Whole-Class Inquiry: Science

The question of facilitating inquiry in the context of whole-class interactions versus individual work in the laboratory is not a new issue in science education. Science teachers have always been confronted with the question of the value added by the time and expense required for individual work in the science laboratory versus inquiry facilitated through whole-class demonstrations.

Technology simply shifts these issues to another context. The following series of parallel vignettes compare:

1. a traditional textbook-based astronomy lesson
2. an example of the same lesson taught in a computer laboratory setting using a hands-on approach
3. scaffolding provided to facilitate inquiry in a whole-class setting.

Traditional Textbook-Based Lesson

Consider the traditional approach to teaching about circumpolar stars, a common astronomy concept in a ninth-grade earth science class. The topic is covered during a unit on the apparent motion of celestial objects, including the sun, moon, and stars. In traditional instruction, the lesson is textbook-based, where description is the emphasis. Consider, for example, this description from the 1989 edition of Holt, Rinehart and Winston's textbook *Modern Earth Science:*

> Some stars are always visible in the night sky. They lie so close to Polaris that their apparent nightly orbit does not carry them below the horizon. From the Northern Hemisphere, these stars can always be seen circling the North Star. The circling stars are called circumpolar stars. The stars of the Little Dipper are circumpolar for most of the Northern Hemisphere.

This description is accompanied by a photograph like the one in Figure 1. Although accurate, this approach does not engage students as active learners and does little to help them develop meaningful understandings about the concepts of apparent stellar motion and circumpolar stars.

By Randy Bell

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Technology: Projector system

Standards: *NETS•S* 3–6; *NETS•T* II; *NETS•A* II (http://www.iste.org/nets/)

Figure 1. A timed exposure of circumpolar stars in the Northern Hemisphere. The long streak from lower center to upper right of image is a satellite. © 2003 Larry Flick. (Used by permission.)

Hands-on Lesson in the Lab

Computer-based planetarium programs can be used to teach the same concepts. A variety of commercial and freeware versions of planetarium programs are readily available to teachers (***Editor's note:*** See the Planetarium Software page for an extensive list and description of planetarium software. You'll find the URL along with other Resources on p. 47.) Any of these programs can display the night sky for any location on earth and typically at any time between 9999 BC and 9999 AD. Additionally, the software allows the user to speed up time to make the motions of celestial bodies apparent.

For our lesson, we will use the commercial program Starry Night as an example. A teacher who is committed to hands-on instruction could use Starry Night to provide a more student-centered, experiential environment in which to learn about stellar motion and circumpolar stars than in the traditional approach. The Starry Night Web site provides a worksheet (as part of Herb Koller's student guide) designed to help students use the program to understand circumpolar stars. The worksheet includes the following items relevant to our discussion:

> Locate Ursa Major and Ursa Minor. One of the most easily recognized star patterns is the Big Dipper. The Dipper is part of the constellation Ursa Major.

1. Outline the Big Dipper on the chart, above.
2. The Little Dipper is part of Ursa Minor. Can you find the Little Dipper on the diagram? It's a little more difficult since some of the stars aren't as bright. *Action:* Let time flow continuously for some time.
3. Describe the motion of the constellations with respect to Polaris.
4. Notice that some constellations never go below the horizon. Such constellations are called circumpolar. List two or three circumpolar constellations.

Note that in this approach, students are led through the activity with a worksheet and, in this case, the definition of circumpolar stars is provided to the students. Although it may be argued that the planetarium program provides a more student-centered context for the lesson, students are not challenged to construct meaning from their observations. Essentially, the approach in the hands-on lesson is much the same as the traditional approach—the focus is on presenting and describing target concepts.

Facilitating Inquiry through Whole-Class Exploration

Imagine a third approach to the lesson, in which the teacher uses a projector with a wireless connection to a tablet and facilitates a whole-class exploration.

Ninth-grade science teacher Ms. Whitaker first sets the context by using Starry Night to show what the local sky will look like at 8 p.m. that evening. She points out the prominent constellations and the locations of the planets that are readily visible. After this orientation, she asks students to predict the apparent motion of the stars when she sets Starry Night to speed up time by a factor of 10.

Several students participate in this discussion, which converges on the notion that the stars will appear to rise in the east and set in the west. Ms. Whitaker anticipated her students' predictions, which though mostly correct, do not fully describe that the stars appear to move in arcs across the sky from east to west. By setting the sky in motion on her tablet and directing Starry Night to show the sky facing east, south, and then west, students are able to see for themselves which part of their predictions is correct and which part must be revised to more accurately reflect the apparent motion of the stars.

Next, Ms. Whitaker asks students whether all stars appear to move in this manner. The tone of her question cues students in that they may have missed something important, and they begin to talk among themselves about the possibilities. One student eventually remarks that the North Star doesn't rise or set and several other students nod their heads in agreement.

Ms. Whitaker acknowledges the response with what students have come to recognize as her favorite question: How can we find out? The students all respond that they could direct Starry Night to show the sky looking north. Having previously demonstrated how to do this, Ms. Whitaker places the tablet into Billy's hands, a student who has yet to contribute to the discussion, and suggests that he "drive." Billy takes to the controls with initial reluctance, but quickly catches on as he mimics Ms. Whitaker's use of the navigation and time-skip buttons.

Soon the class is treated to the familiar star groups of the Big Dipper, the Little Dipper, and Cassiopeia circling the North Star, Polaris. Jessica declares that it's not just the North Star that doesn't set, but none of the stars in these constellations ever sets. Ms. Whitaker thanks Jessica for her response, then challenges the class to work in their table groups to come up with a statement explaining why these stars in the northern sky never set.

The groups quickly get to work, often glancing at the screen, which continues to show the stars circling around Polaris. After about five minutes, they are ready to share their conclusions with Ms. Whitaker. Each group selects a spokesperson to share their statement, discussed, and revised, the class converges on a statement, which Ms. Whitaker writes on the board:

> Stars that are near the North Star do not rise or set. Instead, they appear to circle the North Star in a counterclockwise direction throughout the night.

Ms. Whitaker informs the class that they have defined what astronomers call *circumpolar stars*. Knowing that students still need to expand their understandings of the concept, she challenges students to apply their definition to a new situation with the question, "Are the circumpolar stars the same everywhere on earth?" None of the students had anticipated this question, and the only response is puzzled looks.

In response, Ms. Whitaker asked the inevitable question, "How can we find out?" and the lesson continues.

Accountability and Learning

On reflection, each of the three approaches—traditional textbook, hands-on computer lab experience, and inquiry facilitated through whole-class exploration—has its individual advantages and limitations.

A traditional textbook lesson employs traditional methods and materials and does not require any new training or support. A hands-on experience in the lab can go beyond static pages in the textbook but requires advance planning and scheduling. In this instance, the students must be taught to master a sophisticated piece of software, consuming time mastering technology that might otherwise be employed for instruction. Written materials, which of necessity are somewhat linear, are employed to guide the experience. In the hands of a capable science teacher, an interactive simulation can be used to facilitate learning through whole-class inquiry in a manner that goes beyond the textbook experience, but in a shared rather than solitary setting. This allows the teacher to respond spontaneously to questions that may occur and for one student's question to stimulate a thought by another member of the class.

The ultimate test involves comparisons of what might be learned under the different conditions. In a recent study I conducted, my co-author K. C. Trundle and I found that under proper conditions, student teachers could learn as much or more about science concepts related to phases of the moon through use of an astronomy simulation than through direct observation. These gains were accomplished in considerably less time than through direct observation.

The basic research on how to deploy new technologies most effectively in schools has not yet been conducted. We are at a juncture when it is important to frame appropriate and relevant questions and secure data that will provide insight. The thought experiment outlined in the three vignettes above is intended to stimulate productive dialogue about appropriate questions, as well as how we might best obtain useful answers.

Resources

Bell, R. L., & Trundle, K. C. (2005). *The sky's the limit: The impact of planetarium software on preservice teachers' conceptions of moon phases.* Paper presented at the annual meeting of the Association for the Education of Teachers in Science, Colorado Springs, CO.

Planetarium Software: http://www.seds.org/billa/astrosoftware.html

Starry Night: http://www.starrynight.com/education.html

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