Labs

Interfacing in the Biology Laboratory: State of the Art

Don Igelsrud
Department Editor

William H. Leonard
Guest Editor

It is commonplace now to see microcomputers used in the science classroom, especially for drill and practice, review, testing and other tutorial functions. For several years microcomputers have been used for data analysis and computations such as statistical analysis. Just a few years ago, a new dimension was added by interfacing the microcomputer to the videodisc player. Several applications and programs using the interactive videodisc have been described in this column and elsewhere (Leonard 1983, 1985). The main advantages of this new videodisc technology are broadcast-quality video images, greater speed in assessing video materials and more extensive interactivity for the user.

The interfacing of laboratory instruments to the computer has been done in industry and scientific research almost as long as the computer has existed. This application has been the source of many ideas for current classroom use of interfacing. Only in the past two or three years has interfacing been used with success in the science classroom, primarily because of increased activity in classroom use of the microcomputer. This article will focus on some of the very basics of interfacing, what is now state of the art and the educational benefits of computers interfaced to laboratory instruments for use in biology classrooms.

The simplest possible interface consists of a switch connected by two wires to a port in the microcomputer. The computer can detect if the switch is on or off approximately 80,000 times a second. The switch can be replaced by a photodetector and interruptions in the beam can be timed over very short or long periods of time. Instruments that have a signal output, such as pH meters, spectrophotometers and chromatographs, can be connected directly to the computer. If measurement of continuous variables such as temperature or light intensity is desired, an analog to digital converter (ADC) is added. ADCs are basically transducers which convert the input variable into a voltage or resistance. A thermister can measure temperature and a phototransistor can measure light intensity. Transducers can also be used to measure humidity, radioactivity, pressure and the presence of various gases (Nicklin 1985). Most of these take advantage of the built-in game controller or paddle port found in most microcomputers. Typical paddle ports can read a variable resistance in the range of 0-500 kiloohms. There are many other possibilities.

State of the Art

Let's examine some of the interfacing for the biology laboratory which has been recently reported or recently made available to classroom teachers. By far the most common of the current applications is the replacement of the standard drum kymograph to study concepts in physiology. Rhodes (1986) describes such a system with the Apple II which uses muscle levers and Morey tambours for recording diverse physiological phenomena, including frog heart contractions, frog skeletal muscle contractions, human respiratory movements and human pulse-volume changes.

This transducer plugs directly into the paddle port with no additional electronics and is easy to construct for about $10 in parts using hand tools and a soldering iron. Rhodes interfaced both a transducer and an electronic stimulator to show the effects of increasing stimulus frequency on the force and duration of contractions in the frog skeletal muscle. On the screen the student can see a graph of force over time for different frequencies. In this case, the transducer consists of a miniature incandescent light bulb and an infrared phototransistor because the infrared phototransistor has a slow rate (in the microsecond range) and is insensitive to fluorescent lighting typically found in laboratory classrooms.

Sievers (1986) describes how to build interfaces to the game port of the Commodore VIC-20 for three laboratory input devices. He gives directions and schematics for a thermometer, a light meter and a general-purpose device constructed from a phone jack. He shows how the light meter can be converted to a colorimeter. The solution is placed in a test tube between the light source and the light meter. His software allows you to enter the number of readings desired and the wavelength for each. The program has the computer average three samples for each wavelength and store the averages in memory.

Westline and Bahe (1986) discuss using interfaces for a variety of diverse physiological phenomena such as temperature probes, reaction timers, pulse-rate timers, constant-tempera-

Donald E. Igelsrud began teaching biology at Delaware Valley College in 1966, became Biology Laboratory director at Northwestern University in 1973, and taught at the University of Calgary from 1976 to 1984. He is founder of ABLE (The Association for Biology Laboratory Education). Currently developing a series of biology videodiscs, he works through his consulting firm: LIFE Consultants, 403 21 Ave., Calgary, Alberta, Canada T2M 1J6. His main interests are in increasing awareness and understanding of living phenomena and in developing cooperation among biology teachers and institutions.

ture regulators and a wet spirometer. These permit student investigations of environmental temperature, vital capacity, breathing rate, pulse rate, muscle fatigue, reaction time and breathing movements. A muscle level transducer recorded a single muscle twitch, staircase responses and contractions, including tetanus. A final device was attached to an exercise wheel to study animal photoperiodic behavior. Westline and Bahe made the following observation: "As students used the new system, we discovered that the time needed for data collection was only half that of the old method, so we had to lengthen the lab by suggesting some additional variables for investigation."

Morgan, Markell and Feller (1987) take a different but very interesting approach for developing more active experiences for learning muscle physiology concepts. They replaced the frog gastrocnemius muscle with the student's own flexor digitorium superficialis muscle. These experiments were done on an interface consisting of a pistol grip transducer which contained a stimulator cable to the pistol grip and a stimulator cable for exciting the flexor digitorum superficialis muscle. The following muscle phenomena were illustrated:

1) threshold stimulus, measuring the liminal stimulus causing the muscle to flex and effects of increasing stimulus strength,
2) wave summation and tetanus, showing that, as the contractions become more frequent, the muscle cannot relax completely before the next contraction, and very rapid stimulation results in fused tetanus,
3) muscle twitch, showing the rapid, jerky response to a single stimulus in three phases: latent, contraction and relaxation,
4) fatigue and muscle contraction, showing the muscle becoming progressively weaker until it no longer responds, and
5) fatigue, by extended stimulation and eventual muscle relaxation.

They felt that students liked the interfaced version of physiology experiments better than the traditional kymograph or oscilloscope.

By far the most complete set of interfacing information is a resource book written by David Vernier (1987). This is an excellent and well written guide to 14 different interfacing projects with the Apple II, including many specific classroom applications and a diskette with software to run each project for only $25. Very clear directions and resources for inexpensive parts to assemble the projects are given. Although most are more appropriate for the physical sciences, especially for physics, those which can be used in a biology classroom laboratory are described here. For a complete list of projects and other information, write to Vernier Software, 2920 S.W. 89th St., Portland, Oregon, 97225.

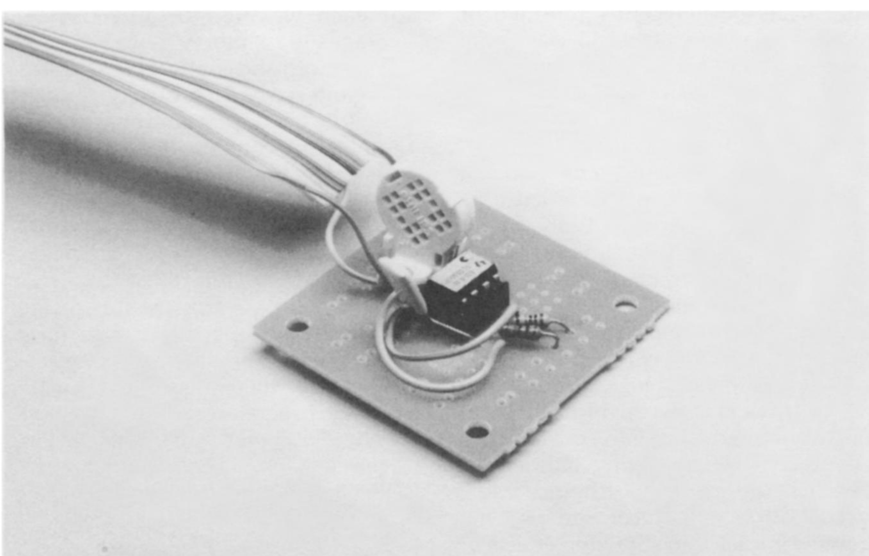
The Reaction Time project uses a simulated brake pedal to test individual brake reaction time. This project explains how to make an inexpensive mechanical brake pedal on a stand and how to connect the pedal to a simple switch which is wired to the game port of the computer. A number of variations are suggested, such as starting with the foot on the gas pedal instead of the brake pedal, studying the braking time for various groups of people and using other experimental variables such as distractions, background music, fatigue, caffeine, or time of day. Many science museums have such an apparatus and it is usually a very popular exhibit, indicating that this interface would be highly motivating to students. The cost of parts for this project is less than $10.

The Humidity Meter project measures the relative humidity of the air. The advantage of using this with a computer is that humidity can be measured in different environments for prescribed periods of time and the data can be stored and analyzed. The total cost of parts for this interface (shown in the photo) is about $23. Other suggested activities include calculating the now popular "humature" (Temperature-Humidity Index), checking the effectiveness of a room humidifier or dehumidifier and measuring dew point.

The IC Temperature Probe project accurately measures temperature changes between −55 degrees Celsius and +150 degrees Celsius. Parts cost about $13. Extensions of the project include adding another temperature probe and using the probes with the humidity meter to make a systematic weather station. Adding barometer and anemometer interfaces (not part of the Vernier kit) would make the weather station complete. Other activities suggested are measuring the latent heat of fusion of ice, measuring specific heats of various materials compared to water, measuring the efficiencies of insulation materials, measuring heat of reaction and studying thermal gradients in layers of natural water.

The pH Meter project materials cost about $80, including the cost of the electrode. With this project you can test the pH of common substances and compare those measurements with published values. Other applications can include monitoring the pH of rainwater or land water bodies, titration and identification of certain ions.

The Strain Gage project can be constructed for about $90 and used in place of a several hundred dollar electronic balance. The Better Mousetrap project can be used for a variety of creative animal behavior studies. Other projects such as the Photogate Timer, Resistance/Capacitance Meter and Switches can, with some imagination,



The humidity meter interface constructed from *How to Build a Better Mousetrap* by David Vernier. Such devices linked to the microcomputer can add a rich dimension to the biology classroom laboratory.

have numerous applications in the biology classroom. All of these are far less expensive than purchasing the conventional instrument. Because they are not linked to a microcomputer, they can be modified and adapted to a variety of needs. You will discover that working with these interfaces is also a great deal of fun.

Educational Benefits

There are some specific benefits in terms of student learning to using computer interfacing to laboratory instruments in the biology classroom. Some of them are:

1) *Interfacing is very cost effective.*

Once the microcomputer has been purchased, the cost of linking it to laboratory instrumentation is very inexpensive if the teacher is willing to buy the parts and do some of the hooking up. Parts for a single interface device are generally in the range of a few to tens of dollars, much less than that spent for most laboratory instruments. In cases such as the pH meter and timer, the cost is not only far less than purchasing the stand-alone instrument, the computer/interface system is far more flexible and powerful. It is also often more accurate. Frequently only one system for a given interface is needed in a typically-sized biology laboratory classroom because the data for many experiments are collected and analyzed in only a few minutes.

2) *Interfacing can save student time and prevent boredom.*

A very positive consequence of interfacing is freeing students from repetitive data recording tasks, giving them time for more productive and challenging activities such as analyzing data, developing inferences, studying more variables, improving the accuracy of measurement, making more measurements and writing reports. More time is available to focus on major concepts rather that adjusting gadgetry.

3) *Learning to use the instrumentation of modern technology is fun and motivating to students.*

Students enjoy using current technology and appreciate the opportunity to learn to use instruments that might be useful outside of school.

4) *Interfacing can make data analysis much simpler and conceptually more meaningful.*

Most interfacing apparatus allow the students to instantaneously see a graph on the screen that illustrates the relationship between independent and dependent variables. They can also instantaneously see the effects of their manipulation of the independent variable.

5) *Students can effectively learn science concepts and skills using interfacing.*

Microcomputer-based laboratories used for real time data gathering have demonstrated effective teaching of graphics skills and provide powerful motivators for students in a laboratory classroom (Mokros & Tinker, 1987; Nachmias & Linn, 1987). Microcomputers linked to laboratory measurement devices have also been demonstrated to teach selected science concepts more effectively than traditional instructional strategies (Brasell 1987). It has been hypothesized that there are four possible reasons for these effects of computer laboratory instruction:

a) they reinforce the physical experience of data collection with a visual experience,
b) they pair, in real time, events with their symbolic representations, thus bridging the gap between concrete and formal operational thought,
c) they provide a genuine scientific experience, and
d) they eliminate the drudgery of long term data collection and graphing (Morkos & Tinker 1987).

6) *Using microcomputer interfacing in the ways described above may allow students who are not formal thinkers to bridge the gap between concrete and formal thought so they can understand abstract science concepts.*

If students can see on the screen a concrete result of manipulating variables, they may be more likely to understand the abstract relationship between those variables than by collecting and analyzing data in the traditional, manual fashion. This is a particularly important consequence for a typical high school biology class, because most of these students are not consistently abstract thinkers. In fact, approximately one-third are solidly concrete thinkers and the vast majority of this population are transitional (sometimes formal, sometimes concrete) (Lawson & Blake 1976). Those in the transition group may benefit immensely from this instructional strategy. It is also believed that approximately one-half of freshmen enrolled in introductory college biology courses are also transitional. They may realize similar benefits as well.

7) *Greater opportunity for creativity, problem solving and the development of reasoning skills is a likely indirect consequence of the direct benefits of using the computer interfacing described above.*

If we can take the "labor" out of the laboratory and the "manual" out of laboratory manuals, we will be making a big step in the direction of fostering those broad educational goals which are often reflected only in course and curriculum outlines.

Future Developments?

Since many of the ideas for classroom interfacing have come from scientific research, let's consider some very recent developments from the scientific community. Among these are:

1) tracking eye, head and hand gestures,
2) tracking eye direction and focus tracking, and
3) voice recognition and synthesis (Foley 1987).

All of these have tremendous implications for classroom application.

The sophistication of microcomputers themselves will evolve rapidly. Future developments are expected to make the computer more natural for us to use, through such innovations as voice- or handwriting-based access (Peled 1987). IBM currently has an interactive system capable of recognizing 20,000 words (98 percent of the typical speaking vocabulary) if they are spoken with brief pauses between words. Peled sees a definite trend toward more powerful computers replacing existing ones at every level, including microprocessors with six to twelve times the present speed, magnetic storage capacity 10 times more dense than at present, optical storage media with five times the density of information of magnetic disks and RAM of hundreds of kilobytes, all within a few years. Another very new technology called "image capturing" may be used. It permits real-life images captured on a video camera to be entered into and manipulated by the microcomputer. Image capturing is currently limited to still images, but it is just a matter of time before it will be possible to enter moving images into the computer as well.

The possibilities only stop with the limits of one's imagination. Imagine, for example, interfacing a spectrophotometer or a nuclear magnetic resonator to identify qualitatively and quantitatively various compounds and elements in a living system. Imagine the physiological concepts that could be developed with an inexpensive lie detection system consisting of galvanomic skin responses, EKG patterns, blood pressure, and heart and breathing rates. Imagine what could be accomplished by interfacing a computer to a microscope or a video camera or videodisc player. How about interfacing a sound level meter to study the effects of sound volume and quality on the hearing mechanism? How about studying brain patterns or possible telepathy by analyzing EKG stimuli?

There is no question that laboratory interfacing is and will continue to be an exciting instructional tool for the biology classroom. However, since most of what is currently available has come from the physical sciences, we need more ideas for the use of interfacing in teaching biology. You are encouraged to share interfacing ideas you may have developed by writing to the *Labs* column or by submitting a "How-To-Do-It" article to the *ABT* editor. Let's spread the word so we can all benefit from this wonderful technology.

References

Brasell, H. (1987). The effect of real-time laboratory graphing on learning graphic representations of distance and velocity. *Journal of Research in Science Teaching, 24,* 385-395.

Foley, J.D. (1987). Interfaces for advanced computing. *Scientific American, 257,* 127-135.

Lawson, A.E. & Blake, A.J.D. (1976). Concrete and formal thinking abilities in high school biology students as measured by three separate instruments. *Journal of Research in Science Teaching, 13,* 227-235.

Leonard, W.H. (1985). Biology education with interactive videodiscs: Development of laboratory simulations. *The American Biology Teacher, 47,* 38-40.

Leonard W.H. (1987). Interactive videodiscs: Computer instruction of the future? *Collegiate Microcomputer, V,* 197-200.

Morgan, R.M., Markell, C.S. & Feller, R.F. (1987). A microcomputer exercise on muscle physiology. *Journal of College Science Teaching, XVII,* 23-27.

Mokros, J.R. & Tinker, R.F. (1987). The impact of microcomputer-based labs on children's ability to interpret graphs. *Journal of Research in Science Teaching, 24,* 520-524.

Nachmias, R. & Linn, M.C. (1987). Evaluations of science laboratory data: The role of computer-presented information. *Journal of Research in Science Teaching, 24,* 491-506.

Nicklin, R.C. (1985). The computer as lab partner. *Journal of College Science Teaching, XV,* 31-35.

Peled, A. (1987). The next computer revolution. *Scientific American, 257,* 57-64.

Rhodes, S.B. (1986). A microcomputer kymograph. *Journal of College Science Teaching, XV,* 523-527.

Sievers, D. (1986). The game port connection. *The Science Teacher, 53,* 49-52.

Vernier, D.L. (1987). *How to build a better mousetrap.* Portland, OR: Vernier Software.

Westline, B.D. & Bahe, M.E. (1986). Interface it yourself. *The Science Teacher, 53,* 45-47.

William H. Leonard is a professor of science education and biology at Clemson University, Clemson, SC 29634. He taught high school biology for 12 years and earned a Ph.D. in biology education from the University of California at Berkeley in 1976. In 1979 he became director of the introductory biology program at the University of Nebraska. A former director of NABT, Leonard is a frequent contributor to *ABT* and has won awards for distinguished teaching and research.