PER User's Guide
Physics Education Research
Evidence-based resources for teaching physics

Guide

Peer Instruction

Indicates a research-demonstrated benefit

Overview

Small group discussion of conceptual questions interspersed with lectures, increasing engagement and providing formative feedback on student thinking.

Type of Method	Instructional strategy
Level	**Designed for:** Intro College Calculus-based , Intro College Algebra-based **Can be adapted for:** High School , Intermediate , Upper-level Undergraduate , Teacher Prep Course, Teacher Professional Development, Intro College Conceptual, Graduate School
Setting	**Designed for:** Lecture - Large (30+ students) **Can be adapted for:** Lecture - Small (<30 students) , Recitation/Discussion Session , Studio
Coverage	Many topics with less depth, Requires more in-depth coverage of individual topics than a traditional lecture, so lecture cannot cover as many topics, but it is still possible to cover a lot of material by assigning reading and/or homework on topics not covered in lecture.
Topics	Mechanics, Electricity / Magnetism, Waves / Optics, Thermal / Statistical, Modern / Quantum, Mathematical, Astronomy, Other Science, Pedagogy
Instructor Effort	Low, (If suitable ConcepTests are already available, "low" is appropriate; if the instructor needs to write his/her own ConcepTests, then it requires more effort. There are many databases of ConcepTests in a wide variety of subjects.)
Resource Needs	Multiple choice questions and polling method. A projector, clickers, and TAs/LAs are helpful but not required.
Skills	**Designed for:** Conceptual understanding **Can be adapted for:** Problem-solving skills , Making real-world connections, Using multiple representations, Metacognition

Research Validation	**Based on research into:** theories of how students learn **Demonstrated to improve:** conceptual understanding, problem-solving skills, beliefs and attitudes, attendance, retention of students **Studied using:** student interviews, classroom observations, research at multiple institutions, research by multiple groups, peer-reviewed publication
Compatible Methods	PhET, UW Tutorials, JiTT, Ranking Tasks, ILDs, CGPS, Physlets, Context-Rich Problems, RealTime Physics, TIPERs, ABP Tutorials, SCALE-UP, OSP, SDI Labs, OST Tutorials, Thinking Problems, Workbook for Introductory Physics, LA Program, CAE TPS, Lecture-Tutorials, Astro Ranking Tasks, MBL, New Model Course, CPU, SCL, TEFA, CU Modern, CU E&M, CU QM, QuILTs, IQP, Thermal Tutorials, Mechanics Tutorials, Paradigms, Tools for Scientific Thinking, PI QM, M&I, Tutorials, Clickers, MOP, Responsive Teaching
Similar Methods	ILDs, Workbook for Introductory Physics, CAE TPS, TEFA, PI QM, Clickers
Developer(s)	Eric Mazur, Catherine H. Crouch, and colleagues
Website	http://www.peerinstruction.net/
Intro Article	4990
Intro Article	Peer Instruction: Engaging Students One-on-One, All at Once

What does it look like?

According to Crouch, Watkins, Fagen, and Mazur 2007, "The goal of PI is to transform the lecture environment so that it actively engages students and focuses their attention on underlying concepts. Instead of presenting the level of detail covered in the textbook or lecture notes, lectures consist of a number of short presentations on key points, each followed by a ConcepTest – short conceptual questions, typically posed in a multiple-choice format, on the subject being discussed." In Peer Instruction, the instructor intersperses short lectures with multiple choice conceptual questions called ConcepTests or clicker questions (see below for sample questions). The questions may be written on the board or displayed with a projector. Students use some kind of polling system (clickers, flashcards, or a show of hands) to answer the questions, first after thinking about them individually, and then after discussing them in a group of 2-4 peers. A 1-hour lecture can address approximately four topics, with the presentation structured as follows:

Presentation of a topic in Peer Instruction	**~15 min**
Mini-lecture	7-10 min
Question posed	1 min
Students think quietly on their own	1-2 min
Students record/report initial answers	<1 min
Students discuss their answers in small groups	2-4 min
Students record/report initial answers	<1 min
Feedback to teacher: tally of answers	<1 min
Explanation/discussion of correct answer	2+ min

Peer Instruction questions may take many forms. The most commonly recommended form is a conceptional question based on research and/or teaching knowledge about common ideas that students are likely to have about the topic. For these questions, both correct and incorrect options should be worded as similarly as possible to the wording that students actually use when answering the question. Instructors can find questions from databases of ConcepTests, or develop new questions by looking at open-ended questions from exams and homework that students have trouble with, and using common student responses as multiple choice options. See Resources for links to question databases and guides to writing questions.

Classroom Video

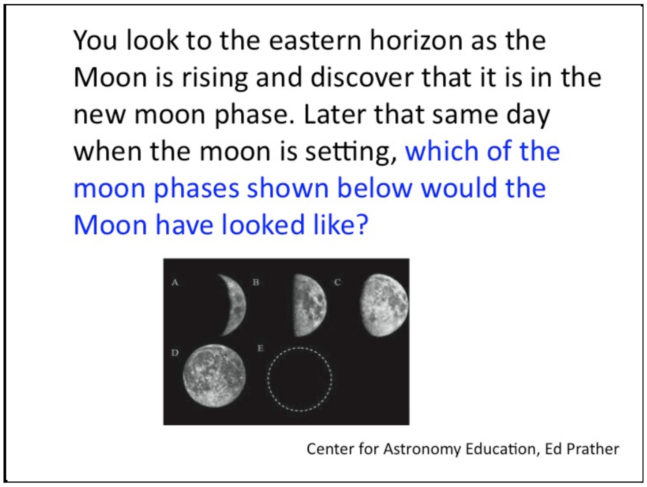
Eric Mazur demonstrates Peer Instruction:

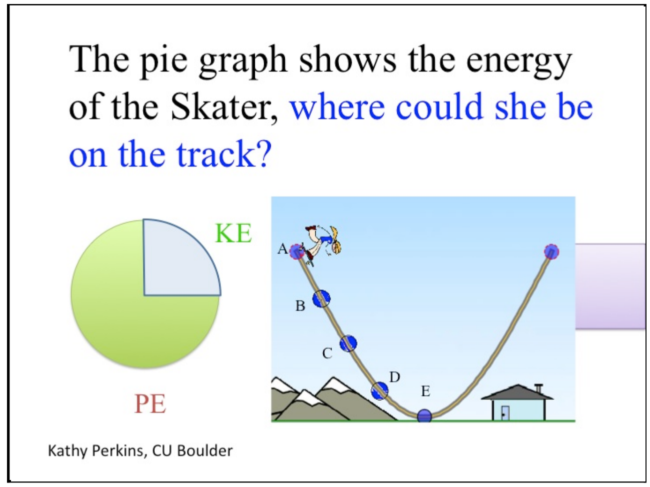
The University of Colorado Science Education Initiative has a series of videos illustrating Clickers in the classroom:

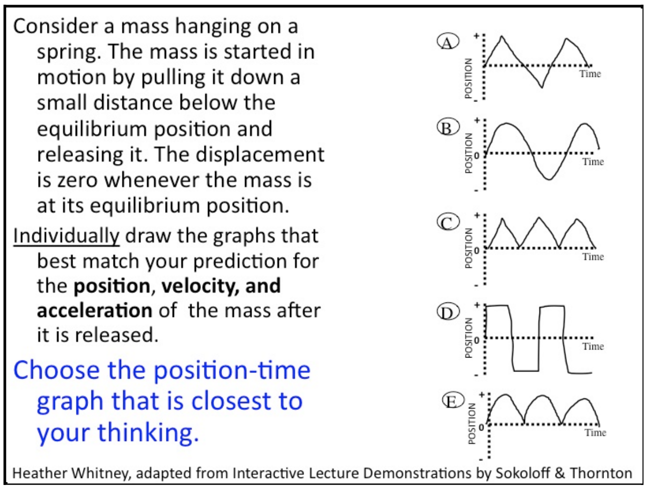
To see a video of Brazilian high school students discussing a Peer Instruction question, see this blog post from the Peer Instruction Network blog.

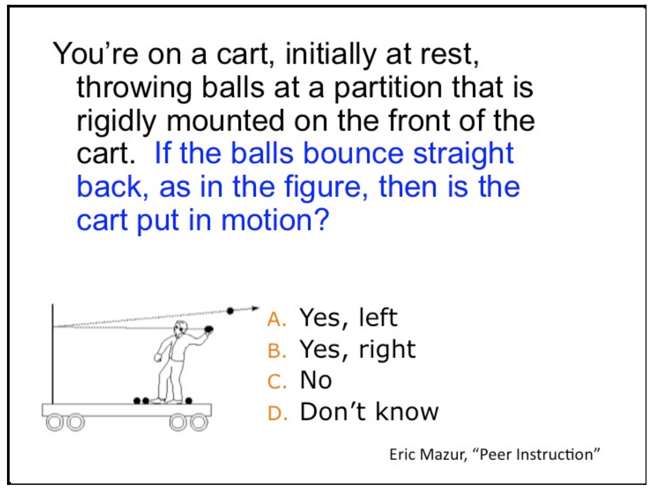
Sample Materials

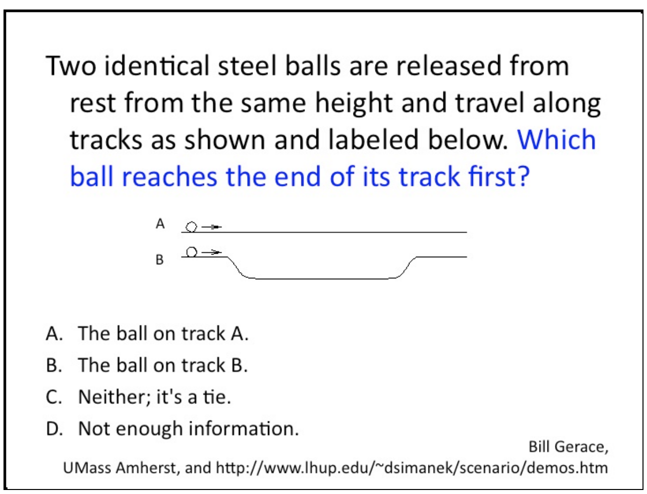
Below are a few sample ConcepTests collected by Stephanie Chasteen for her workshop "The gentle art of questioning: Writing great clicker questions". You can find many more in the teaching materials section.











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- C. Crouch, J. Watkins, A. Fagen, and E. Mazur, Peer Instruction: Engaging Students One-on-One, All at Once, in *Research-Based Reform of University Physics* (2007), Vol. 1.

What makes it work?

- **Development through research:** Materials are tested by observations of students using them, student interviews, and written tests of conceptual understanding. Materials are then revised in an iterative cycle based on research results.

- **Constructing understanding:** To deeply understand a concept, students must do the work of making sense of it for themselves.
- **Active engagement:** Students spend class time actively working on problems rather than listening to lectures. This enables them to do their thinking in an environment where they can get help from instructors and peers, rather than only while doing homework on their own.
- **Conceptual focus:** A focus on conceptual understanding rather than computation helps students to make sense of the underlying models, giving them reasoning skills that they can apply to both qualitative and quantitative problems.
- **Verbalizing thinking:** Students are more able to internalize new ideas if they verbalize their thinking through writing, peer discussion, responding to instructors' questions, or some combination.
- **Peer discussion:** Students who understand the material benefit from explaining it to others, students who do not understand the material benefit from personalized instruction from peers, and all students benefit from verbalizing their thinking.
- **Group work:** Working in small groups to solve problems helps students learn from their peers and allows them to solve problems that are more difficult than any one student could solve on their own.
- **Model-building:** Students learn how to do physics by modeling real physical systems, doing the work of deciding what approximations and assumptions to make, rather than being given simplified problems where this work has been done for them.
- **Explicitly taking students' prior thinking into account:** Students come into physics class with many ideas and intuitions that can interfere with or contribute to their ability to understand the content of the class. Instruction is more effective if it starts from these ideas and guides students towards a correct understanding, rather than starting with the correct physics ideas phrased in ways that don't connect with students' current understanding.
- **Confronting student difficulties:** Research has identified many common student difficulties that interfere with learning of physics. Addressing these difficulties directly helps students to overcome them.
- **Building on students' productive resources:** Students have many intuitions and ideas that are not necessarily correct or incorrect, but can be refined to form the basis of a correct understanding. Instruction elicits these ideas and guides students to refine them productively.

- **Commitment to an answer:** Asking students to predict the results of experiments helps them commit to an idea and therefore be more likely to remember if the results do not match their expectations.
- **Formative assessment:** Instructors find out what their students are thinking and modify instruction to respond accordingly.
- **Rapid feedback:** Students get feedback on their thinking while it is happening and are guided to use that feedback to modify their thinking.
- **Multiple representations:** Using many different representations (e.g. words, pictures, graphs, equations) for the same problem allows students to understand concepts more deeply and in a less context-dependent way.
- **Organizing knowledge:** Instruction helps students to organize their knowledge into a coherent structure of interrelated ideas so that they have the resources to figure out how to solve novel problems.
- **Metacognition:** Students are encouraged to explicit reflect on their own thinking process in order to learn how to figure things out.
- **Explicitly addressing epistemology:** "Epistemology" is the study of what it means to know. If we want students to learn that physics is a coherent framework that they can use to make sense of the real world, rather than a random collection of facts handed down by authority, instruction must explicitly address what it means to know in physics.

Where did it come from?

Peer Instruction was developed by Eric Mazur at Harvard in the 1990s and is now the most widely implemented PER-based teaching method, used in hundreds of high school and college classrooms throughout the world. Mazur stumbled onto the method during a review session when he could see by the confused looks on his students' faces that they did not understand the concept he was trying to teach, but he did not know how to explain it any better than he had already done. He asked the students to turn to their neighbors and discuss it, and the room erupted into discussion. Many instructors have adopted and adapted this method, and many variations that do not follow the precise instructions given by Mazur are often referred to as "peer instruction." We use capitalized "Peer Instruction" to refer to the specific technique laid out by Mazur, and lower-case "peer instruction" to refer to any number of variations that follow the same basic philosophy.

You can see Mazur's personal story of the development of Peer Instruction on YouTube:

Essential features

Minimal Implementation:

The following list of essential features was developed by Turpen, Dancy, and Henderson 2010 based on interviews with adopters of Peer Instruction and discussion with Eric Mazur. While this list is considered to be essential by the developers of Peer Instruction, many adopters modify one or more of these features.

- **Adapts**: Instructor typically adapts how class proceeds based on students' responses to PI activities.
- **Answer not graded**: Instructor typically does NOT grade students' responses to in-class PI questions.
- **Commit to answer**: Instructor typically gives students a dedicated time to think independently about the question and has students commit to an answer based on their individual thinking. (This feature is commonly modified even by instructors who are experts in PER. See this post on the Peer Instruction blog and the comments on the post for a discussion of this feature.)
- **Conceptual questions**: Instructor typically uses conceptual questions in-class.
- **Conceptual exams**: Instructor typically uses some conceptual questions on exams.
- **In-class tasks draw on student ideas**: Instructor typically has in-class PI tasks draw on common student prior ideas or difficulties.
- **Out-of-class assignments**: Instructor moves some student work to out-of-class time (e.g., student reading textbook, students study example problem solutions), which allows the instructor to have more flexibility in using class time.
- **PI tasks multiple-choice**: Instructor typically uses in-class PI tasks which have discrete answer options such as multiple-choice, Yes/No, or True/False (rather than open-ended problems or short-answer questions).
- **Questions interspersed**: Instructor typically intersperses PI questions throughout the lecture (rather than cordoned off at the beginning or end of class as a separate activity from the "regular" lecture).
- **Students discuss**: Instructor typically has students discuss their ideas with their peer concerning questions posed in class.
- **Vote after discussion**: Students typically commit to an answer after discussing the question with their peers.
- **Walks around classroom**: Instructor typically walks around the classroom during PI activities (possibly talking with students or just listening to student conversations).

Ideal Implementation:

- **Motivation**: Instructor motivates students by explaining the reasoning and research behind the use of Peer Instruction.
- **Participation credit**: Instructor offers small amount of credit for responding to questions (regardless of whether they answer correctly).
- **Facilitating discussions**: Instructor and/or teaching assistants and/or learning assistants help facilitate discussions among students who are not talking or whose discussions are not productive.
- **Listening**: Instructor listens to student discussions in order to better understand student thinking.
- **Whole-class discussion**: After students discuss and vote on questions in small groups, instructor facilitates a whole-class discussion in which students share and respond to reasoning for different answers.
- **Valuing reasoning**: In discussing the solution to a question, instructor emphasizes the reasoning that might lead to different responses in a way that values reasoning over merely getting the correct answer.
- **Allowing separation from answers**: Instructor elicits student responses using phrases like "Why might someone pick B?", allowing students to discuss incorrect answers without being personally associated with these answers.
- **Additional types of questions**: In addition to questions designed to elicit and address student difficulties, instructors may use questions with other goals, such as directing attention and raising awareness, promoting articulation and discussion, and stimulating cognitive processes. (Beatty, Gerace, Leonard, and Dufresne 2006)
- **Selective use of histogram**: Most clicker programs allow the instructor to view the results of the initial vote as a histogram. Instructors can choose to display this histogram to the students before peer discussion, or keep it hidden. If most students chose a single answer, showing the histogram may encourage students to accept the majority answer without thinking it through. However, if the response is evenly split between two or more answers, showing the lack of consensus can help spur discussion. See this post on the Peer Instruction blog and the comments on the post for a discussion of this feature.

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What does the research say?

Research base behind the design of Peer Instruction

The development of Peer Instruction was motivated by Halloun and Hestenes 1985, who developed the Force Concept Inventory (FCI) (Hestenes, Wells, and Swackhamer 1992), a test of students' conceptual understanding of forces. This research showed that after traditional lecture instruction, students' understanding of the most basic concepts of forces is very poor, but that using PER-based teaching methods can significantly improve this understanding.

Many of the questions used as ConcepTests in Peer Instruction are also based on the research literature identifying specific student difficulties with physics concepts (for an overview, see McDermott and Redish 1999). ConcepTests are often designed to elicit these difficulties, with the wording of multiple-choice options based on actual student responses to open-ended questions reported in the research literature.

Research involved in the development of Peer Instruction

Mazur, the developer of Peer Instruction, read about earlier research on student difficulties, and thought it could not possibly apply to his students at Harvard. He gave the FCI in his traditional lecture class and was shocked to find that the learning gains for his students at Harvard were comparable to those for students in lecture classes at other institutions. (Mazur 1997)

Mazur tells the story of a student who asked, while he was giving the FCI, "Professor Mazur, how should I answer these questions? According to what you taught me? Or according to the way I usually think about these things?" This story inspired later research in which students were asked to answer the question according to their own understanding, and according to how a physicist would answer the question, and there were large differences between the two. (Mazur 1997)

To test how problem solving relates to conceptual understanding in a different area of physics, Mazur gave two different exam problems on electric circuits. One was a complex mathematical problem, and one was a conceptual problem that to a physicist appears much simpler. In fact, he had trouble convincing a colleague to allow him to put the conceptual problem on the exam because the colleague thought it would be too easy. He found that students performed much better on the mathematical problem than on the conceptual problem. He plotted students' conceptual scores as a function of their conventional score, and found that while there were many students who scored well on the conceptual problem and poorly on the conventional problem, the converse was not true: there were no students who scored well on the conventional problem and poorly on the conceptual problem. This result suggests that conceptual understanding helps with problem solving, but the ability to solve traditional problems does not help with conceptual understanding. (Mazur 1997)

Research showing the effectiveness of Peer Instruction

Mazur gave the FCI in class before implementing Peer Instruction and after. Before, he got a gain of 25%, typical for a traditional lecture class, and after he got gains on the order of 50%, which is about average for PER-based teaching methods. (Mazur 1997)

One common concern about PER-based teaching methods such as Peer Instruction is that the focus on problem solving might hurt students' ability to do traditional problem solving. To address this concern, Mazur used a final exam that was entirely focused on traditional problem solving. He gave the same exam in 1991 after implementing Peer Instruction, that he had given in 1985 when he was using traditional lecture methods. The average score in 1991 was 69%, compared to 63% in 1985, a statistically significant difference. (Mazur 1997)

Crouch and Mazur also tested problem-solving ability by giving the Mechanics Baseline Test (MBT), research-based assessment instrument that includes quantitative questions as well as conceptual questions, in classes using Peer Instruction and traditional lectures. Students in the Peer Instruction classes scored higher on the test as a whole and on the quantitative questions. (Crouch and Mazur 2001)

Crouch and Mazur tested retention of learning from ConcepTests by matching them to free-response conceptual questions based on the ConcepTests but with a new physical context on exams. Student performance on the exam questions was comparable to their performance on the original ConcepTest after discussion. (Crouch and Mazur 2001)

Research on the use of Peer Instruction in different environments

Peer Instruction is one of the most widely adopted and most commonly modified of any PER-based teaching method (Henderson and Dancy 2009). A great deal of research has been done on the implementation and adaptation of Peer Instruction in different environments. Fagen, Crouch, and Mazur 2002 surveyed 384 PI users and collected FCI scores from instructors of 30 courses at 11 colleges and universities, and found an average gain of 39%. This average gain is less than that found at Harvard, but still within the "medium-g" range typical of classes using PER-based teaching methods, and higher than that found in classes using traditional lecture methods (Hake 1998).

Turpen and Finkelstein 2009 conducted qualitative research using classroom observations and interviews to characterize the different ways that instructors implement Peer Instruction, and have found that practices vary widely and that different practices establish different classroom norms. Henderson and

Dancy 2009 interviewed instructors using Peer Instruction and found that most instructors made significant modifications to the method.

One frequently asked question about Peer Instruction is which of the specific elements outlined by Mazur are critical to success, and which may be adapted without negative consequences. For example, is it necessary for students to answer each question twice, first individually and then after peer discussion?

Lasry, Charles, Whittaker, and Lautman 2009 studied the importance of peer discussion by assigning students to participate in one of three variations on Peer Instruction. Each group answered a series of questions twice. For each question, they answered it first after thinking individually, and then after some time. In between responses, one group discussed the question with peers, a second group reflected quietly, and a third group looked at an unrelated sequence of cartoons. Lasry et al. found that students who engaged in peer discussion performed significantly better on the questions the second time than the students in the other two groups. These results suggest that it is the peer discussion, rather than simply having extra time to think about the question, that leads to the increase in correct answers.

Another common concern is whether the increase in correct answers after peer discussion is due to learning through discussion, or due to the students who know the answer giving it to the students who don't. Smith, Wood, Adams, Wieman, Knight, Guild, and Su 2009 studied this concern by asking students a pair of isomorphic clicker questions. They found that after discussion of the first question, there was a significant increase in the number of students answering the second question correctly individually, suggesting that students had learned something from the peer discussion of the first question that they could apply to the second question. This was true even among students who answered the first question wrong both times.

A more controversial question is whether it is necessary for students to answer questions individually first, or if Peer Instruction works just as well if this step is skipped. See this post on the Peer Instruction blog and the comments on the post for a discussion of this question. While no studies have directly addressed the question, the results of Singh 2005 suggest that answering individually first may not be critical. Singh asked two groups of students to answer questions on the Conceptual Survey of Electricity and Magnetism (CSEM). One group answered the questions individually first, then worked in pairs and answered the same questions again (similar to Peer Instruction), and the other group answered the questions in pairs first and then individually. For the first group, as expected, their scores increased significantly after they worked in pairs. However, the second group performed just as well after working in pairs with no time to think through the questions individually first (and the extra time working on their own afterwards did not significantly change their scores). These results demonstrate that students can perform just as well on group activities if the individual answer step is skipped. However, this study did not test whether they were able to apply this learning in any other context.

Peer Instruction was originally developed for introductory physics classes, but it can also be used in upper-division classes. The University of Colorado has implemented Peer Instruction in their upper-division E&M and Quantum Mechanics courses, and found that it is effective for student learning (Chasteen and Pollock 2009), and both instructors (Pollock, Chasteen, Dubson, and Perkins 2010) and students (Perkins and Turpen 2009) value it.

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- C. Turpen and N. Finkelstein, Not all interactive engagement is the same: Variations in physics professors' implementation of Peer Instruction, Phys. Rev. ST Phys. Educ. Res. **5** (2), 020101 (2009).

Common challenges

- ⊟ My students aren't talking to each other.

  Effective implementation of Peer Instruction requires carefully setting up expectations. This style of peer discussion may be unlike anything your students have encountered in a science class before, and may take some getting used to. Explaining why you are implementing this method and what you expect them to do will help. During ConcepTests, you (and your teaching assistants and/or learning assistants) can try walking around the class and facilitating discussions if students are not talking. One way to do this is to ask one student what they think, then ask another if they agree or disagree, and why or why not.

- ⊟ My students complain that they don't like Peer Instruction.

  Students may initially be uncomfortable with teaching methods that are unfamiliar and require them to engage in new (and often more difficult) ways. Instructors who have implemented these methods report that explaining what you are doing and why can help make students more comfortable, and that students can eventually get used to and come to appreciate interactive engagement methods.

  For ideas about how to explain the benefits of interactive engagement methods to students, see Steve Pollock's FAQ page on Tutorials in Introductory Physics and Peer Instruction for his students, or this suggestion from Eric Mazur in *Peer Instruction*:

"I argue that it would be a waste of their time to have me simply repeat what is printed in the textbook or the notes. To do so implies that they are unable to read, and they ought to be offended when an instructor treats them that way. I explain how little one tends to learn in a passive lecture, emphasizing that it is not possible for an instructor just to pour knowledge in their minds, that no matter how good the instructor, they still have to do the work. I challenge them to become critical thinkers, explaining the difference between plugging numbers into equations and being able to analyze an unfamiliar situation."

Many instructors also find that there are only a few vocal students who dislike the new methods, while a less vocal majority actually appreciate them. If this is the case, you can help bolster your own confidence, silence the vocal minority, and get useful feedback by giving students a survey about their impressions of your teaching methods early in the semester. Sharing the results in aggregrate can help the vocal minority realize that they are a minority, and help everyone realize that you are taking their feedback seriously.

- ⊟ I can't get through all the material I need to cover.

It is certainly true that you can't "cover" as much content when you take the time to have students actively work through it as you can when you simply explain it. A good rule of thumb for Peer Instruction is that you will probably need to eliminate about 10% of your content.

Since research suggests (see our Arguments for skeptical colleagues) that students don't learn much from lectures, simply covering the content may not be doing your students much good anyway. Some advocates of interactive engagement argue that in order to achieve the more important goal of students actually understanding anything in your class, you need to give up on the goal of covering a lot of content. Others recognize that institutional constraints often do not allow such a radical stance, and suggest that it is possible to use interactive engagement and still cover just as much content.

One strategy that allows you to cover just as much content in your *course*, while still covering less in *lecture*, is to shift some of the content into out-of-class reading and/or homework. One way to do this is with Just-in-Time Teaching.

Frequently Asked Questions

Other sites with lists of Frequently Asked Questions about Peer Instruction:

- Peer Instruction Network FAQ page: The developers of Peer Instruction answer Frequently Asked Questions from adopters.
- Carl Wieman Science Education Initiative Clicker Resource Guide: Pages 20-27 answer Frequently Asked Questions About the Use of Clickers and Clicker Questions.

More Frequently Asked Questions:

- ⊟ Should I use clickers, flashcards, or show of hands?

  See our recommendation on Which polling method should I use for Peer Instruction? for tips on the advantages and disadvantages of clickers, flashcards, and show of hands.

- ⊟ Should I grade ConcepTests?

  If you use clickers, it is possible to grade student responses, either for completion or for correctness.

  Most advocates of peer instruction suggest that student responses to in-class questions count for some small percentage of their grade (2-15%) to encourage participation, attendance, bringing clickers to class, and taking clicker questions seriously. (However, for a dissenting view, see this blog post by Joss Ives.)

  Most advocates suggest grading only for participation, not for the correct answer, in order to emphasize that the goal of clicker questions is to help students learn, not to evaluate them. Research supports this view: James 2006 audio-recorded student conversations in two introductory astronomy classrooms with different grading techniques for Peer Instruction questions. They summarize their results as follows:

  > "In the high stakes classroom where students received little credit for incorrect CRS responses, it was found that conversation partners with greater knowledge tended to dominate peer discussions and partners with less knowledge were more passive. In the low stakes classroom where students received full credit for incorrect responses, it was found that students engaged in a more even examination of ideas from both

> partners. Conversation partners in the low stakes classroom were also far more likely to register dissimilar responses, suggesting that question response statistics in low stakes classrooms more accurately reflect current student understanding and therefore act as a better diagnostic tool for instructors."

If you do grade clicker questions for correctness, it's important to grade only those questions for which students can reasonably be expected to know the answer. Thus, questions that are intended to introduce students to a new topic, elicit student thinking, or help students engage with ambiguous ideas should not be graded.

- ⊟ Can I use Peer Instruction in small classes?

Peer Instruction is often used in large classes because there are not many other ways to be sure of engaging every student in a large class. Instructors may be reluctant to use Peer Instruction in a small class because it seems artificial in an environment where you know all your students and it is possible to engage them in other ways. However, Peer Instruction has many benefits even in small classes. Joss Ives, in his blog post Why I use clickers in small courses, says:

> "Even in a class of 10, I find that there are usually some students that often do not feel comfortable discussing their understanding with the entire class. The clickers facilitate the argumentation process for these students in a smaller-group situation in which these students feel more comfortable, but are still help accountable for their answers. They help establish a culture where on most questions each student is going to be discussing their understanding with their peers. Clickers are not the only way to accomplish this, but are the way I do it."

- ⊟ Can I use Peer Instruction in upper-division classes?

Peer Instruction was originally developed for introductory physics classes, but it can also be used in upper-division classes. The University of Colorado has implemented Peer Instruction in their upper-division E&M and Quantum Mechanics courses, and found that it is effective for student learning (Chasteen and Pollock 2009), and both instructors (Pollock, Chasteen, Dubson, and Perkins 2010) and students (Perkins and Turpen 2009) value it.

Stephanie Chasteen, one of the leaders in the implementation of Peer Instruction at

CU, describes how it works in several blog posts (part 1: What does it look like?, part 2: What kinds of questions do we ask?, part 3: The critics speak, and part 4: Tips for success) and several videos (Upper Division Clickers in Action, What Kinds of Questions Do We Ask in Upper Division?, and Writing Upper Division Clicker Questions).

Teaching materials

See our Expert Recommendation on finding good questions to use with clickers or Peer Instruction for an extensive list of databases of Peer Instruction questions, as well as suggestions for writing your own questions.

Resources, training, & community

Book: E. Mazur, *Peer Instruction: A User's Manual* (Prentice Hall, Upper Saddle River, 1997). Mazur's book contains an introduction to the method, an overview of the research behind it, directions for implementation, and a library of ConcepTests.

Blog: Turn to Your Neighbor is the official Peer Instruction blog, with many suggestions from the developers about how to implement Peer Instruction effectively.

Online Community: Peer Instruction Network is a global community where you can connect with other Peer Instruction users, share tips, and learn more about implementing Peer Instruction.

Online Clicker Resource: The University of Colorado Science Education Initiative has developed an online guide to using clickers in STEM classrooms, including suggestions for effective implementation, videos, a podcast, and links to other resources.

Video: Eric Mazur discusses his experience creating Peer Instruction:

No pilot configured for 'application/binary'

Community

Peer Instruction Network is a new global community developed by the Mazur group for current and future users of Peer Instruction and related interactive teaching methods. Its goal is to provide a forum for instructors to **Connect** with other innovative educators, **Share** experiences and resources, and **Learn** how to transform teaching and learning using research-based methods.

You can join the Peer Instruction Network at www.peerinstruction.net. Once they have registered a significant number of users, they will launch site features which include the ability to locate other Peer Instruction users from your discipline, at your institution, or in your country. They will also post frequently asked questions and associated answers and publish user experiences with PI. Eventually they plan to facilitate the sharing and dissemination of materials.

References

- I. Beatty, W. Gerace, W. Leonard, and R. Dufresne, Designing effective questions for classroom response system teaching, Am. J. Phys. **74** (1), 31 (2006).

TA/LA training

Peer Instruction, unlike many other PER-based teaching methods, does not *require* the using of teaching assistants in class. However, if you do have access to teaching assistants and/or learning assistants, they can be helpful in making Peer Instruction run more smoothly. At the University of Colorado, learning assistants are often required to attend lectures and circulate through the room during ConcepTests to help facilitate discussions between students and listen to student thinking. They then meet with the instructor weekly and report back on what kinds of ideas they heard in student discussions. Having "spies" in the room can be helpful in getting feedback on student thinking, since the instructor can usually only listen to one or two group discussions during each ConcepTest. Also, students may be more comfortable saying what they really think around other students closer to their own age than around the instructor. Having assistants to help facilitate group discussions can be helpful for making sure students have productive conversations, particularly in large lectures where the instructor cannot get to all the students. In general, teaching and learning assistants should facilitate conversations by asking questions that get students talking *to each other*, not by having a lengthy discussion of the content with a single student or by explaining the correct answers.

Crouch, Watkins, Fagen, and Mazur 2007 offer the following suggestions for TA training:

> Before the course begins, we explain to our TAs the reasons for teaching with PI and give them the data on improved student learning... One way to help TAs see the value of PI is to have them think about and discuss challenging ConcepTests, so that they experience

the benefits of discussion. If such ConcepTests are related to the course material, this also makes them realize that they don’t know everything already! (Questions on introductory fluid statics and dynamics are usually challenging for our TAs.) At Harvard, we hold a weekly meeting for our teaching staff, during which we go through the material to be covered the following week in section, emphasizing the pedagogy we wish them to use.

References

- C. Crouch, J. Watkins, A. Fagen, and E. Mazur, Peer Instruction: Engaging Students One-on-One, All at Once, in *Research-Based Reform of University Physics* (2007), Vol. 1.