Learner-centered, interactive instruction has a proven track record in improving "Astro 101" courses for non-majors, but has rarely been applied to higher-level astronomy courses, such as for majors. Yet the basic cognitive principles supporting active learning should hold true for students at all levels - so shouldn't we hope for similar gains in classes aimed at majors?

We present here an initial report on an updated calculus-based Introduction to Astrophysics class, taught at UCLA this spring using techniques such as Think-Pair-Share and Just-in-time teaching, that suggests such active-learning techniques can indeed enhance the learning experience for astrophysics majors, too.

The Class

- **Introduction to Astrophysics: Light, Stars, and Nebulae.**
   - The first course in the UCLA astrophysics major.
   - 1 quarter (10 weeks) long, followed by another quarter on galaxies & cosmology.
   - Two 75-minute lectures each week, plus one 50-minute discussion section.
   - ~20 students, mostly sophomores intending to major in physics or astronomy.
   - Prerequisites include calculus, mechanics, and E&M, but students vary widely in previous exposure to more advanced physics, particularly including astronomy.

What We Did Differently

- Pre-class online reading questions to motivate students to actually do the reading on time before class. Typically we asked 3-4 questions (multiple choice, matching, or free response) per 5-10 page reading assignment, designed to take no more than about 5 minutes after the reading was done. These were due by midnight the night before each class period, and counted for 5% of the grade.

- Students were also asked to submit online their own questions for clarifications of the readings, so that lectures could be tailored to focus on the topics students found most difficult. ("Just-in-time Teaching")

- During class, Think-Pair-Share questions were used extensively to engage students and get them actively thinking about the material and working with their peers. For such a small class, rather than using electronic clickers, students just held up colored 3x5 cards to indicate their answers.

- An "weekly problem solving session" encouraged students to gather and discuss homework problems, working together in a classroom with several whiteboards.

What We Left the Same

- The content: Coordinates and sky motions, telescopes, the interaction of light and matter, atomic structure and spectral line formation, spectral types, the H-R diagram, orbital motions, binary stars, stellar structure, stellar evolution.

- The text: Fundamentals of Astronomy by Karttunen et al.

- Biweekly lectures at a blackboard with derivations of equations, explanations, etc.

- Challenging weekly problem sets, counting for 20% of the course grade. The majority of problems were re-used from previous years, though some new ones were developed too. Students were encouraged to work in small groups, but write up solutions individually.

- 2 midterms, 1 final exam. These were given in class, no calculators allowed, and in total counted for 75% of the course grade.

Conclusions

Our informal observations after one term with this approach are that students are more engaged and alert, and score higher on exams than typical in previous years. This is anecdotal evidence, not hard data yet, and there is clearly a vast amount of work to be done in this area. But our first impressions strongly encourage us that interactive instruction is superior to traditional lectures for this level of class, too. Interactive instruction does require more preparation than pure lectures, but we find it also to be more rewarding and enjoyable, since there is so much more immediate feedback on how well students are learning. We strongly encourage others to adopt this approach, and look forward to many classes ahead.

The GOAL after this class, students should be able to
• Apply Kepler’s 3rd Law to calculate the period or semi-major axis of an orbit, or the mass of the gravitating body.

Before the term began we developed a list of 72 specific goals for students (3-4 per class period). We constantly referred to these goals to guide our instructional design, ensuring that each goal was addressed in turn at each stage of activity. We show here one such thread through the course.

We developed a set of ~40 new Think-Pair-Share questions based on our content and skill goals, and used these in every class. Our aim was for these questions to be answerable in just a minute or two using basic reasoning and simple mathematics (e.g. ratios or scalings, rather than detailed calculations, which were left for problem sets). Writing good questions proved one of the hardest and most time consuming aspects of this whole process, and not every question worked out the way we hoped. Yet the surprises were often valuable lessons for us, when some questions we had expected to be easy proved surprisingly challenging for students, thus showing us areas to cover more carefully.

Our library of questions (and our notes on how well each of them worked) are available for any interested instructors - just ask!