

Effective design and use of clicker questions

Relevant article: E. Mazur – A step-by-step guide to preparing for a peer instruction lecture (book chapter), available here: <https://drive.google.com/file/d/0B2y2x09KHt4fRFpQM1NTMW9SVjQ/view>

Eric Mazur is a physics education researcher who has popularized the Peer Instruction method for teaching (he did not come up with it). Initially, he wasn't using technology (early 90s) and had students answer by showing cards.

Before talking about anything, must emphasize: **you have to get your students to talk to each other, without peer discussions, the approach is much less effective**

- His approach is to have students answer individually, then answer again in groups. Personally, I have only asked them to answer after talking to a neighbor.
 - Chandralekha's research showed that it didn't matter how you group students: a C student grouped with another C student gains just as much from a discussion as when grouped with an A student. Similarly, an A student paired with an A student gains just as much as an A student paired with a C student.
 - Reference – C. Singh – Impact of peer interaction on conceptual test performance, Am. J. Phys. 73(5), 446-451 (2005).
 - You don't need to go through trouble trying to figure out how to pair students; research shows that for answering clicker questions, simply telling students to talk to their neighbor is good enough

One of the things mentioned is that nowadays there are clickers which allow for free responses from students (instead of just multiple choice). While it can be helpful to ask a free response question to students, it can often happen that it is difficult to categorize their answers in a few groups and use the feedback to inform the lecture. It was suggested that if you want to use free response clicker questions, make students' answers short (e.g., by requesting a one word answer). In general, keeping use of clickers simple is a good idea.

- You can ask free response questions and use student responses to craft good multiple choice clicker questions.

How do you increase student engagement during the discussions?

- A faculty member mentioned that he uses clicker questions every class, but he always notices a certain subset of students (perhaps ~20%) who don't engage with one another, and he struggles to figure out how to motivate students to engage. Several suggestions were discussed:
 - Giving credit not for just answering the question, but also for getting it correctly. If students get participation grade regardless of how they answer a clicker question, some of them can just answer randomly and not try to engage with other students. A practice some faculty members from physics use is to give students 80% for trying and 100% for answering a question correctly (clicker questions are considered in grading, but as bonus). The small 20% is enough incentive to get students to talk to each other
 - Framing to students why you use clickers at the beginning of the term, and several times during the term is important. Making it clear that students who engage in discussions about the material in class are likely to perform better in subsequent exams (e.g., by briefly presenting research results).
 - If students are motivated (via grade incentive) to get clicker questions right, and they know that discussing with others will make it more likely to answer the questions correctly, they are motivated to engage with other students
- It may be tricky to get students who agree on a particular answer to discuss it with their peers. Again, framing is important and the instructor can stress that articulating your own thinking helps solidify concepts in your mind which makes you understand things for yourself better. In addition, the instructor can walk around (more difficult in a large class, but can at least go up and down an aisle) and ask students who are quiet. The culture of the class can gradually turn to discussing the questions all the time.
- Another way to increase engagement is to tell students that you will always randomly ask someone to give an explanation for the correct answer. An instructor mentioned he does this, and usually points to a particular section of the class, and has no trouble getting volunteers to discuss the correct answer. If a student's explanation is not complete, the instructor can always ask "does anybody have something else to add?"
 - Since students know they may be asked to provide reasoning for the correct answer, they are more likely to engaged in discussions with other students
- Research in science learning has shown that students who self-explain as they are reading a scientific text (e.g., course book) learn a lot more than students who read passively. The more self-explaining a student does, the more he/she learns. Students can be motivated to explain their answers to others if they are told about this research.
 - Reference: Chi, De Leeuw, Chiu, LaVancher – Eliciting Self-Explanations improves understanding, *Cognitive Science* 18, 439-477 (1994).

Discussing answers after students submit theirs: Should you focus on just the correct answer, or spend some time talking about one or two incorrect answers?

- You certainly should not spend too much time on incorrect answers, and spend most of the time discussing the correct way of reasoning about a question. However, after revealing the correct answer, you can ask students to say why someone may think a particular incorrect answer (which is common) is actually correct, and what they are missing.

Starting to use clicker questions in a course: You do NOT need to rewrite all your lecture notes:

- For each lecture: what are the key points?
- Mazur gets rid of definitions, derivations and examples
 - I think getting rid of examples is a good idea: instead of you solving problems for students, have them solve problems on their own after which you provide feedback
 - Seeing someone solve a problem is very different from doing it yourself.
 - Also, students don't get much out of derivations. They are typically more interesting to experts than they are to students.
- For each key point, he selects several clicker questions
 - One approach others encourage is to use sequences of clicker questions of increasing difficulty: 1st – easy: builds confidence; 2nd – more difficult, students get 50% or lower response rates; 3rd – about same difficulty as 2nd, but reinforces concept, and after students are able to answer the third (e.g., via hints or feedback), come back to the 2nd and answer correctly (answers are not discussed until all three are answered).
 - You do NOT need to discuss the answer to a question after posing it. There can be several questions asked back to back and only after answering several, students can be told what the correct answers are. Also, you can go back to a question and have students re-vote after you have perhaps explained something related to a previous question or given a hint.
- Features of clicker questions:
 - Focus on a single concept
 - Conceptual (should be difficult or impossible to solve via mindless application of equations)
 - Have adequate multiple choice answers (incorrect answers be based on student incorrect reasoning)
 - Surveying literature on student difficulties
 - Careful look how students answer free response exam questions
 - TAs can be a good resource (can meet with them regularly, ask what students find difficult)
 - Pre-lecture assignments
 - Pre-tests, conceptual assessments
 - Be unambiguously worded
 - Neither too easy nor too difficult
 - ~50% correct initial response rate makes for great student-student discussions

- Keep in mind, this is before peer discussions: after peer discussions, rates of correctness go up, should strive for >70-80%
- This is difficult to achieve, but you can use the feedback from each class to improve on the clicker question: too easy? Make it harder, include another question afterwards! Too hard? Make it easier, include other question before!

It is in general helpful to walk around and hear what students are saying for two reasons:

- You can get some insight into how they think
- You ensure that they understand the questions in the way in which they were intended.
- You can hear how students explain the correct answer to other students: this can be valuable information because their explanations may be better than yours (for convincing other students)
 - We often overestimate our own capability of explaining things to students. Students are often much more capable of explaining things to one another because they have recently understood the concept
 - Think about terminology we use: have you ever heard students speak using this terminology? It is painfully clear that they do not differentiate between concepts clearly, for example in physics, they'll use terms like energy, force and momentum interchangeably. Now imagine how our beautifully articulated explanations which are in terms of these weakly differentiated concepts sounds to students!

The quality of the clicker questions is very much connected to the effectiveness of the instructional approach.

- They published data on FCI normalized gains in various years after adopting the approach: you can see the gains gradually improve – they've been getting better at writing clicker questions
- Better clicker questions provide better feedback to both the instructor and students

Clicker questions can be used with demonstrations

- Students predict the outcome of an experiment (talk to each other)
- Experiment is carried out
- Students see outcome (if good experiment is selected, outcome may be different from what they expect)
- Students can discuss again why the outcome occurred
- Instructor can elaborate on the correct interpretation of the demonstrations
- Clicker questions can also be used after the demonstration to get students to apply what they just learned in a different situation

Lectures are less rigid, but it's actually easier to teach using clicker questions: you can pause and catch your breath, figure out what you want to say next, and how to say it; figure out if there was something you wanted to say, but forgot etc.

He then provides some evidence that using Peer Instruction does not hurt students' ability to solve conventional problems, but it increases their conceptual understanding (ability to solve conceptual problems – more important goal).

One thing not mentioned here is that research has shown that using clicker questions (and active learning in general) reduces the gender gap and gap between underrepresented and represented students (at least in physics).

Uses of clicker questions

- Conceptual questions after discussing key points/principles/concepts
 - Sequence of question: different questions can build on each other – abstract questions followed by concrete or vice-versa
- Before demonstrations – predict outcome
- After demonstrations – use what you learned from the demonstration to answer a question
- Review of previous class (conceptual/quantitative questions)
 - Can be done outside of class to tailor instruction to student difficulties
- At end of class as review of key points
- Get student opinion on various things anonymously (although can be done through courseweb as well)
 - Is concept <x> more difficult than concept <y> → can help guide what you focus on (pre-lecture questions can do this as well)