 3-D wave function for hydrogen atom stationary states?
A) \( u(\rho, \theta, \phi) \)
B) \( u(\rho)Y_l^m(\theta, \phi) \)
C) \( \rho u(\rho)Y_l^m(\theta, \phi) \)
D) \( \rho^2 u(\rho)Y_l^m(\theta, \phi) \)
E) None of these
What does it look like?

• A range of courses
• Depends on faculty:
  – # of questions per lecture
  – Timing of questions
  – Amount and character of peer discussion
  – Depth of questions
Example: Quantum I
Video (1 m) - what do upp div clicker questions look like?
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
Preferred types of questions

N=4 courses, 66 students

How useful for learning?

- Very useful: 91% (91), 35% (35), 18% (18)
- Useful: 36%
- Somewhat useful: 36%
- Mostly useless: 18%
- Completely useless: 0%

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

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

Clicker Use in Upper-Level Courses

Univ. of Colorado
Tips for Success

• Tell students *why* you’re using clickers
• Ask challenging questions
• Tie the questions to the lecture
• Make environment comfortable to talk
Types of questions

• Video (1 min) writing upper division questions
Example Questions

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

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) ???
We have a large copper plate with uniform surface charge density $\sigma$. Imagine the Gaussian surface drawn below. Calculate the E-field a small distance $s$ above the conductor surface.

A) $|E| = \sigma/\varepsilon_0$
B) $|E| = \sigma/2\varepsilon_0$
C) $|E| = \sigma/4\varepsilon_0$
D) $|E| = (1/4\pi\varepsilon_0)(\sigma/s^2)$
E) $|E| = 0$

61% correct

30% correct (60% voting “C”) before discussion - then 60% correct

Given a pair of very large, flat, conducting capacitor plates with surface charge densities $\pm \sigma$, what is the E field in the region between the plates?

A) $\sigma/2\varepsilon_0$
B) $\sigma/\varepsilon_0$
C) $2\sigma/\varepsilon_0$
D) $4\sigma/\varepsilon_0$
E) Something else
Questions: Conceptual

5.17 If the arrows represent a B field (note that |B| is the same everywhere), is there a nonzero J (perpendicular to the page) in the dashed region?

\[ \vec{B} = B_0 \phi \]

A. Yes
B. No
C. Need more information to decide

74% correct
("Need more info")

80% correct

2.28 A point charge Q is placed outside a uniformly charged shell of charge (uniform \( \sigma \))

What is the electric field inside the sphere?

A: 0 everywhere inside
B: non-zero everywhere in the sphere
C: Something else
D: Not enough info given
Questions: “Next step”

- **Next step**
  - Derivation
  - Proof
  - Calculation

84% correct

Part of generalized uncertainty principle proof in QM

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

A) $<AB>$
B) $<BA>$
C) $<B><A>$
D) MORE than one of these is correct!
E) NONE of these is, in general, correct!
Questions: “Application”

• Application
  – Of abstract idea
  – To new situation
  – To real-world
  – Variations on a theme

A "ribbon" (width a) of surface current flows (with surface current density K)
Right next to it is a second identical ribbon of current.
Viewed collectively, what is the new total surface current density?

A) K  
B) 2K  
C) K/2  
D) Something else

5.14 What is B at the point shown?

A) \( \frac{\mu_0 I}{\pi s} \)
B) \( \frac{\mu_0 I}{2\pi s} \)
C) \( \frac{\mu_0 I}{4\pi s} \)
D) \( \frac{\mu_0 I}{8\pi s} \)
E) None of these

(What direction does it point?)

Mostly correct, but good discussions
Questions: Math/Physics

- Math/Physics
  - Apply mathematics to a physical situation
  - Translate physical situation into math

The voltage is constant everywhere along a line in space.

\[ V = \text{constant} \]

You can conclude that:
A) The E-field has constant magnitude along that line.
B) The E-field is zero along that line.
C) You can conclude nothing at all about the magnitude of \( E \) along that line.

Understanding
\[ E = -(\nabla) V \]
Resources

• PER course materials for Quantum and E&M
  http://www.colorado.edu/sei/departments/physics.htm

• Clicker videos and today’s talk at
  STEMclickers.colorado.edu

  http://per.colorado.edu
Questions?

- per.colorado.edu
- www.colorado.edu/sei