Excerpts from:

Peer Instruction for Astronomy

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Visit the WWW site and ConcepTest Library at:

http://hea−www.harvard.edu/~pgreen/educ/PI.html

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Chapter 1: INTRODUCTION

... As any teacher knows, the real test of learning is to be able to explain what you've learned to others. Regardless of the subject matter, when students are actively involved, they learn more and retain it longer than when they try to absorb knowledge passively. Small group learning techniques are now in use in science classes all over the country. Various forms have been tested and evaluated, and are even now being sculpted by experience in the class and laboratory. Students who work collaboratively report more satisfaction with their classes (Beckman, 1990; Cooper et al. 1990; Johnson, Johnson, and Smith, 1991a). This form of learning has a variety of names and implementations falling under the classification of Collaborative Learning (CL), including cooperative learning, collective learning, peer teaching, peer learning, peer instruction, team learning, study circles, study groups, work groups, etc.

Group work can take the form of informal learning groups, formal learning groups, or study teams. The latter two usually are formed for projects that span many classroom or laboratory sessions, with the aim of completing a project. *Peer Instruction for Astronomy* focuses on what instructors can do in class to boost student learning and satisfaction, and so the emphasis here is on informal learning groups. These are temporary clusters of students, formed as needed, often within a single class session.

These informal groups help gauge students' understanding of the material, allow students to apply what they are learning, and provide a change of pace. *Peer Instruction (PI)* (sometimes called peer teaching) is a form of collaborative learning that involves and engages students. Peer Instruction has been developed and implemented for introductory Physics by Eric Mazur at Harvard University. The improvements in student performance have been widely publicized in Sheila Tobias' book *Revitalizing Undergraduate Science* (Research Corporation, 1992). By encouraging student participation and interaction during the lecture, PI encourages students to critically think through the arguments being developed, and to discuss and defend their ideas and insights with their neighbors. At any time and in a class of any size, you can implement PI. For instance, you may simply ask students to turn to a neighbor for 2 minutes to solve a puzzle or question you've just posed during a lecture.

The goal of this book is to facilitate the implementation of PI in introductory astronomy classes by providing ideas, guidelines, and a wealth of examples ready for your use in the classroom. I'll first outline active learning techniques like PI, and the wealth of usage and research behind them. When you first undertake to incorporate PI, you will not be alone! I will also provide detailed classroom recipes for the implementation of PI, with specific examples. A broad library of ConcepTests forms the core of the book. ConcepTests are short, conceptual multiple-choice questions for use during class, that serve to gauge comprehension of scientific principles in real-time, to challenge misconceptions, and to foster student engagement through PI. All along the way, I provide quick summaries of how to implement PI in the classroom for the harried instructor. In addition, I will encourage you to participate in broad range of assessments. I describe options for assessing your students, and for evaluating your own implementations of PIA using input from students or colleagues. I also invite you to join a broad-based collaboration of instructors working to enhance Peer Instruction for Astronomy (PIA) by building and improving the library of ConcepTests, and by assessing and improving PIA itself using data from the field – the reported experiences of you and other astronomy instructors.

Chapter 3: RECIPES for the CLASSROOM

A BRIEF RECIPE

Briefly, lectures are broken into sections covering key points. Start with a more-or-less standard format mini-lecture on one of the fundamental concepts to be covered. This mini-lecture might last about 10 minutes, and is then followed by a ConcepTest - a short multiple-choice question that tests the students' understanding. After one minute, you may ask the students to record or display their individual answers. Recording the initial answers affords the opportunity to track the improvements in understanding that Peer Instruction later builds. You may then ask students to turn to their neighbors to try and convince them of their individual answers. This invariably leads to animated discussions. After another minute or so, the students are asked to reconsider their answer and record it again. You then take quick poll to decide whether to move on to the next concept, or to continue exposition on the same material. A variety of options are available to suit your taste, which I sketch below. The process, lecture/test/discuss/retest, may repeat several times until the end of the class. Depending on the material, you may thus expect to cover 3-4 key points during a typical one hour lecture period. When you implement peer instruction in your classroom, a good plan might be to break your lecture outlines into 3-4 subsections. As an example, a lecture I presented on quasars was broken up as follows:

1. How nearby `active' galaxies differ from normal galaxies.
2. Evidence for supermassive black holes.
3. Quasar distances and luminosities.
4. The epoch of quasar formation.

Before class, you can choose (or compose) a couple of ConcepTests for each key point you plan to cover. Following your mini-lecture on one such point, the briefest possible use of a ConcepTest might be as follows – simply as a real-time gauge of class comprehension.

ConcepTests for Feedback Only − High Comprehension

1) Mini-lecture
2) Quick-read tally via ConcepTest.
   Yields >90% correct answers.
3) Move on.

You may instead discover that comprehension is so low that you feel the students should not try to convince each other of the correct answer since so few of them know it

ConcepTests for Feedback Only − Low Comprehension

1) Mini-lecture
2) Quick-read tally via ConcepTest
   Yields <20% correct answers.
3) Continue mini-lecture, allow for greater detail, review and questions.
4) Retally with a new ConcepTest to gauge comprehension.

The figures of 90% and 20% are of course simply suggestions. Use your own judgment. If the comprehension is intermediate, as is most often the case for well-chosen ConcepTests, then PI comes fully into play. Here I provide some time estimates as a guide.

ConcepTests with Peer Instruction

1) Mini-lecture (10 minutes)
2) Pose ConcepTest (1 minute)
3) Quick-read tally (1 minute)
   Yields 30-80% correct answers
4) Students break into buzz groups for discussion. (2 minutes)
4) Retally after discussion. (1 minute)
5) Iterate or move on.

If students have already had their first buzz group discussion, and a tally shows that a significant but not overwhelming fraction (say half) of the groups found the right answer, then you can ask each group to combine with the nearest group that has chosen a different answer. For a concept this knotty, I suggest allowing about 4 more minutes of discussion for the new large groups to arrive at a single answer.

For Peer Instruction, the largest and most crucial investment of instructors' time is in choosing good ConcepTests that fall in the middle group, allowing students to teach each other most effectively. This generates the greatest student engagement, but also relieves you from having to cram material into a full-time lecture, since you now emphasize key concepts over rote learning. I cover hints for constructing good ConcepTests later on, and a primary goal of this book is to provide many of them, so that the skids are greased for your foray into Peer Instruction.

Now you can see that in the most common situation, covering this key topic should take just about 15 minutes of class time, even allowing for the real-time feedback, and the student interaction and discussion that Peer Instruction provides. While the back-and-forth with students may seem to throw a wrench into the clockwork of a traditional lesson plan, your adaptation will be easier than you might think, because while the students deliberate, you will have some time to think, an opportunity to evaluate where any confusion might lie, and how to address it.

Chapter 4: CONCEPTESTS

Short, conceptual, multiple−choice questions can be used for two purposes simultaneously − feedback and learning. *Feedback* gives you the ability to quickly gauge student comprehension during class, allowing real−time adaptation of the lecture. *Learning* is facilitated by challenging students to reorder their preconceptions confront their misconceptions, by discussing conceptual puzzles with peers in a collaborative atmosphere.

Accessing ConcepTests

One of the most labor-intensive parts of using *PIA* is the creation of a large collection of appropriate multiple choice `puzzlers' of this type. A significant number would be needed simply to cover all the many major topics spanned by most beginning college astronomy courses. However, since class levels vary dramatically both within and between institutions, an even larger collection is advisable. The sample of ConcepTests provided in this chapter are meant to ease an instructor's entry into Peer Instruction for Astronomy. This collection contains contributions from instructors across the country, and should be considered a truly collaborative, ongoing community effort of astronomy educators who are interested in progress and innovation in the classroom. The ConcepTests Library remains accessible on the WWW at

http://hea-www.harvard.edu/~pgreen/PI.html.

Astronomy instructors can both access and contribute to this library. Furthermore, as discussed later, feedback from instructors on the content and scoring of individual ConcepTests will be used to continually adapt and refine the Library in the future, making it a dynamic, accessible tool suitable for direct use in the classroom, but also as a potential *database* for research on and assessment of the technique of *PIA* and its results.

A LIBRARY OF CONCEPTESTS

COSMOLOGY, DARK MATTER, & LENSING

Cosmology

Which of the following observations about the nature of the universe can be made without using any special equipment?
 a) The universe is expanding.
 b) Most of the matter in the universe does not emit light.
$c) Luminous matter in the universe occurs in clumps rather than being evenly distributed.
 d) There is background radiation from the Big Bang.

The cosmological principle enables astronomers to generalize from what they observe in the nearby universe to the properties of the universe as a whole. The principle means that no matter where you are in space, you should see that
 a) galaxies are all moving away from a center.
 b) the universe does not change with time.
$c) on average, space looks the same in all directions.
 d) every region of space is unique.

Your job is to compile a representative catalog of galaxies. Assuming our region of the Universe is typical, the best criterion to use to decide whether to include galaxies in the catalog is to include all galaxies on the sky with
 a) magnitudes brighter than some chosen limit.
 b) apparent diameters larger than some chosen limit.
$c) recession velocities less than a certain (large) amount.
 d) recession velocities less than a certain (small) amount.

Suppose the Universe were not expanding but were in some kind of steady state. Galaxy recession velocities would
 a) still correlate directly with distance.
 b) reverse the trend we see today and correlate inversely with distance.
 c) be a scatter plot with most recession velocities positive.
$d) be a scatter plot with equal amounts of positive and negative recession velocities.

The night sky is relatively dark because
 a) the Earth's atmosphere obscures most of the light.
 b) the universe is mostly empty.
$c) the Big Bang happened about 15 billion years ago.
 d) the universe is very large and old.

The blueshift exhibited by some nearby external galaxies lends support to the
a) Big Bang model, because those galaxies are expanding towards us.
$b) Local Group concept, because nearby galaxies interact gravitationally.
c) evolution theory, because galaxies change color as they evolve.
d) oscillating universe theory, because some galaxies are moving together already.

Chapter 6: EPILOG

Try Peer Instruction in your college introductory astronomy class. It's not hard to implement, and yields rapid rewards for both you and your students. While *PI* is scalable to your level of interest and commitment, you will benefit by putting much more than a toe in the water. Experience shows that a full implementation, meaning 2 to 3 ConcepTests and discussions per lecture hour, accomplishes a lot. *Peer Instruction for Astronomy,* thoughtfully administered will almost surely

- raise class attendance and lower course attrition.
- boost and hold the interest of your students.
- heighten your awareness of students' comprehension.
- highlight common misconceptions to be addressed directly in lecture.
- increase student understanding of key physical concepts.
- improve student retention.
- develop students' ability to communicate scientific ideas.
- enhance students' collaborative skills.
- raise student satisfaction with your course and appreciation of your teaching.

Now, why should you buy all that? While there is a huge body of research documenting the effectiveness of cooperative learning techniques like *PI,* the effectiveness of the specific techniques discussed here, and their particular application to astronomy have only begun to be studied. Are all the above points true? In what circumstances? How can you trouble−shoot your implementation of *PIA*? It is crucial that the experience of teachers like yourself be shared in the community of astronomy instructors and educators. *PIA* should be researched and documented in detail. Don't just go it alone. Check the WWW sites, readings, and references below so we can all learn and benefit from each other. Share the wealth!