

# CHAPTER 1

## Educational Technology in the Science Classroom

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**T**echnology has transformed the way in which science is conducted. Almost every aspect of scientific exploration has been touched in some way by technology, and much of today's science would not be possible without it. The mapping of the human genome, astronomical observation, weather forecasting, and the development of emerging nanotechnologies are all dependent upon information technology.

Information technology is simultaneously transforming society. The way in which leisure time is spent is very different than a few years ago. In the last half of the 20th century a typical child watched television an average of three to four hours per day. This experience essentially consisted of passively viewing materials created by others.

The most recent Pew Foundation survey (2005) found that 87% of all teenagers report using the internet. The majority of students interact with one another socially via the web. They use text messaging, voice over internet protocol (VOIP) communications, and videoconferencing to communicate with one another. They interact with and use online media—digital music, video, and news accessed through the web.

Students are also becoming content creators—creating and sharing media such as original artwork, digital photographs and videos, blogs, and web pages. Many of these students have grown up with the internet and can be characterized as digital natives.

The nation has made a concerted effort to provide the infrastructure that will make it possible to employ these technologies in school, as well. Each year billions of dollars are invested in establishing an effective infrastructure for employing information technology in schools. Almost all classrooms have been wired for internet access, computers have been installed, and inservice sessions are being offered to demonstrate ways in which technology can be employed. The ultimate goal is to enhance student learning.

Some science teachers have been in the forefront of this technological transition. These innovators and early adopters have integrated microcomputer-based probes into their laboratories, employ digital videos and imagery to illustrate concepts in class discussions, and are using administrative programs and electronic gradebooks to organize their classes.

Other teachers are waiting until best practices emerge that will allow them to determine the conditions under which gains in learning outcomes justify use of technology in the classroom. This book serves science teachers in both categories.

It has long been our philosophy that technology can be worth the time and expense when (a) it is used to address worthwhile science in ways that are pedagogically appropriate, (b) it makes scientific views more accessible, and (c) it helps students be able to engage in science learning they could not otherwise do without the technology (Flick and Bell 2000). A base of research literature is emerging that provides evidence that some computer tools are effective in these areas. Practically speaking, computer technologies that will appeal to the widest variety of science teachers should also be easy to learn and should, ideally, be able to address a wide range of science topics.

The goal of this book is to provide an overview of a range of computer technologies having the potential to help students better learn science content. Some of these technologies are relatively easy to master—the majority of American households now have a digital camera, for example, because they are inexpensive and easy to use. Other technologies such as some geographic information systems and digital probe-ware will appeal to those who welcome the challenge of more complex systems.

We hope that each chapter will stimulate your thinking about the potential of these tools to engage your students in science learning. The chapters that follow offer a snapshot of the latest trends, providing for each technology:

- (1) A summary of current research regarding the technology's effectiveness and classroom implications
- (2) Best practice guidelines for teaching with the technology, drawn from the research and practitioner literature
- (3) A few innovative ideas for teaching science content with the technology tool

### **Pedagogy + Technology + Content**

The chapters that follow provide insight into ways to employ technology both to address existing educational objectives and to examine possibilities for exploring new conceptual frontiers. The technology itself is typically neutral—it is only when a technology is combined with an appropriate teaching strategy that it becomes effective.

Therefore, the technology cannot be discussed in isolation—it must be combined with a description of the teaching strategy. A description of the manner in which a *pedagogical strategy* is combined with *technology* to teach specific *content* is crucial.

### *Pedagogy*

The authors of the chapters that follow provide illustrations and examples of pedagogical strategies in a range of contexts. Often the same technology can be used for a variety of instructional approaches. For example, classroom use of a virtual planetarium is discussed in Chapter 3 on simulations. As this chapter indicates, virtual planetarium software can be used in a number of different ways—for direct instruction (e.g., to orient students and provide scaffolding) or in a student-centered, experiential way.

As illustrated in Table 1, either of these approaches could be employed in the computer lab or through whole class instruction with the aid of a computer projector.

<b>Table 1. School uses of information technology.</b>		
	<b>Classroom</b>	<b>Computer Lab</b>
<b>Direct Instruction</b>	X	X
<b>Student Inquiry</b>	X	X

These approaches are not mutually exclusive. In some instances the teacher might choose to scaffold a computer activity through direct instruction in a whole-class setting followed by a student-centered inquiry-based experience.

### *Technology*

Technology provides a means to good science instruction but is not an end in itself. To be effective, technology must provide tools that facilitate and enhance instruction. Improving data collection, visualization of abstract phenomena, and simulations of experiments that would otherwise be impossible in school classrooms are some specific ways that technology can enhance student engagement and learning.

In practice, every technology tool involves a certain amount of instructional overhead. The ideal technology has a low threshold and a high ceiling. In other words, it will be intuitive for the novice to learn and yet support increasingly sophisticated activities.

If the technology will be used for a wide range of topics through the entire school year, the time required for mastery may be a good investment. On the other hand, if a tool will only be employed for a lesson or two, the functions of the tool must be straightforward to justify its use.

Advances in technology and user interface design can make tools that were once cumbersome to use more accessible. For example, probeware at one time was difficult to install and configure. A newer generation of scientific probeware that interfaces directly with standard USB ports has simplified configuration and setup.

### *Content*

People who enjoy new gadgets may be tempted to incorporate technology into the science classroom for its own sake. However, technology use is more appropriate when it enhances the learning of worthwhile science concepts and process skills. It should be used to help students explore topics in more depth and in more interactive ways and to promote student-centered, inquiry-based learning.

Many scientifically accepted ideas are difficult for students to understand due to their complexity and their abstract or counterintuitive nature. A number of studies have documented the potential of specific educational technologies to make scientific concepts more accessible through visualization, modeling, and multiple representations. Many of these studies are cited throughout the chapters of this monograph.

As a practical matter, educational technologies must support existing instructional objectives in order to be effective, and science activities should not be developed merely because technology makes them possible. An increasing emphasis has been placed on educational accountability in recent years. Instructional objectives identified at the state and national levels reflect the distillation of considerable effort by expert groups. Although technology can sometimes offer the opportunity to add new objectives to this inventory, it is most likely to be used when it can also address existing educational objectives as well—especially those found on high-stakes assessments.

## **A Framework for Integrating Technology**

Much of the value of information technology can be found in its capability to allow students to work with data, to enhance visualization of complex concepts or of unfamiliar places and objects, and to facilitate communication and collaboration.

### *Data Collection and Analysis*

The *National Science Education Standards* Science as Inquiry Standard (NRC 1996) stated that all students need to learn how to *analyze evidence and data* by, for example, determining the range of the data, the mean and mode values of the data, plotting the data, developing mathematical functions from the data, and looking for anomalous data. The Standards suggest that the data analyzed can be drawn from students' own investigations or from other students' investigations, but can also be acquired from external scientific databases. They also recommend that computers

be used for collection, analysis, and display of data. The chapters that follow address use of technology in this manner.

Real-world data has an inherent messiness, with anomalies sometimes cropping up. It is productive to allow students to understand the nature of the scientific data collection process. This is the rationale for scientific laboratories. Technology simply extends these capabilities, just as it has for scientists themselves. Chapter 4 on scientific probes describes ways in which these tools can be used to support scientific inquiry. Similarly, Chapter 5 describes how specialized sensors in geosynchronous Earth satellites can be used to acquire data that can extend scientific exploration by students.

Much of today's science involves acquisition of massive databases by teams of scientists and others. These databases exceed the capabilities of a single student or class to replicate. Fortunately, in the spirit of scientific sharing, many of these databases are freely available on the web. Chapter 6 on acquisition of online data describes how these databases can be employed to facilitate scientific analysis and understanding.

Scientific simulations are derived from models based on data collected by scientists. These models can be useful in allowing students to visualize patterns that would be difficult to understand otherwise. Chapter 3 on scientific simulations describes research indicating that this approach can be effective in enhancing student learning.

By combining the triad of data collected by students, data collected by scientists, and scientific simulations and computer models derived from scientific data, science teaching can take advantage of new facilities for enhancing student learning. Technology can allow students to explore data, make predictions, and form conclusions. It can be used to confirm textbook assertions but is perhaps most powerful when it also facilitates inquiry and guided discovery.

### *Imagery and Visualization*

The value of imagery for understanding scientific concepts is well known. Technology has improved access to science-related digital photographs and video. It has also improved the feasibility of students collecting their own visual data. Digital cameras are perhaps the most ubiquitous technology in society today. Digital cameras have been incorporated into cell phones and personal organizers. Thousands of webcams with live feeds now span the globe. Millions of publicly available images are being uploaded to photo-sharing services. The next generation may become the best documented visually.

Chapter 2 describes best practices for use of both still and moving images in the science classroom. Although images can be valuable for learning, the research available to date indicates that this only occurs under certain conditions. These conditions are described in the chapter, along with illustrations and suggestions for ways in which digital images and video can enhance learning.

### *Communication and Collaboration*

The advent of the internet has changed the way in which scientists communicate and collaborate and it is changing science teaching as well. Chapter 7 describes ways in which the web can be used to support science inquiry in teaching. Often these projects take place in a conventional classroom but take advantage of the web to extend the boundaries of the project in ways that would not be practical otherwise. For example, the National Geographic Society Kids Network Acid Rain project allowed students across the United States to measure the acidity of local rainwater and aggregate these results to construct a composite picture around the world in concert with the efforts of similar classes. As noted in Chapter 7, it is the combination of the web-based tools and capabilities in concert with a specific inquiry-based teaching strategy that produces the outcomes associated with these kinds of initiatives.

### *Distance Education and Evaluation*

The internet has also enabled distance education. Distance education is rapidly growing at all levels: in high schools, community colleges, and research universities. Theoretically, all the advantages of online technologies can be available through virtual science classes. Chapter 9 summarizes what is currently known about best practices associated with teaching and learning science in virtual science classrooms.

Computer technologies have affected other areas of education, as well. Many teachers have adopted administrative technologies to help them keep track of assignments and grades and computerized testing programs that provide banks of test questions. Since this book is about uses of technology to teach content, Chapter 8 describes an innovative use of online assessments to encourage student collaboration in their science learning.

## **Summary**

At the dawn of the computer age, then-director of the U.S. Office of Scientific Research Vannevar Bush published an influential paper, “As We May Think” (1945). This paper attempted to consider the implications of a world in which all information would be stored with the capacity to create associative links between related materials. This visionary essay ultimately influenced innovators who conceived the computer mouse and the modern graphical interface as well as the subsequent development of the internet.

Today we are rapidly approaching an era in which the majority of the world’s information is digitally stored and searchable. Schools have arguably been affected by technology less than any other aspect of society. In certain respects this is appropriate; schools are conservative institutions, so will be less subject to fads and shifting educational cycles. However, it is clear that the digital revolution is anything but



temporary—it is a permanent change that is affecting all of society.

The question to consider is how this capability may be best employed, both in society and in science teaching. If you are an early adopter, you should find some interesting new concepts here for using computer technologies in your science classroom. On the other hand, you may have been waiting to be convinced that computers offer more to the science class than expensive bells and whistles. The chapters that follow describe many ways in which even inexpensive technologies combined with appropriate teaching strategies can be effective at helping science students learn science concepts more effectively.

