FASTBACK

297

Using Microcomputers for Teaching Science

Steven J. Rakow, Terry R. Brandhorst

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STEVEN J. RAKOW

TERRY R. BRANDHORST

Steven J. Rakow is an assistant professor of science education at the University of Houston-Clear Lake, where he teaches courses in elementary science methods and education research. He also teaches a class of fourth-grade gifted and talented students for a local school district. Rakow received his B.S. in chemistry from Illinois State University, his M.A. in education from the College of St. Thomas, and his Ph.D. in curriculum and instruction from the University of Minnesota. His research interests include the status of minority (especially Hispanic) students in science education and the use of computers in science education. He is currently the editor of *Science Scope*, the National Science Teachers Association journal for middle and junior high school teachers.

Terry R. Brandhorst is a chemistry teacher at Clear Brook High School in the Clear Creek Independent School District near Houston, Texas. He has won numerous awards for teaching excellence, including the Science and Engineering Fair of Houston Teacher of the Year Award two years in a row and the Southwest Texas ACS Teacher of the Year Award in 1988. He was a 1984 Dreyfus Fellow in Chemistry. Brandhorst received his B.S. in zoology from Texas A&M University and his M.S. in biological sciences from the University of Houston-Clear Lake. He currently is a doctoral candidate in curriculum and instruction at Texas A&M University.

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by
Steven J. Rakow
and
Terry R. Brandhorst

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A Computer-Enriched Science Learning Environment

The science laboratory can be exciting. In the laboratory students can ask questions about the world around them, design experiments, make observations, and unravel the mysteries of nature by manipulating the physical world.

My laboratory, however, is very special. In my laboratory, students are collecting data with a precision that would have been unthinkable only a decade ago. Students are measuring times to the millisecond and masses to the milligram. Students are engaged in creating and testing models to explain their observations about the world.

Why is my laboratory so unique? In my laboratory, in addition to beakers, test tubes, and balances, the students have one more piece of scientific equipment. They have computers. Let's take a walk around the lab and see how the students are using their computers to enhance their science laboratory experience.

The first impression of the laboratory is one of organized chaos. Twenty-four middle school students are divided into groups of four. Each group is engaged in a different activity. What these activities have in common is that the computer is a central part of the investigations.

The first group is intently studying a stack of LEGO™ building blocks. One of the students has drawn a plan of a car the group will construct with the blocks. But as the students begin to build the car, they discover that they need to make some modifications in their design.

"What are you building?"

"This is a car. We're going to have a sensor in the front that will know when the car bumps into the wall. Then it will tell the car to turn around."

"What will make the car run?"

"There is a motor on the car that is run by the computer. Mary is going to write a computer program in Logo that will tell the car where to go. Right now we are trying to figure out how to get it to turn around."

A second group of students is engaged in a chemistry experiment.

"Did you know that some chemicals get really cold when they are mixed with water?" one of the students asks.

"I wonder how you could measure just how cold it gets?" I reply.

Almost as a chorus they respond, "Our temperature probe."

Quickly the students retrieve the Science Toolkit: Master Module™ from the file cabinet. They attach the small black box to the back of the computer, plug the thermometer probe into the box, and load the program into the computer.

"I think that we should use the strip chart. Then we can tell how the temperature changes over time."

Once the students have the computer ready, they begin the experiment. They put some water into a styrofoam cup.

"Let's be sure to record the temperature of the water."

They press the space bar and the computer begins to receive hundreds of data points each minute from the thermometer probe. The strip chart begins to move and the temperatures are plotted against time. Next the students add a tablespoon of baking soda to the water. Slowly the line begins to dip downward as the temperature decreases. After two minutes of recording, the temperature decreases by almost four degrees Celsius.

"I guess we can't make ice cream with it, but it did get colder."

As I move around the room, I notice another group carefully studying a collection of rocks.

Students plot the sound waves of their voices and musical instruments using the program, Sound, *by HRM Resources.*

"The computer is asking if it is shiny and black?"

"Type in 'yes'."

"It says that it is 'obsidian.' Put the obsidian label next to that rock."

Using glass, plastic, and metal plates, the students proceed to investigate the relative hardness of each of the rock samples. With the aid of the computer and the results of their investigations, they are able to classify each of the rock samples.

"We're trying to identify an organism from another planet," a student in the fourth group says. "We have to find the temperature where it grows best and the best amount of light. Right now we are doing an experiment where we have a hot temperature on one side and a cold temperature on another side. There go six of the creatures. Look! Five of them went to the hot side and one stayed near the middle. I guess the organism grows best in the hot. Next we have to keep the temperatures the same and change the amount of light. It is important to change only one thing at a time. If I get it right, the computer will name the new organism after me."

My attention is drawn to laughter from the fifth group.

"That's the strangest looking bird that I've ever seen," laughs one of the students.

"What are you working on?" I ask.

"We're trying to find the bird that is best adapted to our environment. We want a bird that will soar to great heights and swoop down on its prey."

"See, we have to decide which beak the bird should have," said one of the students. "We have six choices. I think that one would be best."

"Now we need to see what kind of claws the bird should have. Those look like they would be good for grabbing fish. Let's see what kind of bird we have now."

"Yeah! We got it right," they shout. "The computer says that it is an eagle."

As I approach the sixth group, I hear one of the students shout, "Look out!" Just then a plastic dart shoots past my head.

"Sorry," says one of the students. "We are trying to find out how far the dart will go."

"How are you using the computer?" I ask.

"We are entering information into the computer and it is telling us where the dart will land. See! We tell the computer how high the dart goes when it is shot straight up. Then we say that we are going to shoot the dart at a 45 degree angle. It says that the dart should go 15 meters. But we found that it only went 13. Let's change the model. We will tell the computer that the dart is two centimeters in diameter. That way we can take into account air resistance. Now the computer says that the dart will go 13 meters. I guess it is important to give the computer as much information as possible."

To many teachers, this laboratory might seem to be a futuristic scenario. However, it is very real and found across the country in science classrooms where teachers have been bitten by the computer bug.

How are computers being used in the nation's science classrooms? Most indicators suggest that in the majority of science classrooms computers are not being used at all. According to a recent Office of Technology Assessment report (*Elementary and Secondary Education: A Technical Memorandum*, Washington, D.C.: U.S. Government Printing Office, 1988), only 1% of computer use in elementary schools is for science and only 5% to 10% of computer use in secondary schools is for science. Perhaps part of the reason for the limited use of computers in science classrooms is that few science teachers are trained in the use of instructional technology. This same report indicates that fewer than one-third of the science teachers have had coursework in instructional computing or computer programming.

Where computers are used, there is typically one computer for a class of 25 to 35 students. In these cases, the computer most often is used only as an extension of the teacher's demonstration. There are some excellent pieces of science software that have been written especially to be used for teacher demonstrations. However, computers should be used for much more than just demonstration.

In a few cases, teachers have access to multiple computers, either in a computer lab or through portable computers that may be brought into the teacher's room. Although the computer lab is a practical way of managing computers for most subject fields, it can be very limiting when a teacher is attempting to use the computer to collect laboratory data. Rarely does a computer lab have the necessary access to water, gas, or laboratory equipment that is needed for hands-on laboratory investigations.

It is a rare science classroom that has multiple computers permanently installed in the classroom. Although rare, this nevertheless should be the goal if computers are to achieve their rightful stature beside the Bunsen burner, the analytical balance, and the microscope as an indispensable piece of laboratory equipment.

The next few sections will summarize some of the various applications of computers in the science classroom. Specifically, traditional computer-assisted instruction, simulations, computer interfacing, and classroom management will be considered. Finally, the role of emerging technologies will be discussed with an eye toward the future of computers in science teaching.

In addition, the computer programs discussed in this fastback are listed in the Appendix. These are examples of software that the authors have found to be particularly useful. However, science educators should investigate a variety of computer programs, read the reviews of these programs published in computer education journals, and talk with other educators who have used these programs. In this manner, science educators will find the best software to meet their needs.

Computer-Assisted Learning

A little more than ten years ago, the educational use of computers was very different than it is today. Before personal microcomputers were available, computer users sat in front of an oversized typewriter (similar to a teletype machine), telephoned a remote computer, and communicated by typing responses to the computer's promptings.

In these PM (Pre-Microcomputer) days of instructional computing, most computer programs followed a common format:

1. Ask a question.
2. Accept a student's response.
3. Compare the student's response to a set of acceptable answers.
4. Provide feedback.

These programs were referred to as drill and practice programs because they drilled students in basic facts and allowed them to practice their mastery of these skills.

Drill and Practice Programs

As computer programmers developed more sophisticated programs, drill and practice programs began to adapt to students' abilities. As students answered questions correctly, the computer presented increasingly more difficult questions. When students answered incorrectly, the computer responded with easier questions until the student had mastered the content.

Drill and practice programs use the computer in much the same way that a teacher might use flashcards. The advantage of the computer is that it never gets tired or bored. Also, the computer's inability to criticize also is an advantage for many students. However, both drill and practice programs and flashcards assume that students have first been introduced to a concept before they are drilled on its mastery. This limitation led to the development of another class of programs, the tutorial.

Tutorial Programs

Tutorial programs are based on a standard lesson format:

1. Present information.
2. Test students' mastery of information.
3. If students achieve the criterion level of mastery, introduce new material.
4. If students fail to achieve the expected level of mastery, reteach the material.

Tutorial programs come closer to employing the computer as a teaching machine than do drill and practice programs. Theoretically, a tutorial program could introduce students to new information, quiz them on the information until they achieve mastery, and reteach the information as necessary.

In fact, this represents such a standard teaching methodology that authoring systems have been developed that follow this format. An authoring system is a computer program that allows teachers to develop computer-assisted instructional materials without learning a programming language. The teacher is presented with a series of screens on which the lesson is typed. The first screen asks the teacher to enter any text information. For example, the teacher might enter several paragraphs describing the process of photosynthesis. More advanced authoring systems would also allow the text to be illustrated with diagrams. The next screen might ask the teacher to enter any questions about that text. Several questionning formats are available, with the most common being fill-in-the-blank, true-false, and multiple-choice. The next screen will ask the teacher to indicate which responses are correct for those questions and what feedback should be given to the student who answers incorrectly. In more advanced authoring systems, another screen allows the teacher to enter possible incorrect answers and to provide students with specific remediation for their errors. The computer then formats this information and produces a tutorial lesson. While they represent the easiest way for teachers to develop tailor-made instructional lessons, authoring systems are limited to the text-question-answer-feedback format of the tutorial program.

Drill and Practice and Tutorial Resources

Although many poor examples of drill and practice and tutorial programs are on the market, there are several good examples, such as those cited below, that engage students' interest, are educationally sound, and are effective in reinforcing skills. In addition to regular commercial programs, local computer users' groups, state and national computer education organizations, and science education organizations provide public domain software at low cost. These public domain programs may be freely copied for classroom use. Many of these programs have been written by classroom teachers and, consequently, fit well into the existing science curricula.

There are fewer examples of commercially available drill and practice programs in science than there are in other subject disciplines, such as mathematics or spelling, where the mastery of basic facts and skills is stressed to a greater extent. The focus of contemporary science education is on the development of thinking skills rather than on the retention of science facts. This approach to science education lends itself to more open-ended types of software programs. However, many older science programs do follow a drill and practice or tutorial format. These programs, most of which were developed before the introduction of sophisticated graphics and simulations, are useful in helping students master basic science facts.

Some notable examples of drill and practice software currently available for science education include *The Body Transparent*, which drills students on their understanding of the location and function of human bones and organs. Students can "construct" a skeleton by correctly identifying the location of the bones as they are presented on the computer screen. Another is *Science Square-Off*, which uses a tic-tac-toe format to review the content covered in the Scott, Foresman's elementary science series for grades four, five, and six.

Tutorial programs in science are more plentiful. *The Body in Focus* deals with the function and systems of the human body. This program uses high quality graphics to explore eight major body systems. Students can observe the mechanisms behind breathing, eating, moving muscles, and pumping blood. *Simple Machines* introduces students to pulleys, levers, wheels and axels, inclined planes, wedges,

Computers can provide the motivation for students to do extra work, and many computer programs are excellent for providing individualized instruction.

and screws. *Writing Chemical Formulas* takes high school chemistry students step-by-step through the process of writing formulas and balancing charges. *Project Zoo: Charts and Graphs* is an exciting program that takes students to the zoo to learn the skill of reading, interpreting, and constructing charts and graphs. Students learn information about different types of animals as they read a chart to determine the daily food requirements of an adult elephant or compare the length of various snakes using a histogram.

Although drill and practice and tutorial programs are sometimes viewed as low-level uses of the computer, simply working with the computer can be a powerful motivation for reluctant learners to master basic skills. They can also be extremely effective in helping students to review material that they do not fully understand or that they missed because of an absence.

Computer-Simulated Environments

Much of the effort of the past 25 years in science education has been to lessen the dependence on textbooks and to focus more on the laboratory. However, while most science teachers view laboratory experiences as a vital part of their curriculum, there are many constraints that limit the amount of time in which students are engaged in challenging, hands-on activities. Cost, materials, time, and safety are just a few of the reasons teachers cite that limit their ability to conduct more laboratory investigations.

The computer can help to eliminate these constraints, at least in part, by providing students with inquiry experiences through the simulation of real-world events and by providing models that students can use to explain phenomena.

A model is a simplified view of the world. Scientists develop models to help explain structures and events that they cannot readily perceive, such as the structure of the atom or the replication of DNA. Models may be pictorial representations, verbal representations, or mathematical representations of the real world. For the most part, science attempts to develop models that can be represented by mathematics. The advantage of this is that mathematical models can be tested.

The process of testing a model by entering data into the model to see how effectively the model reproduces real-world events is referred to as a simulation. A good example of a computer program that uses the idea of simulating models is *Modeling*. This program, developed under a National Science Foundation grant as part of the Computer Literacy Instructional Modules Program, introduces students to the development of a scientific model through the use of a plastic dart gun. Students enter information about the gun into the computer, and the computer plots the trajectory of the dart when the gun is fired at various angles. Students quickly realize that entering only limited information about the dart gun produces an erroneous calculation by the computer. As the model is refined by taking into account air resistance, the model more closely represents the real-world behavior of the dart.

Simulation and modeling programs come closest to representing the nature of science. They engage students in scientific problem-solving. Through the use of simulations and the development of models, students use the science process skills of observing, classifying, communicating, measuring, predicting, inferring, hypothesizing, and experimenting. Simulation programs allow students to freely explore the modeled environment without the constraint of real-world limitations.

Simulation and modeling programs can serve many important roles in the science classroom. They allow students to conduct experiments (such as chemistry experiments at high temperatures and pressures or activities inside a nuclear reactor) that might otherwise be unsafe or impossible. They take students on imaginary field trips (such as inside the human body or to Mars). They allow students to change events in history and observe the outcomes or to predict what will happen in the future, given selected conditions.

Simulation and modeling programs turn the computer into a laboratory where students can freely explore phenomena without the fear of accidents. The worst that might happen is that the computer will tell the students that they have "blown up the lab" and that they have to start again.

Simulation/Modeling Resources

There are several excellent science programs that allow students to develop models or to explore models by simulating conditions. *Ex-*

plorer Metros takes students on an intergalactic journey where they have to make use of their knowledge of the metric measurements of mass, length, volume, and temperature in order to complete their mission. Students are confronted with 12 encounters, such as "A 15 milligram stone is in the road in front of you. Do you wish to a) step over it, b) move it out of the way, or c) take another route to avoid the obstacle." If they answer enough of the questions correctly, then they are able to complete the mission. The program also allows the students to get hints ("five grams is about the mass of a nickel") and summarizes their results at the end by pointing out areas of metric measurement in which they might need more review.

One of the oldest and most popular simulations is *Odell Lake*. Students take on the role of a fish. Their goal is to identify the relative position of the fish in the food chain. The students are placed in randomly selected encounters with other fish, ospreys, otters, and fishermen; and they must decide what action to take in each case. For example, when confronted with another fish, they can choose to eat, swim to deeper water, or swim to shallower water for protection. If they make the wrong decision, they might see themselves eaten by a hungry predator, and they have to start over.

Discovery Lab focuses on the scientific method by allowing the students to investigate the requirements of fictitious alien forms. The program has three progressive levels. At the first level, the students have the option of varying light and temperature with two possible values for each. It is important that the students vary only one condition at a time in order to get reasonable results. At the second level, they have the option of investigating the light, temperature, moisture, sound, and food requirements of their organism, but still with only two possible values for each of the five variables. The third level of difficulty offers the students the same five variables to investigate, but this time with three possible values for each. Students who are able to correctly identify the requirements for their alien are rewarded by having the organism named after them.

Another popular simulation is *Operation Frog*. Students dissect a frog on their computer. Using a graphic probe, they investigate the incision point for each body part. Then using scissors, they make their incision. Finally, using forceps, they transfer the body part to the holding tray. All of these manipulations take place on the computer screen. If they want to learn more about a dissected body part, they choose the magnifying glass icon and are presented with information about its function. Finally, through the magic of computer simulation, the students can reconstruct their disassembled frog.

Computer-Enhanced Laboratory Instruction

One of the most exciting developments involving computers in science instruction has been the development of laboratory probes, instruments that attach directly to the computer and record data into the computer's memory. A sampling of the kinds of laboratory interface probes that now are available includes temperature probes, light-sensing probes, biofeedback probes, pulse-rate probes, electromyograph probes, humidity and pH meters, and skin-resistance probes. And there are many others.

Nearly every laboratory interface probe operates on the same basic principle. A physical phenomenon (such as temperature) is converted into an electrical signal or current (in the case of temperature, by means of a thermocouple). This electrical signal is converted by the computer program into the proper units and scale for the probe. For most computers, the interface device is simply attached to the same port (plug) to which the joystick, graphic tablet, or mouse would be connected. For some probes, there needs to be an intermediate device between the probe and the computer, which converts the electrical signal into a form that the computer can detect.

Laboratory interfacing provides tremendous potential for using computers in the science classroom. Most interface devices are extremely accurate. They often will collect hundreds of data points each second and can detect very small changes in temperature, light intensity, or whatever physical condition is being investigated.

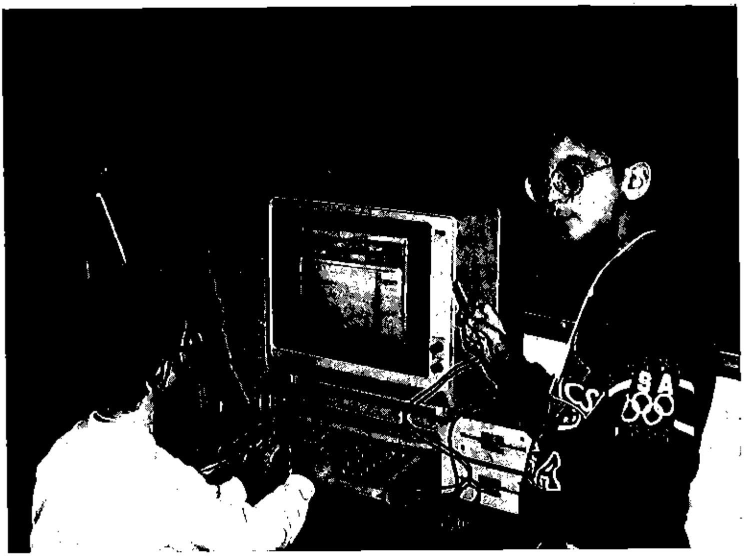
Early laboratory interface devices used the joystick. Camille L. Wainwright ("The Joystick Pendulum," *The Science Teacher* 53, no. 6, September 1986, p. 53) describes a pendulum activity that can be conducted with a simple modification of a joystick. The joystick is inverted and mounted on a ringstand. A weight hanger is attached to the end of a heavy wire, which is attached to the joystick. As the pendulum oscillates, its motion is transferred to the joystick, which, in turn, sends signals to the computer. A short program, which Wainwright wrote, plots the resulting data for analysis.

Until recently, aside from the direct use of the joystick, teachers who wished to use laboratory interfacing had to be familiar with electronics to create their own probes. In the past couple of years, several laboratory interfacing products have come on the market, making access to this technology readily available to all science teachers.

Some of the earliest work on laboratory interfacing was conducted at the Technical Education Research Center (TERC). Many of their development products now are distributed through HRM (Human Resources Management). Products such as *Experiments in Science*, *Biofeedback Microlab*, and *Experiments in Chemistry* have opened new horizons for the use of laboratory interfacing in the classroom.

In the past couple of years, several other producers of computer materials have entered the field of science education. One of the most respected is David Vernier. Vernier produces several different types of laboratory probes that can be purchased in kit form or preassembled. Project SERAPHIM, a federally supported project, also has developed laboratory interfacing materials that can be assembled easily. Project SERAPHIM has a cadre of teacher-trainers who provide inservice workshops for science teachers interested in investigating laboratory interfacing.

One of the most expensive laboratory interfacing packages available is the *Science Toolkit: Master Module*. The complete package consists of four modules. The first, *Master Module*, consists of a thermometer probe, a light probe, an interface box, software, and



These students are using a special light-sensitive probe to measure changes in light intensity. They are using the Science Toolkit: Master Module *for their experiments.*

a teacher's guide. The interface box plugs into the game port of Apple II computers, and an IBM PC version also has been released recently. Students can collect temperature data in degrees Celsius or Fahrenheit and light intensity in foot candles. In addition, the software also supports a strip chart that allows students to collect temperature or light data over time. A fourth feature of the software is a timer that can be activated either from the keyboard or by use of the probes.

The second module in the series, a physical science activity, is called *Speed and Motion*. This module comes with an additional light probe and a small, balloon-driven car. Using the two probes, students can measure the speed of objects by assigning one probe to turn on the timer and the other probe to turn off the timer as objects pass in front of them.

The third module focuses on the earth sciences. *Earthquake Lab* allows the students to build a very accurate seismograph to measure vibrations ranging in intensity from passing trucks to actual earthquakes.

The fourth module deals with the life sciences. *Body Lab* allows students to measure their heart rate, lung capacity, and response time. The package comes with a spirometer, which the students construct to measure their lung capacity.

A key feature of these programs is that they are simple to use. Middle and junior high school students would have no difficulty mastering the software and making accurate measurements using the probes. The probes also are sufficiently accurate to be useful in secondary science classes.

One additional laboratory interfacing product should be mentioned. This differs from those previously mentioned in that the computer is used to control a device rather than to collect data. The *LEGO Logo*™ system allows students to build a variety of structures, then control the structures by writing programs in the Logo computer language. For example, students can construct a stop-and-go light. By writing a simple program, they can cause the lights to blink in sequence. They can build a car that not only will respond to instructions from the computer but also can sense obstacles and turn around to avoid them. LEGOs™ have always been popular with children. Combined with the ability to control the constructions, their motivational value is unlimited.

Another type of computer program that can enhance instruction is the spreadsheet. Spreadsheets, which are readily available for all models of computer, combine the capabilities of an accountant's ledger pad, a calculator, and a pencil. A spreadsheet is composed of cells designated by a letter and a number. Into each cell, you may put a label, a numerical value, or a formula. The diagram on the next page illustrates one example of a spreadsheet that a teacher might find helpful in teaching a unit on acids and bases.

File: TITRATION.LAB REVIEW/ADD/CHANGE Escape: Main Menu

	A	B	C
1	TITRATION LAB	1	
2			
3	WHAT IS THE ACID MOLARITY?	17	
4			
5	WHAT IS THE VOLUME OF ACID?	25	
6			
7	WHAT IS THE VOLUME OF THE UNKNOWN BASE?		
8			
9	THE MOLARITY OF THE UNKNOWN BASE IS	@SUM(B3*B5)/B7	
10			
11			

B9: (Value, Layout-F2) @SUM(B3*B5)/B7

Type entry or use @ commands @-? for Help

Figure 1. Spreadsheet program for determining molarity of an unknown base.

With this program, the students enter a value for the volume of acid they have titrated. The computer will calculate the molarity of the base. By entering different values for the volume of acid, the students begin to see the relationship between volume and molarity. Thus, the computer, through the spreadsheet, becomes a laboratory environment in which the students can explore different values. This same approach can be applied to any mathematical formula in science, such as pressure/volume relationships, density calculations, or population growth predictions.

Computer-Assisted Classroom Management

Science teachers also will find computers useful for non-instructional purposes. Grade records, test generation, and equipment inventories are just a few of the ways in which computers can ease the paperwork burden that science teachers face.

There are many commercially available programs that allow teachers to maintain their class grades. These programs usually are designed so that teachers can give more weight to individual grades or groups of grades. For example, a teacher can require that all tests will count 50% of the final grade, laboratory work will count 30%, and homework assignments will count 20%. At the end of the grading period, the final grade is computed with little more than the punch of a button. Use of a gradebook program also allows the teacher to statistically analyze individual test score ranges. Given the emphasis on having teachers assign more homework and collect more grades during an assessment period, the use of a gradebook can greatly reduce the teachers' time at the end of each grading period.

Test item banks have become an increasingly popular supplement to textbooks. Many publishers, especially publishers of secondary science textbooks, also provide a computer-generated test item bank. This item bank contains hundreds of test items (primarily objective items such as multiple choice and matching) that are coded to the textbook's objectives. At the completion of a unit, the teacher lists the objectives that should be tested and indicates the number of questions on the test; and the computer randomly selects from the item base the correct number of items for the requested objectives. One of the features of a test item generating program is that it can just as easily generate multiple forms of a test, either using the same items in a scrambled form or by generating a new set of items for the same objectives. This can be especially useful for teachers who teach multiple sections of the same course. The final advantage is that the test is formatted and printed on the teacher's printer, saving time in typing the test.

In addition to test generator programs, there are programs that will create crossword puzzles or word-find worksheets, as well as those that allow the teacher to develop labeling worksheets, such as the structure of the heart or the internal anatomy of the frog.

Many teachers who have not used a computer for instructional purposes are familiar with using computers for word processing. Word processing turns the computer into a typewriter, but with many advantages. Mistakes can be easily erased with the punch of a button. There is no need to continually press the return key, the computer automatically starts a new line. And large blocks of text can easily be moved in the document.

For teachers, the word processor can function any place that a typewriter would function, be it typing tests, writing letters to parents, or developing lesson plans. And since information in a word processor can be stored, teachers can write lesson plans one year, retrieve those plans the next year, make any desired modifications, and very easily print out a new set of lesson plans.

In the last few years, a new kind of utility program has become very popular. This is referred to as integrated applications software, and it combines the benefits of a word processor with two other useful applications – a database management system and a spreadsheet. A database management system is similar to a card file. The user creates a form containing the categories to be used. The diagram below illustrates a form that might be used by a secondary science teacher to maintain student records.

Name: ______________________________
Address: ______________________________
City/State/ZIP: ______________________________
Phone: ______________________________
Father's Name: ______________________________
Mother's Name: ______________________________
Previous Science Courses: ______________________________
Does the Student Wear Contact Lenses? ______________

The information entered for each student is referred to as a *record*. All of the records form a *file*. Once the file has been created, the teacher can use the information in many ways. At the simplest level, the teacher can retrieve individual student records in much the same way that one would look up an address or phone number in a directory. Using the database's ability to search and sort records, a chemistry teacher might order the computer to list all students who wear contact lenses so that particular eyewear safety instructions can be provided for those students.

In short, a database can be used for any situation in which you might use a filing system. Databases have been especially useful for science teachers in maintaining equipment and chemical inventories. An end-of-year printout of the chemical inventory could be used to order next year's supply. To comply with the new regulations regarding hazardous substances, a teacher could establish a database on the toxicity, fire hazard, proper disposal, and chemical incompatability for each of the chemicals kept in the storeroom, and have this information readily at hand in the case of a chemical spill.

The same idea could be applied to the maintenance of audiovisual materials, microscope slides, laboratory glassware, and reference materials. In every case, the database management system becomes a convenient means for rapidly surveying the inventory of supplies.

An integrated applications software program combines a variety of applications in a single document. For example, students might use the word processor to write their laboratory report. When they want to enter a table of their data, they can merge their data file from the spreadsheet, and that portion of the file is inserted in the report. Teachers can personalize form letters to students or parents by merging a database of student names and addresses with the letter.

Although the primary focus of this fastback has been on the instructional applications of computers, it is important to recognize that the computer can fulfill an important role in reducing the paperwork burden faced by most teachers. Whenever teachers are freed from clerical responsibilities, they have the ability to do what teachers do best – interacting with students. Some critics have suggested that the introduction of computers in schools will replace teachers with a dehumanized machine. But just the opposite happens. When computers are used for classroom management, teachers have more time to work with students.

Emerging Technologies

Although the mere notion of using computers in the science classroom may be an "emerging technology" to many teachers, there is little doubt that it is a technology that is here to stay. The rate at which computers are being introduced into the schools is increasing each year, and it is only a matter of time before the computer will be as common in the science classroom as a microscope.

In the meantime, there are other innovations that hold great promise for science teachers. Three of these innovations – telecommunications, laser videodisc technology, and CD-ROM technology – will be discussed in this section.

Telecommunications

As mentioned previously, in the early days of educational computing the user had to connect to a remote computer by means of a telephone line. This same technology now serves to provide students with the opportunity to communicate with researchers outside of their school site, to receive real-time satellite weather data, and to share data with students across the nation. *The Weather Machine* gives students the option of using weather data stored on disk or accessing satellite weather data to display weather maps. Using a modem to link the computer to a telephone line or satellite dish, students can communicate with people around the globe.

An interesting project currently under way, the National Geographic Kids-Net Network, involves students from across the nation in collecting information on acid rain. This information is sent by telephone connections to a central site where it is analyzed. The students then receive the information, combined with information collected at other sites, for their own analysis.

Students also are acting as weather forecasters, using the same information received by the National Weather Bureau. Again through the use of telecommunications, students can access the information relayed by weather satellites at the same time that the information is sent to weather bureaus across the nation. The availability of telecommunications holds the promise of bringing the real world of science into the classroom at a minimal cost.

Videodiscs

Imagine having a library of 108,000 photographic slides of plants, animals, and geological features. Further, imagine that this library is the size of one long-play phonograph album and you will have some sense of the retrieval power of the laser videodisc. (See fastback 294 *Interactive Videodisc and the Teaching-Learning Process*, by Edward C. Beardslee and Geoffrey L. Davis.)

Laser videodisc technology is not new. In fact, a few years ago videodiscs attempted to capture the home video movie market but could not compete with the more popular videotape cassette. However, it is only in the past few years that advances in technology, price, and the availability of software have brought the laser videodisc into the schools.

First and foremost, the laser videodisc is an image database. A videodisc is about the size of a long-play record and made of aluminum covered with a clear plastic coating. On each side of the videodisc can be enscribed 54,000 images, stored in concentric circles. These images may be individual still frames (that is, slides), or they may be individual frames making an action film clip.

The videodisc player looks very much like a videocassette recorder (VCR). However, the videodisc has two important advantages over the VCR. The first is that the videodisc player can freeze on a single image without any distortion. Most VCRs will show some degree of distortion whenever you try to pause on an image. Second, with most videodiscs you can rapidly search for any individual frame. At most, it may take five seconds to go from the first image to image number 54,000. Compare that with the time required to fastforward through a videotape and the difficulty of finding a particular section on that tape. On a videodisc, the images are segmented into chapters, which can be searched, and then individually into frames, each of which can be searched and accessed as well.

The educational use of videodiscs has been divided into four levels of interactivity. Level-one use simulates a VCR or slide projector. Videodiscs may be played continuously from start to finish, like a videotape; individual frames may be accessed, like a slide projector; or segments may be played that combine action with still frames.

Level-two use requires a special videodisc player that has a microprocessor (or mini-computer) built into the player. Information is encoded on the videodisc, and this information is read into the player. The information directs the action of the videodisc. This application has been used primarily for industrial training purposes.

Level-three use combines the videodisc with a computer. Since individual frames can be accessed by number, it is logical that the computer can also send a signal to the videodisc to access specific frames. This opens a new level of interactivity. Programs can be written that combine computer graphics with real-world images from the videodisc. The computer can be used to sequence images to aid a teacher during the presentation of a videodisc lesson. Students can interact with a computer lesson because the computer can instruct the videodisc to branch to various outcomes based on the students' responses. In this way, students get the opportunity to see realistic pictures of the outcomes of various decisions that they might make.

Level-four use of videodiscs is still fairly theoretical. This would combine artificial intelligence to diagnose students' learning needs, then provide the proper instruction as needed by means of videodisc images.

One of the most exciting developments in videodisc technology is the creation of Hypertext™ (Apple Computer Corporation). At its simplest level, Hypertext™ is a data resource. Information is stored on "cards" (computer screens). The real power of Hypertext™ is the ability to branch rapidly and almost limitlessly from one card to another. For example, a student might be presented with a screen of information on the topic of metals. As the student reads and wants to know more about "precious metals," highlighting that phrase in the paragraph will branch to another set of cards that go into more detail on that topic. If in reading the section on precious metals, the student is unsure of the meaning of "platinum," highlighting that word results in another branching for more information.

The way in which Hypertext™ arranges information is very similar to the way in which humans store concepts, that is, concepts are related to each other to form semantic units of information. By exploring a Hypertext™ environment, students can increase their understanding of a new concept, relate ideas to each other, and form meaningful relationships among concepts. When combined with a laser videodisc, Hypertext™ (sometimes termed "Hypermedia" when it combines words and images) can allow students to explore ideas using words and images.

The cost of a laser videodisc player currently runs from $500 to $3,000, depending on features and the ability to interface with a computer. The videodiscs range in price from $30 for public domain programs (such as NASA archive discs) to more than $2,000 for programs that are part of a complete curriculum package.

CD-ROM

The CD-ROM (Compact Disc-Read Only Memory) is a smaller laser disc, about the size of an audiocompact disc. Each CD-ROM can hold approximately 150,000 pages of text. Combined with a computer, the CD-ROM becomes a tremendous information storage and retrieval system. Entire encyclopedias have been placed on CD-ROM discs. Students can search through these encyclopedias using key words and identify any reference to their topic in a fraction of the time that a hand search of the resources would take.

The sciences are a natural place for the integration of computers into instruction and classroom management. Whether it be for remediation using a drill and practice program, for the simulation of new models, for direct laboratory interfacing, or for the generation of classroom materials, computers have the potential for expanding the resources of the science classroom beyond imagination. We can envision the day when the computer will be an indispensable piece of laboratory equipment. That day is not far off.

Appendix
Software Sources

Adaptation and Identification
(Biology Series)
Scott, Foresman & Company
1900 East Lake Avenue
Glenview, IL 60025

Biofeedback Microlab
HRM-Human Relations Media
175 Tompkins Avenue
Room GS22 24
Pleasantville, NY 10570

The Body in Focus
CBS Interactive Learning
One Fawcett Place
Greenwich, CT 06386

The Body Transparent
DesignWare
185 Berry Street
San Francisco, CA 94107

David Vernier
Vernier Software
2920 SW 89th Street
Portland, OR 97225

Discovery Lab
MECC-Minnesota Educational
Computing Corporation
3490 Lexington Avenue, North
St. Paul, MN 55126

Experiments in Chemistry
HRM-Human Relations Media
175 Tompkins Avenue
Room GS22 24
Pleasantville, NY 10570

Experiments in Science
HRM-Human Relations Media
175 Tompkins Avenue
Room GS22 24
Pleasantville, NY 10570

Explorer Metros
Sunburst Communications
39 Washington Avenue
Pleasantville, NY 10570-9971

LEGO Logo
The LEGO Educational Dept.
P.O. Box 39
Enfield, CT 06082

Modeling
MECC-Minnesota Educational
Computing Consortium
3490 Lexington Avenue, North
St. Paul, MN 55126

Odell Lake
MECC-Minnesota Educational
Computing Corporation
3490 Lexington Avenue, North
St. Paul, MN 55126

Operation Frog
Scholastic Software
730 Broadway
New York, NY 10003

Project SERAPHIM
Department of Chemistry
University of Wisconsin-Madison
1101 University Avenue
Madison, WI 53706

Project Zoo: Charts and Graphs
National Geographic Society
Educational Services Dept. 87
Washington, DC 20036

Rocks
Spectrum Software
75 Todd Pond Road
Lincoln, MA 01773

Science Square-Off
Scott, Foresman & Company
1900 East Lake Avenue
Glenview, IL 60025

Science Toolkit: Master Module
Broderbund Software
17 Paul Drive
San Rafael, CA 94903-2101

Simple Machines
Micro Power and Light
12810 Hillcrest Road
Suite 120
Dallas, TX 75230

Sound
HRM-Human Relations Media
175 Tompkins Avenue
Room GS22 24
Pleasantville, NY 10570

The Weather Machine
National Geographic Society
Educational Services Dept. 87
Washington, D.C. 20036

Writing Chemical Formulas
Microcomputer Workshops/CBS
225 Westchester Avenue
Port Chester, NY 10573

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