Expanding minds through explorations of our expanding universe

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Expanding minds through explorations of our expanding universe

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Science is the observation of patterns inherent in the universe, composing the language by which the natural world communicates. To provide non-STEM students a meaningful experience of science, I developed a series of engaging, investigative activities through which students in an introductory astronomy course act as scientists to explore the world they inhabit. These activities focus on having students use real data they gather, or data gathered from academic journals and databases, to reach important conclusions about the nature of our universe. As an example, one activity focuses on using Type Ia supernova magnitudes to measure the accelerating expansion of the universe and is the focus of this paper. By including this and other similar activities throughout the course, the students engage in scientific thinking in a fun and exciting way. To evaluate the success of these activities, students were asked an open-ended experimental design question at the start and end of the course. The growth shown by the 11 students in the six-week summer class is an indicator that the inclusion of these activities helped these students learn about the tools available to astronomers, while also facilitating an environment to foster scientific thinking.

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.[1] With this in mind, it is essential that these courses introduce students not only to the study of space, but also utilize this time to 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.[2] 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.[3] 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.[4,5]

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. To overcome these obstacles, a series of short workshops were developed to supplement the available material. Each workshop was designed by breaking down important astronomical discoveries or measurements into pieces that could be completed by the non-STEM students typically enrolled in introductory astronomy courses. One activity included was a graphing challenge that asked students to use data from the Nobel Prize-winning work of Schmidt, Perlmutter, and Riess to determine how the expansion rate of the universe is changing. In this activity, students plot the magnitudes and redshifts of the supernova from Riess et al.[6] For more information on this seminal discovery and the work that led up to it, see Refs. 7 and 8. Students then compare the data they plotted to three theoretical curves for different models of our universe. Based on their findings, they are then able to predict the fate of the universe. The data and blank plot for this activity are shown in Fig. 1.

Although this activity probes cutting-edge astronomical research, it is designed to be completed easily by a novice. This allows the students to do meaningful work without being overwhelmed by concepts they may not have interacted with for years. Students also gain a valuable opportunity to practice graphing and interpreting data, an essential part of scientific inquiry. At the same time, this activity and others like it place the student in the role of scientist, allowing them to make decisions based on observational evidence. After completing their graphs, the students were also asked to evaluate their conclusions by comparing to a more recent survey of similar supernovae. Through completing this comparison, the students grapple with the iterative process of scientific theories, and see how scientific knowledge is continuously tested. Finally, students discuss how certain they are of their results, making space for a rich exploration of why scientists might hesitate to make decisive statements, even when they have strong evidence to support their claims. The novelty of this

Supernova Name	Redshift	Distance Modulus (m-M)
1992bo	0.018	34.72
1992P	0.026	35.76
1990af	0.050	36.53
1995K	0.48	42.45
1995D	0.008	33.01
1995ao	0.24	40.74
1995ap	0.30	40.33
1996E	0.43	41.74
1996H	0.62	42.98
1996I	0.57	42.76
1996J	0.30	41.38
1996K	0.38	41.63
1996R	0.16	39.08
1996T	0.24	40.68
1996U	0.43	42.55
1997ce	0.44	41.95
1997cj	0.50	42.40
1997ck	0.97	44.39

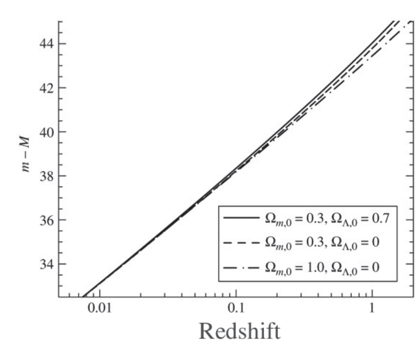

Fig. 1. The supernova data and blank plot with three theoretical curves used by students to determine the fate of the universe using the methods of Schmidt, Perlmutter, and Riess.

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activity's focus on an understanding of cosmology adds to an area of education that is often missing in the average science classroom,[9,10] supplementing other works focused on replicating astronomical experiments, like determining the Hubble constant.[11,12] Additionally, once students have completed the activity, they have performed a part of a Nobel Prize-winning analysis, showing them that they can participate in important science, whatever their educational background.

By including this and other similar activities throughout an introductory astronomy course, the non-science major students are able to develop an in-depth understanding of how science research is performed without being overwhelmed by difficult math concepts. In the example of measuring universal expansion described in this paper, the students rely on knowledge they had already developed on redshifts and supernovae to determine which theoretical model for the future of the universe best fits the data they are given. They then analyze and discuss the significance of their results, which gives students an opportunity to consider how scientific knowledge evolves over time. The addition of activities during each class meeting provided a space for the students to learn to think as scientists in what could be the only science course they take during their undergraduate career. For more information and to see the full set of new activities, visit the author's webpage: www.physics.uwyo.edu/~jessicas .

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Fermi Questions

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Question 1: Coffee consumption

How many bathtubs-full of coffee do U.S. physicists (or mathematicians) consume daily?

Question 2: Active volcanoes

How many active volcanoes are there in the world? (*Thanks to Shaila Patricia Ramirez Vientós, Puerto Rico for asking this during my ODU REYES lecture.)*

Look for the answers online at tpt.aapt.org under "Browse," at the very end of the current issue.

Question suggestions are always welcome!

For more Fermi questions and answers, see *Guesstimation 2.0: Solving Today's Problems on the Back of a Napkin,* by Lawrence Weinstein (Princeton University Press, 2012).

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