Can technology replace live preparations in student laboratories?

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IN RECENT YEARS, the rising costs of equipment and supplies, decreased time within the curriculum, and increased activity of animal rights groups have led many physiology departments to reevaluate the role of student laboratories in their teaching programs. Within the past two years, the National Resource for Computers in Life Science Education has received well over 100 enquiries from life science departments interested in locating software suitable for incorporation into their curricula (1, 2). A significant number of the requests indicated that these departments were looking for "substitutes" or "alternatives" for existing student laboratories using live preparations. The frequency with which the words substitute and alternative appear in such requests raises an issue that few life science educators seem willing to address when faced with designing or redesigning student laboratories. Before seeking substitutes or alternatives, it is necessary to define the specific educational goals of each laboratory. The question "Can a computer or other application of technology serve as a substitute for a live preparation?" can then be asked with respect to each of these goals. When dealing with this question, our definition of live preparation must include any experimental setup involving tissue or systems that are part of a living organism. The spectrum of potential experimental subjects that we must consider, then, ranges from invertebrates to humans.

In 1974, a paper was presented at the annual meeting of the Federation of American Societies of Experimental Biology entitled Computer programs as a substitute for physiology laboratories (7). The intent of the paper was to suggest that computer simulations could provide an active learning experience for students in curricula where another type of active learning experience, the student laboratory, was no longer available. The authors did not suggest that working with computer simulations could provide the same experience as working with a living system, nor did they imply that existing labs be abandoned in favor of computer labs.

Recently, Dewhurst and his colleagues (4), in a paper entitled Computer simulations—an alternative to the use of animals in teaching? argued that, with respect to achieving the major teaching objectives of laboratory classes, computer programs can provide essentially the same experience as working with a living system. They suggest further that, except for selected student populations where experience with live preparations is essential, computer simulations should replace live preparations in student laboratories.

Such a broad claim, however, may be unwarranted. One must first define the educational objectives of the specific laboratory session and then assess whether the computer or other technology can substitute for the live preparation. Defining specific educational objectives is a task that, historically, many physiologists have not addressed adequately. If laboratories are to be successful, their goals should be narrow enough so that students can see their relevance to the rest of the course material and so that the goals can be achieved within the allotted time. In performing this task, the laboratory session should not only be viewed in the context of the specific course but also in the context of the overall physiology program of which it is a component.

Let us focus more closely on the various educational objectives of laboratory exercises in physiology and determine in each instance if technology, including computer programs, can replace a live preparation to achieve this objective, and, if so, does the use of technology offer educational advantages over a live preparation? We must also ask if the objectives can best be achieved by using technology in conjunction with, rather than as a substitute for, a live preparation.

The first goal of all laboratories is to provide an environment in which the student can actively participate in an exercise that results in learning. It is obvious that materials such as videotapes, films, and supple-
mental reading that require only that the student be a passive recipient of information cannot provide such an environment and, therefore, cannot substitute for laboratory exercises. If the only goal is to provide an active learning experience, it can be achieved in a wide variety of ways that do not require a live preparation. The approach can be as simple as a paper-and-pencil problem set or as complex as a sophisticated computer simulation.

However, it is seldom that laboratory sessions are organized solely to provide an active learning experience. They are usually designed to meet additional goals that fall under four general headings:

- familiarizing students with technical issues;
- familiarizing students with experimental design and data analysis issues;
- demonstrating basic physiological principles with which students can build and utilize conceptual models of physiological systems; and
- providing students with first-hand experience with a living system.

The response of many colleagues to this list may be that student labs share all of these goals. While it may be true that many labs have components that could fit within the scope of each of these headings, when the practical issues of time and cost are considered, the focus of the lab narrows to a primary objective. The primary reason for having students go through the exercise, then, usually falls under only one category. Let us consider each of these to see whether technology can substitute for a live preparation.

**Familiarizing Students With Technical Issues**

Some exercises are designed to familiarize students with the basics of using various types of instrumentation before the instrumentation is used during actual experiments. For example, if we consider a physiological recorder or oscilloscope, the goals might be to become familiar with the controls on the recorder, to understand how to connect various transducers, to learn how to calibrate the transducer-recorder combination, and to gain an appreciation for the frequency response of the recorder.

To explore the various aspects of the recorder, the student must have a source of appropriate signals to monitor. Several alternatives to a live preparation are available to generate appropriate signals for the recorder. The alternatives include a variety of electronic physiological simulators (signal generators), recorded signals on magnetic tape, and computers programmed to simulate physiological signals through digital-to-analog converters. A computer simulation of the recorder is another alternative. In each case, the student can thoroughly examine the characteristics of the recorder without using a live preparation.

The technology-based alternatives may even provide the student with a greater opportunity to achieve the goals of the exercise. By removing the live preparation, attention can be focused on the recorder without the distractions associated with keeping a live preparation viable. This, in turn, affords the student a greater opportunity to become familiar and comfortable with the recording apparatus. Student familiarity with the apparatus will also increase the probability of meeting the objectives of subsequent laboratories in which experiments on live preparations are conducted.

**Familiarizing Students with Experimental Design and Data Analysis Issues**

In some curricula, laboratories are intended to provide students with a preview of the research laboratory. The objectives relate to experimental design issues, data gathering, data analysis and interpretation, and data presentation.

Some of these objectives, particularly those associated with data manipulation, can be met by using technological alternatives. One approach is to record data on magnetic (e.g., FM) tape from a series of experiments conducted on a live preparation and have students examine the data by playing the tape through a strip-chart recorder. Another is to digitize signals from actual experiments and use a computer to present the data to students. Using the computer may also provide an opportunity to manipulate data (e.g., adding noise) before the data are presented to students. In fact, some would argue that certain aspects of experimental design could be addressed with mathematical simulations of the experiment if the simulation includes provision for suitable variation in the data. An advantage of these approaches is that students can record and reanalyze the same data in a variety of ways.

However, when using technological approaches, precautions must be taken to ensure that students gain an appreciation for the degree of deterioration that can occur with a live preparation during the course of an actual experiment. If such precautions are not taken, the goals associated with obtaining proper control data may not be achieved. Other aspects of designing meaningful experiments cannot be addressed solely with simulators.

Thus some educational objectives associated with laboratories designed to address experimental design and data analysis issues can be met using appropriate technological approaches. Yet, if students are expected to apply the principles introduced in these sessions, they must, at some point, perform experiments using live preparations.

**Demonstrating Basic Physiological Principles With Which Students Can Build and Utilize Conceptual Models of Physiological Systems**

Perhaps the most widely cited educational objective of laboratory exercises is to demonstrate basic principles so that students can gain a better understanding of the system. This, in turn, enables them to develop better conceptual models with which to solve problems or formulate hypotheses associated with the system in question or its interaction with other systems.

It is with respect to this objective that technology offers the highest potential for making a positive impact on life science education. Computer simulations, for example, offer a latitude not available with living systems. A system can be examined first as simplified components or groups of components and then built up to a complex system.
In cardiovascular physiology, for example, simulations are currently available that allow examination of aspects of the system ranging from an isolated left heart preparation (9) to interactions with other systems (3). In respiratory physiology, one can start by examining a series of models beginning with exchange between the atmosphere and alveoli, build to a system that includes ventilation perfusion relationships, right to left shunt, and tissue gas exchange (8) and ultimately examine a model of cardiopulmonary physiology that allows the user to examine more than 100 parameter values (5).

However, when using such models, students must be made keenly aware of the limitations of the modeling process. The inherent drawback of all physiological models is that they are based on a series of simplifying assumptions. Because of this, no model is sufficient to predict the behavior of the system under all conditions. It is critical for students to understand this and to understand the importance of testing their models against reality. Such testing requires data obtained from experiments involving living preparations. Student access to these data can be either indirect, through examining the literature, or direct by including actual experiments as part of the laboratory experience.

I would argue that the most effective way to help students understand physiological interactions on a systemic basis is to first use technological approaches to proceed from simple to more complex models and then to test hypotheses based on model behavior in an investigative experience with a living preparation.

Providing Students With a First-Hand Experience With a Living System

Some laboratories are designed to provide students with a first-hand experience with a living system. The specific goals of these sessions lie on a continuum with technical proficiency at one end and response of the whole organism to various types of stimuli at the other. A live preparation is required to achieve objectives on this continuum. The following examples illustrate this requirement.

There is need, in some curricula, for students to become adept at performing various surgical maneuvers, because they will need these skills either in future research efforts or in treating patients. Although a certain degree of familiarity with the procedures can be achieved with the aid of simulations, students must ultimately practice these skills on preparations comparable to those that will be encountered in their careers.

Traditionally, a prominent education goal of student laboratories has been to help students gain an appreciation for real biology. More specifically, laboratories falling into this category have focused on helping students to gain insight into the intricacies of structural-functional relationships in biological systems. For example, in learning about cardiac function, students focus on the electrical and mechanical events of the cardiac cycle, and they correlate these events through a series of graphs. They may even work with a number of simulations designed to illustrate relationships between various factors affecting cardiac function. However, it can be argued that the best way to gain an understanding of cardiac action, integrating the importance of the geometry of the heart, the nature of the excitation pattern of cardiac muscle, and the contraction process, is to compare, through sight and touch, a heart beating normally with a fibrillating heart. This experience cannot be duplicated by physical or computer simulations or by viewing images stored on film, videotape, or videodisc. It can only be achieved through exposure to a live preparation.

Finally, the goal of some laboratories is to examine the integrated response of a system to various stimuli. An excellent example is the response to exercise. Although isolated aspects of the response to exercise can be studied through various simulations, the factors contributing to an organism’s response to exercise have not yet been delineated. Hence, the only way to observe the integrated response is to work with a live preparation.

In conclusion, we have seen a trend in recent years toward reduction or elimination of student laboratories in many life science settings. The reasons given for reducing or eliminating these sessions are varied. In succumbing to the various pressures, it seems as if few departments have seriously examined the educational goals of their student laboratories in an attempt to retain these potentially valuable educational experiences.

Such an examination would yield four general categories of objectives, addressing issues ranging from dealing with gaining technical experience to those dealing with gaining insights into the integrative biology of the organism and its interaction with the external environment.

Technology offers a variety of ways to help approach these educational goals. In some cases, technological approaches can replace live preparations to achieve specific educational goals. In others, such approaches, when used in conjunction with live preparations, can enhance the laboratory experience and help to more effectively achieve educational objectives. It is important to recognize, however, that some educational objectives require first-hand experience with live preparations.

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REFERENCES