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ABSTRACT

This description of the use of "probeware," i.e., hardware which connects to a microcomputer and works with the software to measure factors such as temperature, light, or motion in science laboratory experiments, uses as an example an experiment which would involve the measurement of pendulum motion using the "Precision Timer II" software program. Strategies for classroom teachers to become involved with probeware are suggested, additional available probeware is discussed, and information on the providers of workshops and training programs is provided. The 19 reference items listed include the names and addresses of software distributors and organizations providing training, as well as journal articles and books. (EW)

INTRODUCTION TO PROBEWARE

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"Where computers work well is not always where they'll do the most good."--Glenn Fisher (1)

As heretical as that statement must sound, let's look at the typical ways in which computers are used in science classrooms. What do you have in your inventory--drill and practice programs? Any simulations or tutorials?

If your collection is like that of most educators, you predominantly have (and use) a lot of drill and practice programs. Software developers provide many choices in this area. Fewer selections are available in simulations or tutorials. Perhaps you have seen a program that simulates a nuclear reactor or a food chain or a program which tutors students in the basic laws of genetics.

Applications such as these make use of the computer's abilities to crunch numbers and to drill tirelessly. In this sense, the computer enables more efficient use of a teacher's limited time. Beyond this level, though, how does computer technology allow new approaches to education? How can computers be used to have the greatest impact on the quality of science instruction?

A rapidly growing area for the use of microcomputers in science is that of **probeware**. Also known as interfacing or microcomputer-based laboratories, probeware is hardware that connects to a micro and works with software to allow direct measurement of temperature, light intensity, motion, etc. The computer provides instantaneous feedback. Many programs include analysis features with line graphs and data tables. Most significantly, the use of probeware allows the focus of laboratory experiences to change from measurement and recording to experimentation. Large amounts of data can be collected in a class period; the effects of several independent variables can be determined quickly.

In conventional laboratory settings, students often become so engrossed in the collection and analysis of data that they fail to recognize the scientific principles which are being studied. Consider the following example of the study of the period of a pendulum.

PENDULUM PROBLEM

Most everyone has seen the motion of a pendulum in a grandfather's clock or has seen the back-and-forth motion of a playground swing. In physics we learn that the time required for one complete back-and-forth motion (period) is given by the formula: $T = 2\,pi\sqrt{l/g}$. If l is measured in centimeters, the value of g is 980 cm/sec^2. Note that the period of the pendulum is **only** affected by one variable--the length of the pendulum. (The value of g is constant at a particular location).

This law implies that the time required for the back-and-forth motion of a pendulum is not affected by: (1) the height (amplitude) of the swing or (2) the mass of the object on the end of the pendulum. The law further states that the period is proportional to the square root of the length of the pendulum's string--if the length is increased by a factor of four, the period would be doubled.

In a typical lab set-up to test this law, students might be instructed to measure the time for 50 swings of the pendulum and repeat this measurement five times. From the measured times, the average period of a pendulum for a particular length is determined. These measurements are repeated for a) different masses on the pendulum; b) various amplitudes of swings; and c) various pendulum lengths. The entire process of gathering data may take 20 - 30 minutes. From this data, students are asked to graph period vs. length of pendulum, period vs. amplitude, etc. If used as a verification lab, the data which are plotted should hopefully support the predicted findings.

For many students, the successful transfer of knowlege from laboratory experiences does not occur. The breakdown can be attributed to several factors:

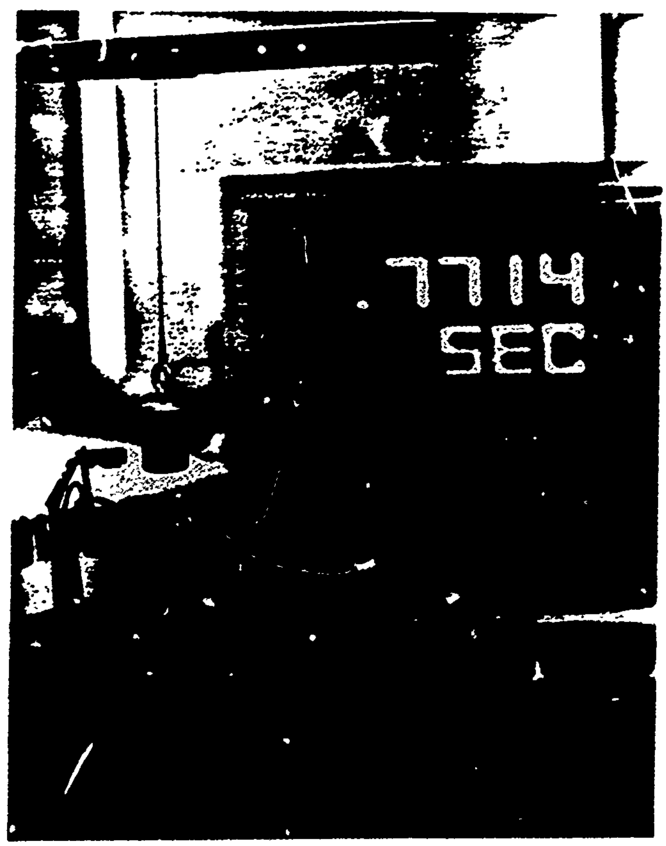
1. Arithmetic or graphical errors which lead to incorrect interpretations occur;

2. Data are changed so to "verify" the desired outcome; and/or

3. Grading emphasis is placed on the recording and graphing of data rather than the interpretation of results.

A BETTER WAY

Consider a probeware approach to the same laboratory experiment. As shown in the photograph below, a conventional laboratory pendulum set-up is used. The sensor for the experiment consists of a light-emitting-diode (LED) and a phototransistor which are mounted on a stand. The pendulum is aligned so that it will pass between the LED and phototransistor.



Large screen display enables the entire class to observe the time for each swing of the pendulum.

Data is analyzed by the Apple IIe computer through the use of a software program, **Precision Timer II**, by Vernier Software (2). The software provides options for timing a variety of phenomena including velocity, acceleration, duration of an electronic flash, frequency of a strobe light and period of a pendulum.

The period of the pendulum is displayed on the screen. Following measurement, data can be reviewed and extraneous readings can be eliminated prior to data analysis. The program contains features to allow printing of data tables and/or graphs.

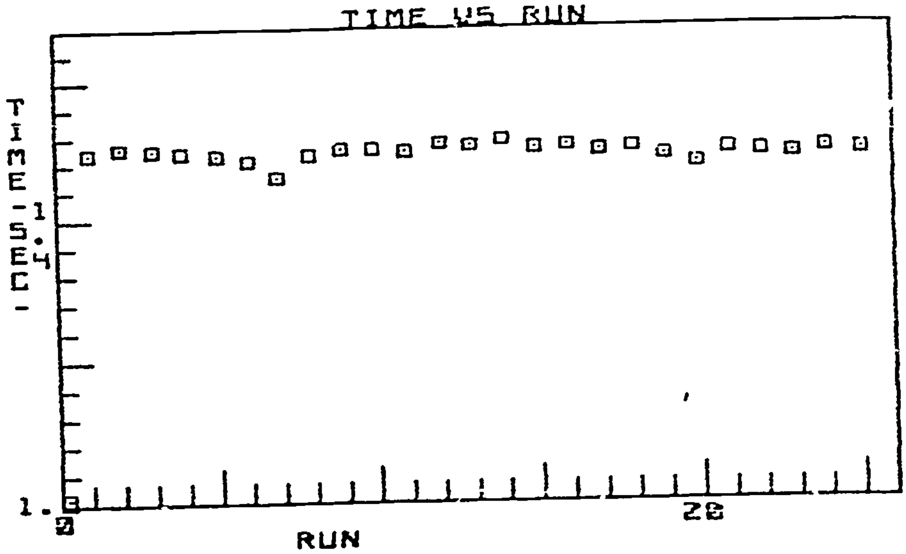
Complete table of time data

#1	1.4231
#2	1.4242
#3	1.4255
#4	1.4238
.	
.	
.	
#24	1.4221
#25	1.4224

Number of data points 25
Mean 1.4231
Standard Deviation 2.6E-03

Individual data values as well as mean and standard deviation are provided.

With this method, the effects of numerous variables can be observed and recorded quickly. The amount of laboratory time used in the collection and recording of measurements greatly decreases. Instead, students can easily observe the effect (or non-effect) of changing the mass on the pendulum. What happens if the amount of swing of the pendulum is changed?



Some probeware allows graphical display of data.

THE BOTTOM LINE

Robert Tinker, in **Microcomputer-Based Laboratories** (3), provides four reasons for the success of probeware:

1. **Direct Sensory Experience.** The measurement of temperature, force, light intensity, etc. takes on a new meaning to students when they observe directly how the computer responds to changing phenomena. The computer is seen as a laboratory partner ready to measure and record values.

2. **Fast Feedback.** In direct contrast to many science labs where students may compute results at home, probeware provides instantaneous feedback. The immediate effect of a change in the experiment can be seen. If something interesting occurs, the student can look to see what is causing it. The laboratory becomes more dynamic, interactive.

3. **Transformations.** Many probeware programs allow the data gathered to be quickly transformed into a graphical format. For some applications, display as a pie chart or histogram may be appropriate. Temperature might be represented by the rate of motion of a molecular model. In all these instances, the transformed data is more meaningful than raw data.

4. **Absence of Verbal Mediation.** Probeware emphasizes experiment-based science. The access to science of learning-disabled students and others who do not have highly developed verbal skills is increased.

GETTING STARTED

Introductions to probeware science can be arranged regardless the size of your wallet. Interface kits and directions are available for most brands of microcomputers with the largest selection for Apple. Check the references at the end of the article to note the availability of products on specific computer systems.

Level I

Description: Defined as software programs found in books and magazines and entered by user. Devices are constructed from Radio Shack parts or from other components which can be procurred locally or mail-ordered.

Advantages: Low cost (starting at less than five dollars) is major advantage. The units are excellent for student projects in which programming and construction are important.

Disadvantages: Parts are sometimes hard to find. No resource person is available if unit does not work. Some programs which have to be typed are lengthy. Advanced computer analysis tools such as graphing and data analysis are usually not available.

References: Several books and articles are available (3,4,5,6,7,8).

Level II

Description: Characterized by software programs with data analysis capabilities provided on diskettes and hardware devices which are constructed from kits and/or locally acquired components.

Advantages: Low cost (usually $10 - $50); excellent projects for more advanced students. Kits offer the opportunity to build items which would cost several hundred dollars for much less.

Disadvantages: More complex kits may require several hours to build. No resource person is available to analyze problems if units do not work. Some expertise in electronics may be needed to build units.

References: Vernier Software (2) provides the **Precision Timer II** and other probeware in kit form. Check with individual distributors concerning other kits which are available (9,10,11,12).

Level III

Description: Category defined as ready-to-use units containing hardware and software. Included in many kits are instructional strategies and activities which are coordinated with science texts. Computer operation is simple and programs are menu-driven.

Advantages: Construction of electronic equipment is not required. Computer operater does not have to be familiar with programming to operate unit. Equipment is warranted and support staff is provided to assist with problems.

Disadvantages: Equipment is generally more expensive, ranging in cost from $40 to more than $1000. Many products can only be used for specific tasks and the ability to modify the unit is not available. The desired software may not be available for a particular computer system.

References: HRM (13) offers a large selection of products. Middle school/junior high teachers may be interested in the **Science Toolkit** (14). Other sources of probeware include (14, 15).

WORKSHOPS, TRAINING PROGRAMS

Several organizations offer training programs and workshops in the construction and use of probeware. Project Seraphim (9) and the American Association of Physics Teachers (12) have cadres of presenters available for workshops. Other groups, such as the Computer Literacy Training Center at the University of Southern Indiana (16), have collections of probeware for preview and provide training sessions.

WHAT'S NEXT?

Probeware continues to evolve at a rapid rate. Recent announcements include devices that will measure actual or simulate earthquake intensities (17), analyze sound (13), and monitor brainwaves, electrocardiograms and electrical activity of muscles (13). Products that will not only measure data but will provide commands based on data which is received (18) are emerging. Institutions such as the Technical Education Research Center (19) continue to research the effects of probeware on students' development of science understanding. New horizons in science are opening; why not be a part of it!

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