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Selected Resources for a Student-Centered Introductory Astronomy Course

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Abstract

During the transition from an instructor-centered to a student-centered introductory astronomy course, decisions have to be made about which topics can be covered by using activities and, because activities take time, which topics can be minimized or left out altogether. Here are some of the choices made by one instructor during such a transition, along with some useful resources found in the process.

1. INTRODUCTION

After attending the 2000 Cosmos in the Classroom symposium (Fraknoi 2000) and hearing more about student-centered approaches to the introductory astronomy course, I decided to change the way I taught this class at Henry Ford Community College. Making such a transition over the last five years has not been easy, especially when it came to deciding which topics to cover in more depth and which topics to shorten or omit. Naturally, other instructors will make different choices, but the important thing to note is that choices do need to be made.

Guiding students while they are doing activities can sometimes be harder than simply lecturing, but research shows that students are more likely to learn material if they themselves get to "play" with the concepts and tools of astronomy instead of passively listening to the instructor. For more on how to make this kind of transition, see Slater & Adams 2003. Further resources are included in the guide "Web Sites for College Astronomy Instructors" at http://www.astrosociety.org/education/resources/educsites.html. This site includes sections for activities, labs, and demonstrations.

2. SELECTED TOPICS THAT CAN BE COVERED MOSTLY WITH ACTIVITIES

2.1 Celestial Motions

This is a difficult area for students to visualize from a lecture. Many college students have trouble putting themselves into a different frame of reference and picturing how things will look. Actually holding and experimenting with models can be very helpful.

Some excellent activities on the observed motions of stars, the Sun, and the Moon can be found in *Mysteries of the Sky* (Adams, Prather, & Slater 2005). These were designed for use in a large lecture classroom, but logistically, they work just as well or even better for smaller classes. If standard Earth-centered celestial globes are available, along with space to spread out and use them, such globes can serve to aid and enhance these activities. (One popular model is the Starship Earth series from Spherical Concepts.)

For another activity, students are given a two-dimensional projection of the celestial sphere and draw their local horizon on transparency that can then be placed on top of the celestial sphere to visualize the view of the sky from different locations on Earth. For more such activities, see LoPresto 2004.

2.2 Solar System Overview

A nice way to begin coverage of the Solar System is with an outdoor activity in which students are given a basketball to represent the Earth, along with a softball, a baseball, and a golf ball. They are then asked which ball is the correct size to represent the Moon and how far away from the basketball it should be placed to accurately represent its orbit. A similar activity can be done with the basketball representing the Sun and having the planets represented by tiny ball bearings, then bigger ones, then marbles, ping pong balls, and golf balls. In my classes, we only take time to space out the inner Solar System and then just try to imagine the rest. In a larger class, some of this could be done at the front of the room, with the students being asked to visualize more of the system themselves.

Plotting bar graphs comparing planetary data is a way to help students visualize and compare terrestrial and Jovian planet characteristics. One group of several students can be asked to plot each different quantity (diameter, mass, density, and so on) from the data tables found in the appendixes of most introductory texts and then share their results with the class. In a large class, multiple groups can plot each quantity.

Another activity for use in a large or small class involves asking groups of students to come up with definitions for the terms *planet*, *moon*, *asteroid*, *comet*, and *meteor* early in the unit, before the terms have been formally defined and without consulting any references. Students usually comment that this is much harder than they expected it to be. This also provides an opportunity to address misconceptions about the objects early on.

Lecture Tutorials for Introductory Astronomy (Adams et al. 2005, 61) has a nice tutorial on the formation of the Solar System, and *Investigating Astronomy: Model Building and Critical Thinking* (McNamara et al. 1997, 49) has one on the formation of the Moon.

All Solar System activities described above can be done comfortably in two 80-minute class periods and can supplement standard reading on the overview of the Solar System and its formation.

2.3 HR Diagram

One way to teach the HR diagram is to have students plot their own. To help them, students can refer to tables of the 20 brightest and 20 closest stars, which are found in many sources, including introductory texts and the Internet.

2.4 Galaxy Classification

A common activity is to provide pictures of different galaxies and ask students to sort them into their own categories. Students often come up with a rough approximation of the spiral, elliptical, and irregular categories on their own without prior coverage of the subject, describing them with such words as *whirlpool*, *round*, *oval*, *weird*, and *strange*. Such an activity can be found in *Mysteries of the Sky* (Adams & Slater 2000) and in "Galaxy Sorting" (Stephens 2000), for example. After students have completed such an activity, it is a good time to begin a discussion of mergers and cannibal galaxies to be sure that the irregular category does not seem so mysterious to them.

3. EXAMPLES OF TOPICS FOR WHICH LECTURES CAN BE INTERSPERSED WITH SHORT ACTIVITIES OR DEMONSTRATIONS

3.1 History—Specifically the Copernican Revolution

A way to keep students engaged while looking at the development of our ideas of planetary motion is through interspersing short activities with short lectures, such as:

- Plotting the motion of a planet during a retrograde (for example, Adams et al. 2005, 51; Zeilik 1998, 25).
- Tracing out the planet's path on an epicycle (Adams & Slater 2000, 201).
- Mapping a superior planet's apparent path when observed while Earth is passing (LoPresto 2004, 68).
- Having student discover parallax for themselves (Adams et al. 2005, 73; Zeilik 1998, 63).

There are also many things that can be done with Kepler's Laws. Making calculations for and graphs of the third law does not take too much time and gets students working with the concepts (Zeilik 1998, 35ff), as does a tutorial that allows students to discover that a planet's motion is independent of its mass (Adams et al. 2005, 53).

Simple experiments, like dropping a book and a sheet of paper--first separate, then with the paper on top of the book, then with the paper crumpled up--help to explain Galileo's contributions (see also Douglas Duncan's weekly challenge Web page at http://casa.colorado.edu/%7Edduncan/challenge.html)

Groups of students can also be asked to discuss and summarize contributions to astronomy and the scientific method of Tycho, Kepler, Galileo, and Newton in tabular form. Having them construct a flowchart or concept map is also a useful way to help students pull together the steps of the scientific method (LoPresto 2004, 93-94).

Finally, there exists an interesting tutorial on converting between Earth-bound geocentric observations of the positions of planets and heliocentric positions observed from space (Adams & Slater 2000, 215).

3.2 Extrasolar Planets

Although this relatively new and hot topic may be interesting enough that lecturing alone may work, activities are now being devised by a number of groups to help students explore on their own. See:

- Meet the Neighbors: Planets around Nearby Stars: http://www.astrocappella.com/activities/meet_the_neighbors.pdf
- *Cycles in the Sky* (LoPresto 2004, 121)

A thought-provoking discussion question to pose for debate during a lecture is whether the discovery of extrasolar planets supports or refutes current theories of planetary formation and why.

3.3 Light and Telescopes

Many demonstrations can supplement lectures on light, among them reflection of a laser beam from a mirror, refraction of a laser beam in colored water, images formed by a concave mirror and convex lens, and a look at portable reflecting and refracting telescopes. Observing continuous and emission spectra through diffraction gratings helps spectroscopy seem more real, as does classifying stellar spectra (Adams & Slater 2000, 165) or matching unknown spectra with the known types.

Some other useful activities are:

- Ken Brecher's Project LITE: http://lite.bu.edu/
- Esther Zirbel's Lab Series: http://cosmos.phys.tufts.edu/%7Ezirbel/laboratories/index.html
- University of Washingtion Lab: http://www.astro.washington.edu/labs/clearinghouse/labs/labs.html

I have had success with a conceptual interactive lecture-demonstration in which I show, on a transparency, drawings of a full-color continuous spectrum and the emission spectra of hydrogen, helium, and sodium above it. I then put pieces of transparency on top of the continuous spectrum with the dark lines positioned first for each individual element, then for combinations. I ask the students to tell me what elements are present in this "star." Transparencies that have thicker lines on either end or the middle can be used to demonstrate spectra from stars with different temperatures. Although this activity is purely conceptual and does not use the spectra of real stars, some members of the audience are always able to verbally identify what they are seeing, even the different temperature spectra. Having students write down the answers and check them immediately after is even better because everyone participates, not just those giving verbal answers. (For another activity, see Sadler 1991, 423.)

3.4 Stars

If time and space are available, here is a way to show the difference between absolute and apparent magnitude. Set up two or three identical small light bulbs on a table and have students observe them with the room lights turned off. First, have students observe from the opposite side of the room where the bulbs are all about the same distance away, then from behind one of the tables where the bulbs are at different distances.

When discussing energy production in stars, one of the most important points to make is that protons will not fuse until the temperature is high enough to accelerate their movement so that they get close enough for the strong force to "hook" them and overcome their electromagnetic repulsion. To demonstrate this, pass around two strong magnets with like poles facing each other and ask the students to try and push them together. Most will be able to do it and see that a stronger force can overcome a weaker opposite force.

Instructors can also have students construct a flowchart or concept map (Adams et al. 2005, 83) that connects the different stages in the lives of various mass stars. This provides an excellent review of stellar evolution. If possible, the map should be put on the board with as many students as possible contributing different steps from their own work. (For another good approach to stellar evolution, see Slater 2004, 347.)

3.5 Galaxies/Cosmology

Giving students real data for a Hubble's Law plot and using the constant to determine the age of the Universe provides an excellent transition from galaxies to cosmology. Hubble's Law activities can be found in many places:

- *Mysteries of the Sky: Activities for Collaborative Groups* (Adams & Slater 2000, 191)
- *Interactive Lesson Guide for Astronomy: Cooperative Learning Activities* (Zeilik 1998, 89)
- Diane Dutkevich's Lab Series: http://www.astro.northwestern.edu/labs/m100/
- The University of Washington Lab: http://www.astro.washington.edu/labs/clearinghouse/labs/HubbleLawShort/lab.htm l

3.6 Life in the Universe

This is a topic of interest to many students, so lectures often hold their attention, but a group activity on making estimates for the Drake Equation is a good way to provide a midperiod break from lecture. Drake Equation activities and calculators can be found at:

- *Interactive Lesson Guide for Astronomy: Cooperative Learning Activities* (Zeilik 1998, 95)
- SETI Institute Drake Equation Calculator: http://www.seti.org/site/pp.asp?c=ktJ2J9MMIsE&b=179074
- PBS Drake Equation Calculator: http://www.pbs.org/lifebeyondearth/listening/drake.html

An abbreviated version of the equation with fewer terms for students to deal with can be found in *Horizons* (Seeds 2004, 448).

4. EXAMPLES OF TOPICS THAT MIGHT BE COVERED BRIEFLY, CONDENSED, OR LEFT OUT

Eclipses

Although it is important to explain why eclipses do not occur at every full and new moon, it may not be necessary to go into much more detail than where they occur in the cycle of lunar phases.

The Discovery of the Outer Planets

These are great stories, but the students can be told to read about them in almost any text being used.

The Sun

Covering nuclear reactions, including neutrino detection, is very important, but this can be done during the star birth part of stellar evolution. Coverage of the Sun's atmosphere and solar activity can be left to the reading with no loss of continuity.

Relativity

I used to take a digression into both special and general relativity the period after doing black holes, but sadly, the time for that is now gone. I do mention them as footnotes to why nothing can escape a black hole and still demonstrate curved space-time around a black hole by placing a heavy mass on a blanket, but I have to recommend reading the text sections for more information.

Active Galaxies

Toward the end of a semester, when time is at more of a premium, a smooth transition can be made through Hubble's Law from galactic types to the beginning of cosmology. Connecting quasars with supermassive black holes is often all that can be mentioned in class; students can be asked to read about the rest.

Note: When relegating topics to reading, it is a good idea to assign questions from the chapter to be handed in. Of course, this is a good idea for all chapters but is especially important when something will not be discussed much or at all in class.

5. CONCLUSION

Several of the references cited have many useful activities and strategies other than those specifically mentioned here. Many more can be found at http://astrosociety.org/education/resources/educsites.html and "Insights into the Universe" (Slater & Zeilik 2003).

I hope that these brief observations are useful for others making this type of transition. I am sure that other instructors may have different ideas on how to treat these topics.

Acknowledgments

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References

Adams, J., & Slater, T. 2000, *Mysteries of the Sky: Activities for Collaborative Groups*, Dubuque, IA: Kendall Hunt.

Adams, J., Prather, E., & Slater, T. 2005, *Lecture Tutorials for Introductory Astronomy*, Englewood Cliffs, NJ: Prentice Hall.

Fraknoi, A. 2000, *Cosmos in the Classroom: A Symposium on Teaching Astronomy for Non-Science Majors*, San Francisco: Astronomical Society of the Pacific.

LoPresto, M. 2004, *Cycles in the Sky*, 2nd edition. Dubuque, IA: Kendall Hunt.

McNamara, B., Burnham, C., Bridges, C., & French, M. 1997, *Investigating Astronomy: Model Building and Critical Thinking*, New York: Mosby.

Sadler, P. 1991, "Projecting Spectra for Classroom investigation," *The Physics Teacher*, October, 423.

Seeds, M. 2004, *Horizons: Exploration of the Universe*, 8th edition. Pacific Grove, CA: Thomson-Brooks/Cole.

Slater, T. 2004, "Stellar Inquiry," *The Physics Teacher*, September, 347.

Slater, T., & Adams, J. 2003, *Learner-Centered Astronomy Teaching: Strategies for Astro 101*, Upper Saddle River, NJ: Prentice Hall.

Slater. T., & Zeilik, M. (Editors). 2003, "Insights into the Universe: Effective Ways to Teach Astronomy: A Collection of AstroNotes Columns and Related Articles Reprinted from *The Physics Teacher*," College Park, MD: American Association of Physics Teachers.

Stephens, S. 2000, "Galaxy Sorting," in *More Universe at Your Fingertips*, A. Fraknoi & D. Schatz (Editors), San Francisco: Astronomical Society of the Pacific.

Zeilik, M. 1998, *Interactive Lesson Guide for Astronomy: Cooperative Learning Activities*, Santa Fe, NM: The Learning Zone.

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83 - 89