FY12 Innovations in Teaching with Technology Awards: Transforming Introductory Astronomical Laboratories to Active Learning

Investigators: Robert Mutel, Cornelia Lang

Department(s): Physics and Astronomy

What do you intend to do?

Undergraduate students in physical science laboratories can be challenged by difficult concepts and unfamiliar instruments and software. There is a steep learning curve, especially for non-science majors, who are often uncomfortable with quantitative analysis. This is particularly unfortunate in introductory astronomy labs, since most students have a natural curiosity about planets, stars, and galaxies, but the abstract nature of laboratory exercises quickly dims their enthusiasm. Our current curriculum exacerbates this problem as many exercises are written in a traditional format (a recipe of instructions that do not foster understanding, but emphasize the end result).

In addition, many of the exercises are computer-based, and do not allow for hands-on intuitive understanding. The Department operates a robotic optical telescope in Arizona, the Iowa Robotic Observatory (IRO, http://astro.physics.uiowa.edu/rigei). The facility is dedicated to student use, and is an integral part of all astronomy lab course. It is used by over 500 undergraduates annually in a range of courses, from introductory non-major level to advanced major-level. It is currently operated using a web-based scheduler, with students submitting schedules and receiving images the following day. Although an amazing student resource, some are left without an intuitive understanding of the system.

We propose to address these problems by revising the introductory astronomy laboratory curriculum to use active learning methods and to include a more hands-on approach to the labs. To do this, we request funding to (1) update and supplement classroom technology to facilitate active learning, (2) transform student work areas to spaces for team work, (3) enhance the existing robotic telescope facilities and (4) support students to help the P.I.s (Professors Mutel and Lang) develop the new curriculum.

Recent upgrades to the internet connection at the IRO telescope now allow for a new live operating mode which we would like to exploit for student real time participation. We will also add a live webcam so that students can see and hear the telescope as they use it. This hands-on mode will greatly enhance student interest and sense of curiosity, allowing realtime adjustments in exposure time, filters, and objects as they observe. In order to implement this mode for lab use, we need to upgrade the telescope camera, add a webcam, and purchase appropriate remote screen software. For daytime laboratories, the live telescope system is not available, so we are experimenting with a novel iPad application (Starwalk) which allows students to observe the sky in real time by holding the iPad overhead. The iPad displays the sky in that direction, so he/she can see the planets, stars, and galaxies exactly as if they were holding a pair of binoculars or a small telescope under dark skies. Every object displayed can be clicked on to obtain additional information, including facts and web links. This remarkable software can transform daytime astronomy labs into inquiry-based observing projects.

Work plan: Implementation of the project would occur during Spring 2012. We would like to renovate both classrooms and install the computers, screen displays, and whiteboards during the first three weeks of January 2012 in time for the first week of labs. The enhancements to the IRO will also be implemented during that time.
The lab curriculum revisions will be written jointly by the P.I.s, two undergraduate students and a half-time astronomy lab coordinator (see below) throughout the semester. All lab materials will be transferred to web-based format, which allows embedded multi-media, links to relevant web resources, and frequent updating. We have already begun the implementation of this project with the help of Departmental seed money during Fall 2011. We purchased seven iPads (including Starwalk) and have been adapting the curriculum. Plans are underway to renovate one of the two classrooms with 3-person curved tables in December 2011.

**How will it improve student learning?**

The primary goal of the proposal is to transform the traditional astronomical laboratory curriculum into an active learning environment, with a specific emphasis on hands-on experiences similar to that of professional research astronomers. As professional astronomers who are engaged in research as well as teaching, we are aware that curiosity, willingness to experiment, and cooperative problem solving are all fundamental to successful scientific research. Unfortunately, these attributes are largely untapped in recipe-style lab exercises. By comparison, the inquiry-based, team approach at the core of active learning emphasizes exactly these qualities. These skills are valuable not just in scientific research, but in any career in which problem-solving is required. We wish to change the laboratory emphasis from finding the correct answer to learning the skills needed to solve problems.

The PIs recently participated in the University of Iowa’s TILE institute (May 2011). We have both taught the introductory astronomy courses for many years, and are acutely aware of the need for improvement in the laboratories. After taking the TILE workshop, we were motivated to apply the active learning pedagogy to a laboratory environment. In order to provide a proof of concept, this fall (2011) we started the transformation to active learning, team-based exercises in all introductory astronomy labs (enrollment 260 students). Using Departmental seed funding, we hired several undergraduate students to assist us in writing several inquiry-based laboratory projects: They are available on the web (http://astro.physics.uiowa.edu/ITU, click on Labs tab).

The first lab exercise (Introduction to Active Learning) introduces students to the inquiry-based scheme, examines the idea of team problem-solving, and provides three simple activities to illustrate the technique. For each subsequent lab exercise, the teams are introduced to relevant tools, and then challenged to devise strategies to solve a central science question (e.g., How can one determine the mass of Jupiter using observations of its moons?). We propose to fully adapt our introductory astronomy curriculum (about 30 exercises and research projects for all astronomy courses with laboratory components).

Our hope is that students will learn not just the astronomical facts and concepts related to each lab project, but how to apply inquiry-based methods to solve a problem. The tools we will emphasize include critical thinking skills (e.g., questioning assumptions, Occam’s razor, assessing relevant variables), numerical estimation, and open-mindedness to alternative explanations. We will also develop good team participation skills by rotating students in various team roles (e.g., manager, scribe, skeptic). Finally, by providing a live research telescope for evening labs, and the iPad application for daytime labs, we will allow students to explore the sky, feed their curiosity, and perhaps gain some familiarity about the night sky that they will retain well after completing the course.

In order to assess the impact of the updated technology on the astronomy laboratory experience, we will rely on close communication and interaction with the TAs who will be staffing the lab sessions. We will provide a training during the Departmental TA orientation which will orient them to the active-learning philosophy and practical considerations. During the semester, the PIs will regularly visit the lab sessions to ensure that all aspects of the new curriculum are being effectively implemented. We will rely on a regular weekly meeting of the TAs, the
undergraduate student employees, the robotic telescope scheduler, the PIs and the astronomy lab coordinator to evaluate the success of the lab exercises and to adapt the labs to reflect TA feedback and updates in technology.

**What resources will you need?**

Classroom infrastructure. In order to implement active-learning in the astronomy laboratories, we need classrooms with appropriate furniture and technology. The Department uses two main classrooms for astronomy laboratories, with a total annual enrollment of approximately 500 students. However, the classrooms are presently not set up for team use, nor do they have appropriate display systems. Since each lab section has up to 18 students, we have designed a classroom with 6 curved desks that seat three students. Each classroom also will have two large (8x4) whiteboards for sketching ideas, equations, etc, and two large-format LED displays for displaying student observations and projects, the remote telescope webcam, live telescope control status displays, relevant web pages, etc. The Department has provided some seed funding for six 3-student tables for one classroom. We request funding for six more tables for an additional classroom and for displays!, and whiteboards for both classrooms.

2. Notebooks and iPads. There are currently standard PCs in the astronomy lab classrooms. We propose to replace these with small Notebooks (laptop computers), which have several advantages over box-type PCs. The Notebooks will be lightweight, instant on computers which can be easily moved to experimental setups, such as the astronomical optics bench for data acquisition, or to a bench with a spectrometer setup. They will also take up much less space on the 3-person curved desks, and can be easily moved from team member to member as needed. The iPads will be used in several ways. As described above, one use will be as a daytime telescope using the remarkable StarWalk application (app) that allows a dynamic realtime view of the sky in the direction the iPad is oriented. Another use of the iPad is to understand stellar parallax (which determines a star's distance) by measuring the parallax of nearly objects from the roof, both using a theodolite application and by photographing the object from several points, and transferring the photos to the Notebook for further analysis. A third app provides a zoomable, high-quality lunar map, with labels and adjustable solar illumination, illustrating the cause of lunar phases (Moonglobe HD). There are potentially many other astronomy-based apps available for this remarkable device once we begin to explore the possibilities. For example, another app allows a student to control [using an inexpensive cable and adaptor] one of several small telescopes that we often take on as! tronomy field trips. The student specifies an astronomical object as an observing target on the iPad and the telescope will respond by pointing to it in the sky.

3. Upgrades to the Iowa Robotic Observatory. The IRO requires an CCD sensor upgrade to the primary camera to operate in live single image mode as described above. The current system has excessive noise, so in order to obtain a quality image during realtime imaging, several images must be averaged. The new sensor will eliminate the high-noise problem. In addition, we would like to add a realtime webcam to the system, with audio, to give the (student) observer a tactile sense that they are operating a real telescope, albeit more than 1,500 miles away.

4. Curriculum Development Support. In order to integrate the updated technology and active learning format with the astronomy laboratory curriculum, the P.I.s propose to work with two undergraduates and a part-time (20 hour/week) astronomy lab coordinator during Spring 2012. The Department will provide funding for the astronomy lab coordinator and part of his/her duties would include helping with the implementation of this project both in technology and curriculum. We therefore request funding for two undergraduate students to
work on the project approximately 10 hours/week throughout the semester (13 weeks). Weekly meetings with the PIs, the astronomy lab coordinator, the undergraduate student employees and the corresponding TAs will allow for frequent feedback and updates to be made to the evolving curriculum.

**Rough estimate of costs**

The proposal comprises three components: costs associated with renovation to the teaching space (both technology and furniture), specific improvements in the robotic telescope equipment, and salary support for development of the active learning curriculum.

The table below summarizes all costs.

**Total $42,050**

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<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit Cost</th>
<th>Total Cost</th>
</tr>
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<tbody>
<tr>
<td>Notebook computers</td>
<td>14</td>
<td>$1,000</td>
<td>$14,000</td>
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<tr>
<td>HDTV display w/ wall mount</td>
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<td>Webcam with motion, IR lighting</td>
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<td>$150</td>
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<tr>
<td>Cabling, power retrofit/classroom</td>
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<td>$1,500</td>
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<tr>
<td>iPads for 665 VAN</td>
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<tr>
<td>Tables for 665 VAN</td>
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<td>$750</td>
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<td>8x4 Whiteboards (2 per room)</td>
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<td>$700</td>
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<tr>
<td>Upgrade telescope camera</td>
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<td>Software (e.g., Rspec, iPad apps)</td>
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<tr>
<td>Salary 2 UG students, Spring 2012</td>
<td>2</td>
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<td>$2,600</td>
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**IT Support Information**

For more information on the **Innovations in Teaching using Technology Awards**, please send an email to: **Innovation Strategies for Teaching & Learning**.

**Article number:**

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