Introduction:

Introductory astronomy courses are a frequent choice for non-STEM majors to fulfill science requirements. Recent studies estimate that 10% of full-time undergraduate students will take an astronomy course at some point in their college career. With this in mind, it is essential that these courses introduce students not only to the study of space but also help students build an understanding of the scientific process. In order to achieve these goals, it has become clear that methods of instruction that involve student engagement are best. These practices, often called ‘active learning,’ have been studied extensively in physics education and have impressive learning outcome gains in a wide variety of settings. In addition, active learning has been found to increase performance on astronomy-based concept inventories (like the Light and Spectroscopy Concept Inventory, or LSCI) for students in a variety of college settings.

Challenges:

Two of the major challenges of adding active learning to introductory astronomy classes are the wide range of students who take these classes, some with little to no recent math or science experience, and the broad range of often lofty concepts covered in astronomy that do not necessarily lend themselves to hands-on activities. In order to overcome these challenges and utilize active learning to increase scientific understanding in a small (eleven person) introductory astronomy course during summer of 2017, I developed a new set of labs and activities to supplement previous works. These activities were written to be accomplished by students with minimal mathematical experience while still probing exciting questions that could motivate all students to participate. By including at least one activity in each class meeting, students were active participants in their learning every day. All new activities are available on my website (physics.uwyo.edu/~jessicas/teach).

New Activities:

The activities used for this class each focused on having the students work with real astronomical data to answer important questions. As the activities were slightly longer, they took up a significant fraction of the lecture meeting times, usually covering between ~30–60% of the class periods. This decrease in lecture time meant that some details in the topics typically covered in an introductory astronomy class were replaced with these hands-on activities. Despite this, the course was still able to cover a wide range of astronomy concepts, starting with properties of the Earth and our Solar System and moving through stars, galaxies, and what we know about the structures and composition of the Universe. In one activity, students used Type-1a supernova
data to replicate parts of the analysis done to show the expansion of the universe is accelerating. In this activity, my students got to put their knowledge of supernova and redshifts to use, while also evaluating a scientific result that garnered a Nobel prize\(^6\). A full list with descriptions of the activities used can be found on my website.

**Evaluation**

To test the success of the inclusion of longer activities in this course, students were asked to create an experimental procedure to determine what stars are both on the first day and on the final exam. On the first day, the students watched a short clip from ‘The Lion King’ in which Timon, Pumbaa, and Simba discuss the stars. They were then asked to answer the question, “If you were Timon or Pumbaa, and you wanted to prove that you were right about what the stars are, what steps might you take to learn more about what the ‘sparkly dots up there’ really are?”

On the final exam, the question was stated as, “On the first day of this class, you created an experiment to help Timon and Pumbaa settle their argument about what stars are (fireflies or big balls of gas). With your knowledge now, how might you adjust your experiment? If you had access to any equipment you wanted, what measurements might you gather to determine the nature of stars?” Unlike many concept inventory questions, this evaluation method focuses on an open-ended assignment where students act as a scientist instead of repeating memorized information. This method of testing was used to focus on probing the students’ understanding of the scientific process.

Word clouds created from the set of answers are shown in Figures 1 and 2. Notice how words like “observe” and “compare” are large in the first day responses while words like “spectra” and “parallax” are emphasized in the final exam answers. This suggests that over the six-week course students have gained a new understanding of the tools available to astronomers and which tools might be useful for answering this specific question. Many students suggest the use of spectrometers on their final exam responses, which are an ideal tool for determining the composition of an object and therefore well suited to the task given. A fair number of final exam responses suggested comparing measurements of the stars to known measurements of gases or distances that could be measured on Earth. This shows that these students realized that in order to best determine the nature of these distant objects we cannot reach, they needed to compare to something known and understood, which is an exciting shift towards an understanding of how astronomers test theories. For full student pre- and post-course answers, see supplemental material available on my website.
Figure 1: Word cloud created from the answers to the first-day response. Notice that ‘observe’ is one of the largest words, suggesting that students have some good ideas about what to do, but do not yet understand the full suite of tools available to an astronomer.
Figure 2: Word cloud created from the answers to the final exam response. In this word cloud, the terms spectra, hydrogen, parallax, and luminosity stand out. These terms all show the students ability to utilize the tools an astronomer has to build the best tests of a certain theory.

Conclusions

Active learning has been found to be a valuable tool for increasing student knowledge in STEM courses. In order to use the principles of active learning in an introductory astronomy summer course, I developed a new set of activities and labs to get students working with real data to answer important questions about the Universe. Using these new activities along with previously written labs and materials helped students learn about the tools astronomers use to answer big questions while also building a better understanding of the scientific method. Introductory astronomy courses reach a wide range of students, so it is vital that we use the best tools possible to engage these students and increase their scientific literacy through the exciting field of astronomy.
References


2. Scott Freeman, Sarah L. Eddy, Miles McDonough, Michelle K. Smith, Nnadozie Okoroafor, Hannah Jordt, and Mary Pat Wenderoth, “Active learning increases student performance in science, engineering, and mathematics,” PNAS, **Vol. 111, No. 23**, 8410 (June 2014)


