TECHNOLOGY

IN THE SECONDARY SCIENCE CLASSROOM

Edited by Randy L. Bell, Julie Gess-Newsome, and Julie Luft

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PREFACE

Technology in the Secondary Science Classroom, and its companion volumes, *Science as Inquiry in the Secondary Setting* (now available from NSTA), and *Science Education Reform in the Secondary Setting* (in development at NSTA), has a long and interesting history. The ideas for these books emerged from our work with secondary science teachers, supportive program officers at the National Science Foundation, and the science education community, which is always seeking a connection of theory and practice. In order to ensure that these books were connected to each of these stakeholders, we adopted a writing plan that involved representatives from all three groups. We considered novel approaches to identify and support science teachers and science educators to participate in the project, and we sought guidance from program officers about the format and dissemination of the final product.

To begin with, we identified three topics of interest to both science teachers and science educators. We wanted the community of science educators to help define the content of each book, so we solicited chapter proposals from science teachers and science educators. The response was impressive, with over 50 chapter proposals submitted for the three books. Our selection of the chapters was based upon the clarity of the topic, the type of idea presented, and the importance of the topic to science teachers.

Chapter authors were then asked to generate a first draft. These chapters were shared among the authors of their respective books for review. We met as a group at the annual meeting of the Association of Science Teacher Educators, in Portland, Oregon, to discuss and provide feedback to one another on our chapters. This session was extremely useful, and several of the authors returned to their chapters, ready for another revision.

Once the second revision was complete, we wanted to draw upon the expertise of science teachers, whom we felt should ground this work. We contacted the National Science Teachers Association (NSTA) and placed a "call for reviewers" in their weekly electronic newsletter. Over 200 teachers offered to review our chapters. Reviews were shared with the chapter authors.

The second revision was also shared among the authors within each book. Each author now had external reviews from teachers, as well as reviews from other authors.

To discuss these reviews and the final revision of the chapters, we met one more time at the annual meeting of the National Association for Research in Science Teaching, in San Francisco, CA. At the conclusion of this meeting, chapter authors were ready to write their final versions.

When the chapters were completed and the books were in a publishable format, we approached NSTA about publishing them both in print and online, so that they would reach as many teachers as possible. The editors at NSTA felt the time was right to attempt to offer the chapters of these books free online for teachers. NSTA has historically offered one chapter of a book for free, but the opportunity to break new ground by offering each chapter of this book free online would be new publishing territory. Of course, paper copies of each book are available for purchase, for those who prefer print versions. We also asked, and NSTA agreed, that any royalties from the books would go to NSTA's teacher scholarship fund to enable teachers to attend NSTA conferences.

This process has indeed been interesting, and we would like to formally thank the people who have been helpful in the development and dissemination of these books. We thank Carole Stearns for believing in this project; Mike Haney for his ongoing support; Patricia Morrell for helping to arrange meeting rooms for our chapter reviews; the 100+ teachers who wrote reviews on the chapters; Claire Reinburg, Judy Cusick, and Andrew Cocke of the National Science Teachers Association for their work on this book; Lynn Bell for her technical edits of all three books; and the staff at the National Science Teachers Association for agreeing to pilot this book in a downloadable format so it is free to any science teacher.

Julie Luft, Randy Bell, and Julie Gess-Newsome

CHAPTER 2

Digital Images and Video for Teaching Science

Lynn Bell and John C. Park

With its emphasis on empirical evidence, a great deal of science and science teaching involves observation. Science teachers also know that students can better understand complex scientific concepts when they can see the phenomenon they are studying. That's why science textbooks are filled with photographs and diagrams, and science classrooms typically include microscopes, specimens, and models.

New technologies have revolutionized our ability to see and learn scientific phenomena. Reasonably priced digital still and video cameras have recently become popular additions to many classrooms, and teachers use them regularly to document student learning activities for newsletters, websites, and electronic slideshows. In addition, the advent of the internet has opened up a limitless supply of images and videos on every imaginable science topic.

This chapter will focus on how science teachers can take advantage of the digital images and video available to them on the web, as well as on how to engage students in capturing their own images and video in the process of learning science.

Digital Images in Science Learning

The idea of using pictures in a science classroom is not new. In the late 19th and early 20th centuries science educators advocated the use of drawings to help students learn science. With the invention of film cameras, science textbooks began including more and more photographs, and methods textbooks were written on how to use photographs, slides, filmstrips, and opaque projectors effectively in science teaching.

The quantity and availability of high-quality science-related photographs has exploded with the growth of the internet. Numerous reliable websites provide digital images specifically dedicated to educational use. These resources provide a convenient supply of ready-made images for observing, analyzing, inferring, and questioning.

If you are fortunate enough to have one or more digital cameras in your classroom, students can capture their own visual data and record their experimental results for further analysis. Digital cameras can record not only individual images—including those viewed through an attached microscope or telescope—but they can also record a series of images over time that can be converted to video to capture movement otherwise too slow to view.

Digital Video in Science Learning

Instructional movies also have a long history in schools. As far back as the 1930s, educators and researchers were examining the use of motion pictures to allow students to view events too fast for the unaided eye to catch or to enable students to view events they could not otherwise see because of time or location constraints. In the 1980s easy-to-use video cameras became available, allowing teachers and students to create their own movies for classroom use.

The combination of digital video technology, the web, and inexpensive digital video editing software has improved both the availability of instructional videos and the opportunities for students to create their own works, while also bringing a number of other advantages. Digital videotape or other solid-state media can be transferred to computers for playing or editing. Some cameras can even record digital video directly to the computer hard drive. Users have random-access ability to locate specific scenes on the video rather than having to watch in a sequential linear fashion or move through a length of film or tape to get to the desired location. Digital movies can also be slowed down and scenes can be advanced or reversed one frame at a time.

Software that enables basic video editing comes installed with newer computers (e.g., iMovie for Macs or Windows MovieMaker for PCs) or may be purchased for around $100. With this software, users can delete unwanted scenes from video or cut out short video clips from longer footage.

Very recently, a number of web-based video editors have become available. As they are further developed and refined, these web-based programs will offer two significant advantages for school-based projects: (a) Because both the software and the video product are stored online, students will be able to work on a project from any computer with internet access and (b) video files created online will be instantly available for sharing with other viewers (for more information see Working With Video On the Web, p. 11).

These flexible features all make using video more adaptable to educational needs than ever. In addition, access to good quality instructional videos has increased. Video can be easily shared on and retrieved from the web. There are even commercial companies with large libraries of instructional video content that can be streamed via the web to school classrooms (e.g., Discovery Education's *unitedstreaming*). Recently, the nonprofit organization Next Vista established a website (*www.nextvista.org*) that disseminates open educational digital media, including videos on science topics.

WORKING WITH VIDEO ON THE WEB

This is a rapidly changing area, but some of the first examples of web-based video editing software include:

- Jumpcut (*www.jumpcut.com*)
- Motion Box (*www.motionbox.com*)
- VideoEgg (*www.videoegg.com*)

These services typically permit a certain number of megabytes of video files to be posted at no charge, with modest fees for larger files.

Other sites are popping up that allow users to store short videos online at no charge. To find them, search on names like YouTube, Vimeo, vSocial, DailyMotion, and OurMedia.

Video tagging services are also appearing, which allow users to create tags linked to individual sections of video, so that viewers can skip straight to relevant sections. Some early tagging services include MotionBox, Click.TV, and VeoTag.

What the Research Says

Digital Images

Since the dawn of personal computers much visualization research has focused on modeling and animations, and there has been little to no research on using digital images in teaching and learning. In prior generations, however, a great deal of research was done on the role of pictures in learning (especially pictures paired with text, as in textbooks), and that research can be transferable to the topic of digital images today.

John Bransford and his colleagues (Bransford 1979; Bransford and Johnson 1972) conducted some of the more well-known studies on pictures and learning. They determined that a picture can increase comprehension and recall by providing context before students read a passage—a form of advance organizer.

Levie and Lentz (1982) reviewed 55 studies investigating how representational pictures affected learning of information presented in written texts. They concluded that these studies provided overwhelming evidence of a significant positive effect of pictures on learning related text information—both in terms of comprehension and recall.

A few years later, Levin summed up the essence of the research findings on the role of pictures in learning in this way: "Pictures interact with text to produce levels of comprehension and memory that can exceed what is produced from text alone" (1989, p. 89).

Digital Video

In 1951, researchers Hoban and van Ormer summarized research on instructional films up to that point with the following generalizations:

- People learn from films.
- The use of effective and appropriate films results in more learning in less time and better retention of what is learned.
- Films in combination with other instructional materials are better than either alone.
- Instructional films stimulate other learning activities.
- Films facilitate thinking and problem solving.
- Films are equivalent to a good instructor in communicating facts or demonstrating procedures.

In the late 1970s and through the 1980s, some educators turned to interactive video (stored on videodiscs or laserdiscs), which included both video and still images that could be computer controlled. An analysis of 10 years of research (McNeil and Nelson 1991) found that uses of interactive video to supplement instruction resulted in "higher achievement affects than when interactive video was used in place of traditional forms of instruction" (p. 3). The researchers also concluded that interactive video worked best when it was guided and structured, as opposed to being entirely under the control of the learner.

Recently, an evaluation of a commercial video-streaming library marketed to schools determined that some students who viewed a number of the subject-specific video clips scored higher on content-knowledge tests than did students receiving instruction "in the usual manner" without the video clips (Boster et al. 2006). The gains were not consistent across all age groups and subject areas, however, and authors suggested that possibly the quality of video content suffered in some areas or that too much time had elapsed since some teachers had undergone training on how to teach with the video clips. Both explanations underscore that there's nothing magic about the videos themselves.

Other studies examined how pictures and video can be used most effectively to aid learning, and their results are presented in the following section that provides guidelines for using digital images and video in teaching and learning.

Guidelines for Best Practice

A few practical guidelines for using digital images and video effectively in science instruction can be gleaned from the literature. The guidelines are based on the assumption that the images and video will be viewed on a computer screen, with or without the aid of a computer projector.

(1) Selected photos and videos must specifically illustrate the targeted content and match the instructional goal.

Bransford and colleagues determined that to be effective a picture must provide information about the relations among the concrete elements being described in the text. In addition, they found that pictures best aid in the comprehension of text (as well as in long-term recall, Findahl 1971) when they are closely related to the information provided in the text. Pictures seem to have the greatest effect when they provide a way for people to interpret what they have read or heard, when they provide a means for connecting or organizing the information in the text, or when they help readers verify their understanding of the text.

On the other hand, Levin, Anglin, and Carney (1987) found that pictures serving a primarily decorative purpose had no positive effect and sometimes served as a distraction from learning the target concepts.

Photos can be especially effective when showing students objects they might not otherwise be able to see—such as microscopic organisms and structures, astronomical objects, spatial relationships in ecosystems, and adaptations of plants and wildlife. They may also be helpful with learners for whom English is a second language.

Dale provided excellent advice in his 1969 text on methods for using pictures: "Each picture should accomplish a definite purpose in the lesson. Plan to introduce each item at the proper point—to bring clarity and reality, to suggest a question, to correct a misunderstanding, to concretize a verbalism, and so on" (p. 447).

Likewise, Dale recommended that before using video (or "motion pictures" in his day) teachers should know what they want students to learn—"new facts, relationships, manual skills, judgment, application of film material?"—and select video accordingly. Hoban and van Ormer (1951) noted that movies cannot stand alone to replace the teacher, but movies have specific strengths, especially in terms of reinforcing and extending previous knowledge, attitudes, and motivation.

In summary, use your limited time to find images and video that engage students' attention in the content they need to learn. Don't succumb to the temptation to spend hours looking for cute clipart and fancy PowerPoint backgrounds. Although these may provide aesthetically pleasing visuals, they have little potential to help your students better learn science.

(2) Ensure that students have a meaningful interaction with images or video.

To be fully utilized by students, photos and video require skillful questioning and discussion led by the teacher. A sure way to cut off opportunities for interaction is to point to the subject of an image and tell students what it is. Instead, begin with general questions, like, "Why did I put this image up? What does it have to do with what we're studying?" The difference between good and bad class discussion is often questioning versus telling.

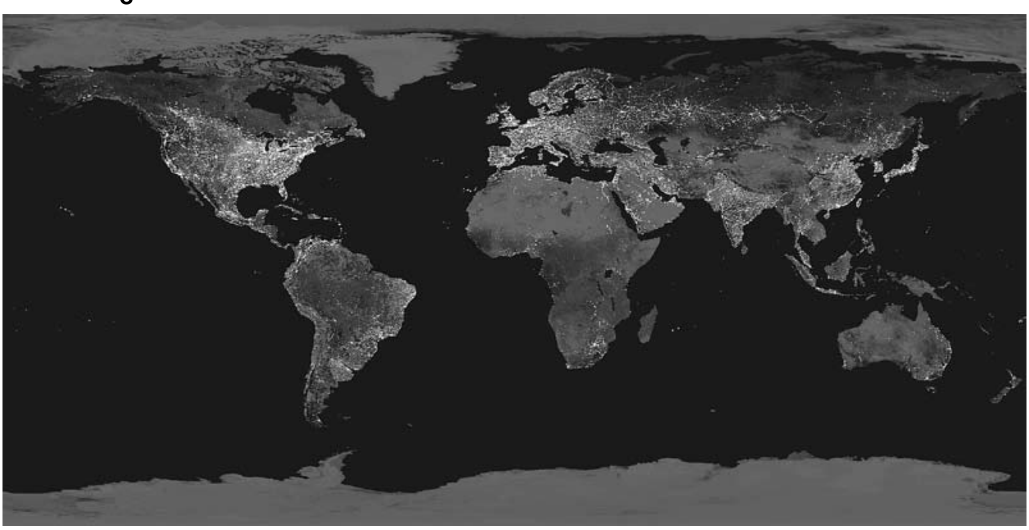
Weidenmann (1989) was concerned that students usually view text as more informative than pictures and that they give even good pictures only a brief glance. Furthermore, he found that a passing reference to a picture in a text (such as, "See Figure 1") is not enough to direct students' attention to the picture. "Most people are convinced that the understanding of pictures requires only a small amount of invested mental effort. As a consequence, one tends to process pictures only superficially" (p. 161). Weidenmann concluded from an exploratory study that learners perceived pictures to be the most beneficial when the text explicitly directed their attention to the pictures' informational aspects.

Weidenmann's findings can also apply to students viewing an image on a screen. Left to their own devices they are likely to consider only the aesthetics of the image and miss the rich information it provides. You may need to guide students in the skill of picture reading, which ranges from simply enumerating objects in a photograph to interpreting and inferring. For example, using an image like the well known "Earth at Night" photo (Figure 1), you can ask questions like,

- What do you see here?
- What is this a picture of?
- Which areas have the most light?
- Why do you think that is?
- Do you think this image represents Earth at an instant in time?

Figure 1.

Earth at night.



C. MAYHEW AND R. SIMMON (NASA/GSFC), NOAA/NGDC, DMSP DIGITAL ARCHIVE

Discussion before and after showing a video (of any length) is also important. Videos are more effective when, prior to viewing, students are instructed what to look for or what questions will be raised or answered in the video (Dale 1969). These issues should be brought up again after the video in a debriefing session. You'll want to evaluate whether students understood what they saw and whether they learned the content you wanted them to learn or noticed the phenomenon you want to explore further.

(3) Make sure the image or video supplements your good instruction, not replaces it. Video and images should never be used merely as filler or so the teacher can avoid teaching the subject. The mere fact that video and images are easier to obtain doesn't mean they add value to learning. Remember, too, that displaying a video or image in the presence of students does not automatically ensure that students now understand the target concept. Every video clip or image should provide good examples of science content or show students what they could not otherwise see (e.g., different types of volcanoes or the consequences of improper lab procedures). Images do not have to be spectacular to add value to your lesson. In some cases, simple close-up photographs are useful. For instance, a close-up image of a volumetric flask provides a much more realistic view of the meniscus than the typical textbook drawing (see Figure 2).

Figure 2.

Close-up photo showing meniscus.

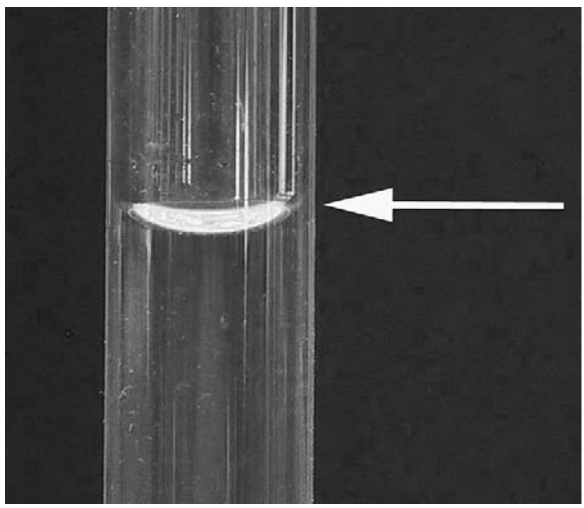


PHOTO BY CHRIS SCHNITTKA

(4) Model appropriate use and attributions of copyrighted digital images and video.

Every teacher should model appropriate use and attributions of digital images and video taken from the web. Web content is not a free-for-all. Images and video are copyrighted just as text is. Although some educational uses fall under "fair use" guidelines, this can be a murky area, so know your school district policies on this issue. Some districts have adopted the Educational Multimedia Fair Use Guidelines, developed in 1996 by the Consortium of College and University Media Centers (Guidelines available online at *www.utsystem.edu/OGC/IntellectualProperty/ccmcguid.htm*).

DIGITAL PHOTO QUALITY

For computer screen or electronic slideshows, the resolution of the final picture (after cropping) needs to be around 72 pixels per inch (ppi). If you want the picture to fill the screen, it should be around 800–1,000 pixels wide at 72 ppi.

Higher resolution means the digital image will take up more file space than necessary. A slide presentation file full of high-resolution photos may become so large that it is difficult to transport it to other computers.

Lower resolution (less than 72 ppi) will result in a blurred image with jagged edges. If you need to enlarge a picture, make sure that the resolution is higher than 72 ppi to begin with, because as you enlarge the picture, the resolution will decrease.

Images can be resized with photo editing programs, like Adobe Photoshop Elements or the GIMP (a free download from the web).

Although these guidelines were never adopted into law, they still provide useful advice. A more simplified summary of the guidelines can be found on the North Carolina Department of Public Instruction website at *www.ncpublicschools.org/copyright1.html*.

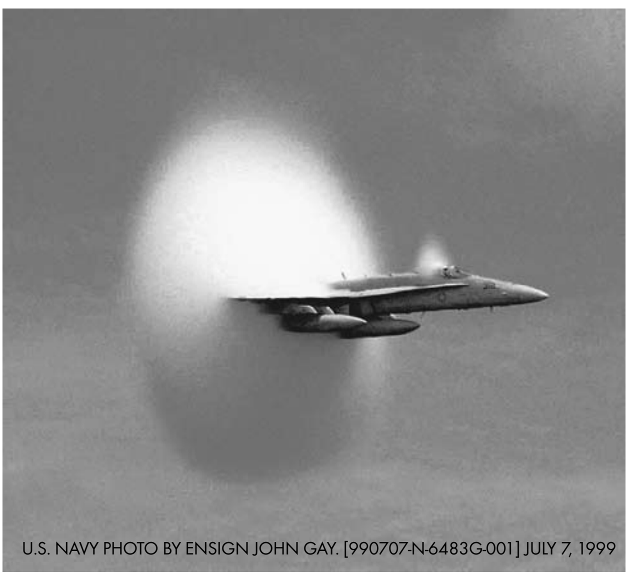
Examples of Best Practice

Using Digital Images and Movies as Hooks or Advance Organizers

Without too much effort (and at no cost!), you can probably find a great photo or movie on the web to introduce about any science topic. Good images or video along with creative questioning can capture students' attention and set the context for their later comprehension of the topic you will discuss.

Figure 3.

Condensation cloud.



Digital Images

For example, after some initial instruction on the Doppler effect, you might challenge students with the cloudburst pictured in Figure 3. You might ask students to use what they know about sound waves and compression to explain the conditions or factors that would cause the cloud to be produced by the jet. (For opposing explanations of this effect, see *http://sonicbooms.org/images/F18Condensation.html* and *www.eng.vt.edu/fluids/msc/gallery/conden/pg_sing.htm*.)

Digital Video

Introduce the topic of average velocity by showing a scene from an action movie like *Back to the Future III*, in which characters Doc, Marty, and Clara are accelerating down the railroad tracks on a speeding locomotive toward an unfinished bridge. The locomotive slams through a barricade stating that the track ends in one-fourth mile. Students can use stopwatches to time the duration from when the locomotive hits that sign to when it reaches the end of the track. Since the distance is known from the movie and the time is known from the stopwatches, the average velocity can be calculated. Were they close to the required 88 miles per hour? The height of a large wheel of the locomotive can be estimated; hence, the circumference can be calculated. Knowing the time that it takes for one rotation of the wheel by counting the number of frames, the average velocity can be calculated.

Figure 4

This photo captures the physical reaction taking place when several Mentos candy pieces are dropped into a 2-liter bottle of soda. Carbon dioxide rapidly goes from the dissolved state to the gas state as it nucleates on the microscopic pits on the surface of the candy. Something about the candy dissolving affects the surface tension that normally keeps the bubbles compressed.

Analysis

Digital Images

An observation and inference exercise can help students learn important process skills.[1] Use an interesting photo, like the one in Figure 4 that shows an object or event not immediately recognizable to students. Then have students perform the following steps.

[1] This activity is based on a photo analysis worksheet constructed by the National Archives (*www.archives.gov/education/lessons/worksheets/photo.html*).

VIDEO IN THE PHYSICAL SCIENCE CLASSROOM

In Mr. Fox's physical science class, students video recorded their rocket flights and were challenged to determine how high their rockets flew (without the aid of video analysis software). Here's how they did it: Students knew that at the peak altitude of rocket flight an ejection charge releases the recovery system (usually a parachute or streamers). Students could see the recovery system ejection on the video and also hear the "pop" of the ejection charge. They timed the seconds between seeing the ejection and hearing the charge, then used what they knew about the speed of sound to calculate the peak altitude of the rocket.

Observe: Study the photograph for one minute. Form an overall impression of the photograph and then examine individual items.

Infer: Based on what you have observed, list three things you might infer from this photograph.

Do you think all the other students in the class will make the same inferences you have? Why or why not?

Questions: What questions does this photograph raise in your mind?
Have students share their responses and bring closure with a discussion about differences between observation and inference.

Figure 5.

Final frame used in a movie that shows the position of the model rocket once every three frames, using the boy as the frame of reference for height.

SCREEN CAPTURE OF VIDEO PLAYBACK USING VERNIER LOGGER PRO SOFTWARE.

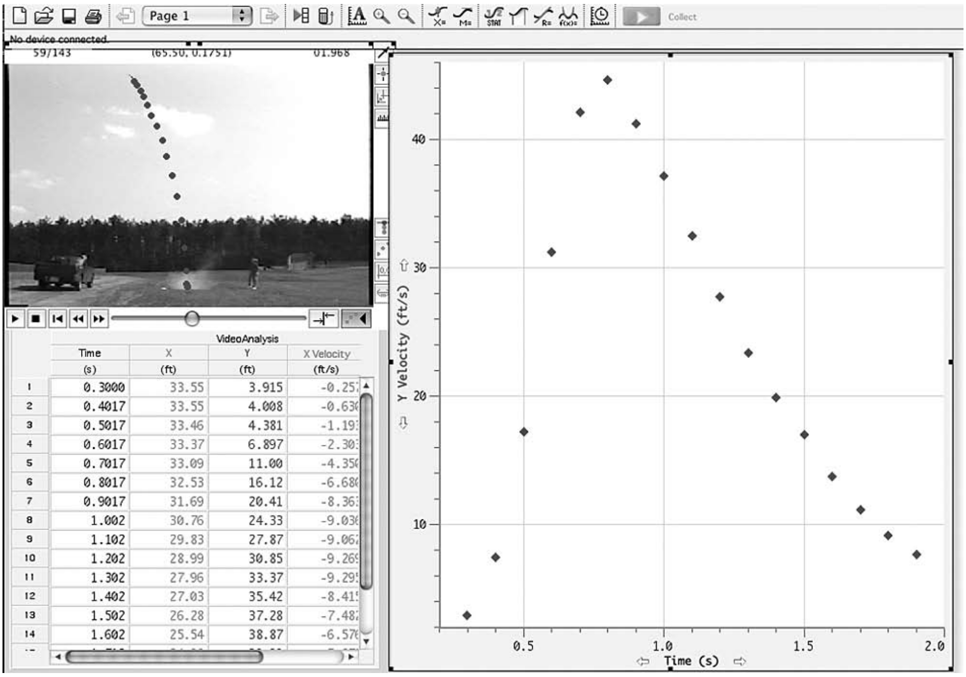
Digital Video

Video recording students' hands-on activities provides multiple opportunities for analysis. For instance, in a model rocketry project, video can capture the rocket flight, allowing students to later review aspects of the event they may have missed because they were occurring too quickly (see text box, above).

A number of video analysis programs have recently come on the market that allow students to mark an object's location frame by frame on a video to determine velocity, acceleration, and (if mass is known) other values like force, momentum, and potential energies. Students see the video

Figure 6.

Resulting vertical velocity–time graph from the position data captured from the movie.



SCREEN CAPTURE OF MOTION ANALYSIS USING VERNIER LOGGER PRO SOFTWARE.

playback and a graphical representation of the data side by side on a computer screen (for examples, see Figures 5 and 6). This technology allows students to study two-dimensional motion and multiple objects in motion. Students can make more precise analyses of model rocket flights, and track movement of other objects such as a car going down a ramp, a ball bouncing or tossed into the air, or a person walking or running. For ideas on using video analysis software with probeware, see Chapter 4.

Figure 7.

July 22, 1980 eruption of Mount St. Helens, with Mount Adams, Washington, in the background.

USGS PHOTOGRAPH TAKEN ON JULY 22, 1980, BY JIM VALLANCE.

Seeing Natural Objects Outside Students' Experience

Digital Images

Lots of free images can be found on the web that allow students to see natural objects they might not otherwise be able to view firsthand—fossils, fungi, marine animals, volcanoes, or fault scarps, for example. The following are a few websites with good images for science.

- **Volcano World**
  A collection of volcano photographs from around the Earth and beyond:
  http://volcano.und.edu
- **Erosion: Sediment Is Transported**
  These images show that rocks and sediments get removed from their original locations, building up in some regions and resulting in stripping in other regions:
  www.crewten.com/g_pinto_t2.html
  http://uregina.ca/~sauchyn/geog323/mw.html
- **Fossil Image Galleries, The Virtual Fossil Museum**
  Picture galleries of fossils organized by taxonomy and fossil site:
  http://www.fossilmuseum.net/index.htm
  Additional fossil images can be found on the Fossil Images Archive:
  www.fossilmuseum.net/Education.htm
- **Hubble Site Gallery**
  This official site of the Hubble Space Telescope includes images of deep-space objects and space shuttles:
  http://hubblesite.org/gallery
- **What We Eat . . .**
  Photomicrograph pictures of popular food items, like hamburger, onion, lettuce and potato… or what your food looks like at a cellular level. These would be good to identify similarities and differences between animal and plant cells, and even differences between plant cell structures:
  http://micro.magnet.fsu.edu/micro/gallery/burgersnfries/burgersnfries.html

Digital Video

Especially when you want to engage student thinking about chemical reactions or other events that may be too dangerous, too expensive, or just impossible to do in the class, digital videos can be useful. Good websites for obtaining science videos include the following:

- **Journal of Chemical Education**
  Sample movies from Chemistry Comes Alive:
  http://jchemed.chem.wisc.edu/jcesoft/cca/cca0/sampmovs.htm
- **Miller Single Concept Films in Physics**
  http://physics.kenyon.edu/coolphys/FranklinMiller

- **Science Junction**
  Day and Night—Changes During the Year:
  www.ncsu.edu/sciencejunction/station/experiments/earthkam/simulation/year.html
- **Phases of the Earth as Viewed From the Moon**
  www.ncsu.edu/sciencejunction/phasesofearth.html

Collecting visual data

Digital Images

The following are some ideas for engaging students in collecting their own visual data:

- Create virtual leaf and flower collections: Students can take their own photos (including photos of habitat). Hold an online digital picture scavenger hunt for students who don't have access to natural areas. Compile images into a dichotomous key or field guide to the local flora.
- Record life cycles: Using a digital microscope or camera that can be set to capture images at regular intervals over extended periods of time, photograph a butterfly emerging from its chrysalis, a pet tarantula molting, or a seed germinating. Then use software to convert the still images into a digital video.
- Record long-term events: Create a photo sequence of changing shadows throughout a day or across seasons. Use a digital microscope (or a camera attached to a traditional microscope) to take time-lapse photographs of crystals forming from a drop of salt water and use software to convert the still images into a digital video.
- Take before-and-after pictures of experiments or lab activities.

Digital Video

Students can create a digital video from still images. Using their own digital images or those obtained from the web, students can insert images into the storyboard of a digital video editor. Many of today's tech-savvy students have this software on their home computers and will be adept at adding text, background music, transitions between images, and even narration in their own voice to create a movie synthesizing their understanding of a science concept.

In addition to filming objects in motion for video analysis in physics classes, students can collect video data on animal behavior or other natural phenomena involving movement. A small wireless video camera attached to a bird feeder is a great way to collect data about the types of birds in the area.

Conclusion

The great thing about digital images and video is that you don't need a huge equipment budget and a roomful of computers to take advantage of them. Even with a single computer connected to a projector or television screen and an internet connection, you can have access to a variety of resources for engaging students and helping them learn science concepts.

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