Proceedings of the Indiana Academy of Science
(1991) Volume 100 p. 179-185

A MICROCOMPUTER WORKSTATION FOR UNDERGRADUATE SCIENCE LABS

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ABSTRACT: A microcomputer software package was developed for use at a workstation in undergraduate science labs. The software provides for basic word processing, simple spreadsheet functions, graphing, real-time data acquisition from laboratory instruments, and file management. The primary program in the package provides three screen windows: one for graphing and data acquisition, one for text editing (lab notes), and one for an on-screen calculator and scratch pad. Since the user may move freely between any of the windows, data plotting, data analysis, and lab notes are all simultaneously available. The program may be used with inexpensive, direct-interfacing transducers or with any laboratory device, if an analog to digital converter is used. In the labs at Franklin College, all physiology students (including allied health students) use the workstations for muscle physiology, cardiac physiology, electrocardiogram recordings, electroencephalogram recordings, and spirometry. In addition, the advanced students use the program for plotting graphs, regression analysis, and preparation of lab reports.

INTRODUCTION

During the past decade, microcomputers have played an increasingly more significant role in science education. Computers are used frequently for data analysis, data acquisition, statistics, graphing, and word processing (DeSieno, 1986). For the scientist, the personal computer is a tool that allows the user to quickly analyze data or prepare graphs. This means that less time is spent transforming "raw data" and more time is freed for interpretation and extrapolation of results. As more and more information is accumulated by scientists and as the methods of data acquisition become more and more sophisticated, the computer is becoming an integral component in the methodology of science.

For many undergraduate science students, data analysis can be a frustrating experience. Using only a calculator, a student may spend one or two hours transforming a long list of lab data into "real world" units. Next, a statistical test may be required in order to help draw a conclusion about the significance of the data. Although these steps are an important part of modern science, the time and energy required to perform the tasks manually may often be overwhelming and serve to dampen enthusiasm. Conversely, a student with a computer may transform, analyze, and graph a set of lab data in a fraction of the time and still be left with the curiosity and enthusiasm to interpret and think about the meaning of his/her results. The student with a computer has more opportunities to ask "why" or "what if." These are the very questions, which most science educators seek to develop in their students.

Computers are also being used increasingly as data acquisition devices in the undergraduate science laboratory. The Vernier Software Co. (2920 S.W. 89th Street, Portland, Oregon 97225) provides a number of easy to use interfacing devices for physics and chemistry. Project SERAPHIM (an NSF-supported program based at Eastern Michigan University) also provides chemistry programs and instructions for interfacing projects using Commodore, Apple, and IBM computers. In biology, a series of hardware-software packages is available from HRM Software (Cambridge, Massachusetts) and from Intelitool (Batavia, Illinois). For each of these hardware-software packages, the computer becomes a dedicated lab instrument used for collecting and graphing data from specific transducers. The range of measurements from various hardware configurations is impressive: temperature, millivolts, pH, audio frequencies, light intensity, electrocardiograms, respiratory volumes, mechanical movements, force, and precise timing number among the more common.

However, there are some short comings of commercially prepared packages. First of all, the software provided with each package tends to be very specific and frequently lacks the flexibility necessary for use in a variety of different experiments. Consequently, for each new experiment, the student needs to become familiar with a new software environment and the college must have an extensive software library on hand to support the use of each computer. Second, although many hardware devices utilize the same "on board" circuits in the computer, there is rarely software compatibility when one attempts to use other hardware with a specific software package.

During the past six years, I have designed a hardware-software package which attempts to meet the needs of the "typical" undergraduate, natural science student. The software was designed around a microcomputer workstation consisting of a Commodore 128 computer with disk drive, monitor, and printer. The computer may be interfaced with any lab instrument by means of an analog to digital converter and is also equipt with a universal game port transducer, which was described previously (Rhodes, 1986). The software and interfacing hardware were also designed to be compatible with sensors and transducers from a variety of commercial manufacturers. A complete workstation may be assembled for less than $900.00 (1989 dollars). In my laboratory, five workstations are available for student use, and they service lab sections of about fifteen students.

THE PHYSIOGRAPHICS SOFTWARE

The software package consists of three principle programs, which are accessed through a menu program. The first program provides simple disk management utilities, such as disk formatting and file deletion.

The second program is a generic calibration program which allows the user to calibrate any analog input device which is interfaced with the computer "game port." Methods for game port interfacing may be found elsewhere (Barker, *et al.*, 1989). The calibration program uses a matrix inversion method of fitting a quadratic equation to data sampled from the game port and paired with keyboard entries. The program was developed using suggestions by Spain (1981). The function of the calibration program is to convert the digitized resistance values obtained from the game port into meaningful units which may be graphed, saved to disk, or analyzed. For example, if a thermistor is interfaced with the computer, an increase in temperature at the thermistor will cause the digitized resistance reading at the computer to decrease (in the range of 0 to 255). These arbitrary units may be transformed into degrees centigrade by providing data samples at specific temperatures. Four beakers of water at four different, known temperatures could be used to calibrate the thermistor. Once the computer has determined the relationship between temperature and the digitized resistance values, all output to the screen is in "real world" units. Data acquisition and transformation may proceed at a rate of about 120 samples per second. After calibration is complete, the transformation equation is saved to disk and may be accessed by the user or by other programs in the Physiographics package. Since the calibration program is generic, it may be used to calibrate virtually any type of input device and therefore may be used with commercially sold transducers as well as "home made" devices.

A second valuable feature of the calibration program may not be obvious. It allows the student to collect data in "real" units, which means he/she will not have to manipulate the data in some way before interpreting it. This feature represents a significant improvement over chart recorder systems. For example, due to the large enrollment in one physiology lab, some students use the computer work stations, and some use chart recorder systems. In both cases, force transducers have to be calibrated, and the procedure actually takes less time with the computer. During the actual experiment, the computer user sees his/her data graphed in meaningful units, while the chart recorder user must manually transform the data, after the experiment is complete.

The heart of the Physiographics package is the Physiographics program. This program provides an integrated science desktop with immediate access to a calculator, graph making routines (both bar graphs and X-Y plots), "real-time" plotting of data from lab instruments, a note pad, statistics, and simple "spreadsheet" functions. The program was written so that the basic functions could be learned quickly (usually in 1 to 2 hours using the tutorials). The more advanced features are learned with more frequent use. Care was taken in the design of the program to make students, who were already familiar with word processors and spreadsheet programs, feel comfortable with the user interface. Pull-down menus and "HELP windows" are available at the touch of a key. Use of the cursor keys and data entry formats are similar to what one would find in commercial software. For the novice, every effort was made to provide a "user friendly" environment with very few commands to remember. A summary of commands is available by pressing the HELP key.

When the program is accessed from the menu, a screen containing three "windows" appears (Figure 1A). The menu window allows the user to select an activity, such as data acquisition, typing, or graph making, and is the control point of the program. The graph window may be used manually for constructing graphs or may be used for direct plotting of data from transducers (see below). In addition, data from the text window may be plotted directly to the graph window. The text (notes) window provides a full page for typing and note taking. The page will scroll up and down in the window and may be printed out separately, using whatever fonts are available on the printer. The text may be saved to disk for future retrieval or for loading by a word processor. The text window is also used for "spread sheet" functions, such as "sums and averages" of rows or columns of data, and for entering data for graphical analysis. Since the text and "spread sheet" functions are integrated, notes and tables of data may be stored or printed on the same document. The document may be loaded into the computer later, and the data may then be used to prepare a graph. The user may move freely between the three windows, leaving all data in view.

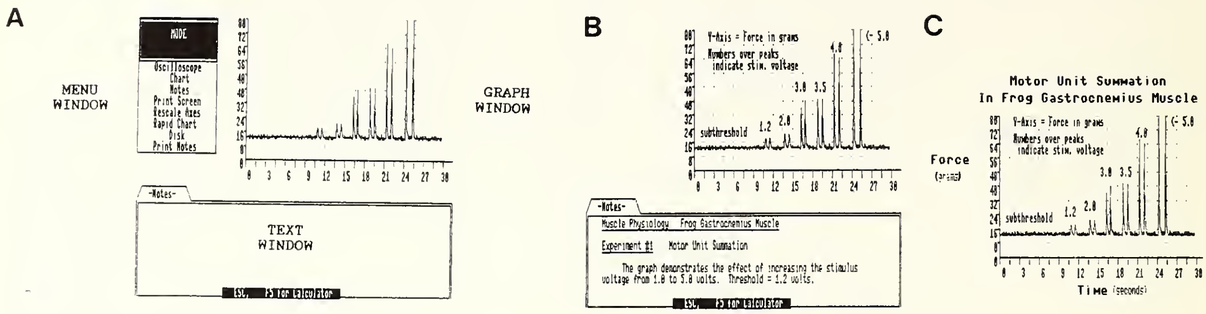

Figure 1A-C. The physiographics screen has three window areas for menus, text, and graphs. **A.** Data from transducers is graphed on the screen in "real time." **B**. A full page of text may be scrolled in the text window. **C**. Labels and text may be added directly to the graph area, and the graph area may also be enhanced with titles and additional labels before printing. a single command. **B**. Statistical analyses and additional labels

APPLICATIONS OF THE PHYSIOGRAPHICS SYSTEM

One application of the Physiographics system would be for data acquisition and analysis during a laboratory period. Figures 1A, 1B, and 1C illustrate an example. Figure 1A shows the force of contraction of a frog gastrocnemius muscle in response to increasing stimulus voltage. The recordings were made using an inexpensive force transducer interfaced via the game port. These data are plotted on the screen in "real time" during the lab (x-axis = seconds; y-axis = grams). In Figure 1B, the student has moved to the text window and "jotted down" some notes concerning this initial recording. Labels were also added to the graph window. Figure 1C shows a printout of the same data with axes, a title, and labels added. The "C" part of Figure 1 could be completed at a later time, using data saved to disk during the lab. Although many other applications are possible, these two examples give the reader some insight into the possibilities for use of the program.

A second application would be to help the student prepare a lab report using data obtained from an earlier lab. An example is given in Figures 2A and 2B. In this example, the student uses the pre-formatted data sheet (which may be loaded into the text window) to enter data on heart rate in a frog as a function of environmental temperature. Next, data are plotted (requires a single command), and the regression line is determined (also a single command). The student adds a label and statistical information to the graph. The next step is to clear the notes window and begin typing the lab report, while looking at the graph. A pull-down calculator is available should calculations be necessary. When typing is complete, the text buffer may be printed. Finally, the axes on the graph and additional labeling may be added before the graph is printed (for an example of a printed graph, see Figure 1C). The advantage for the student is the speed of graphing and statistical calculations. Moreover, the student may edit, change, or regraph data without fear of ruining the graph. Students are much more willing to "redo" a graph or a whole report, if they make an error. Computer graphing also encourages "what if" thinking, because different variables may be plotted rapidly, and the results visually analyzed.

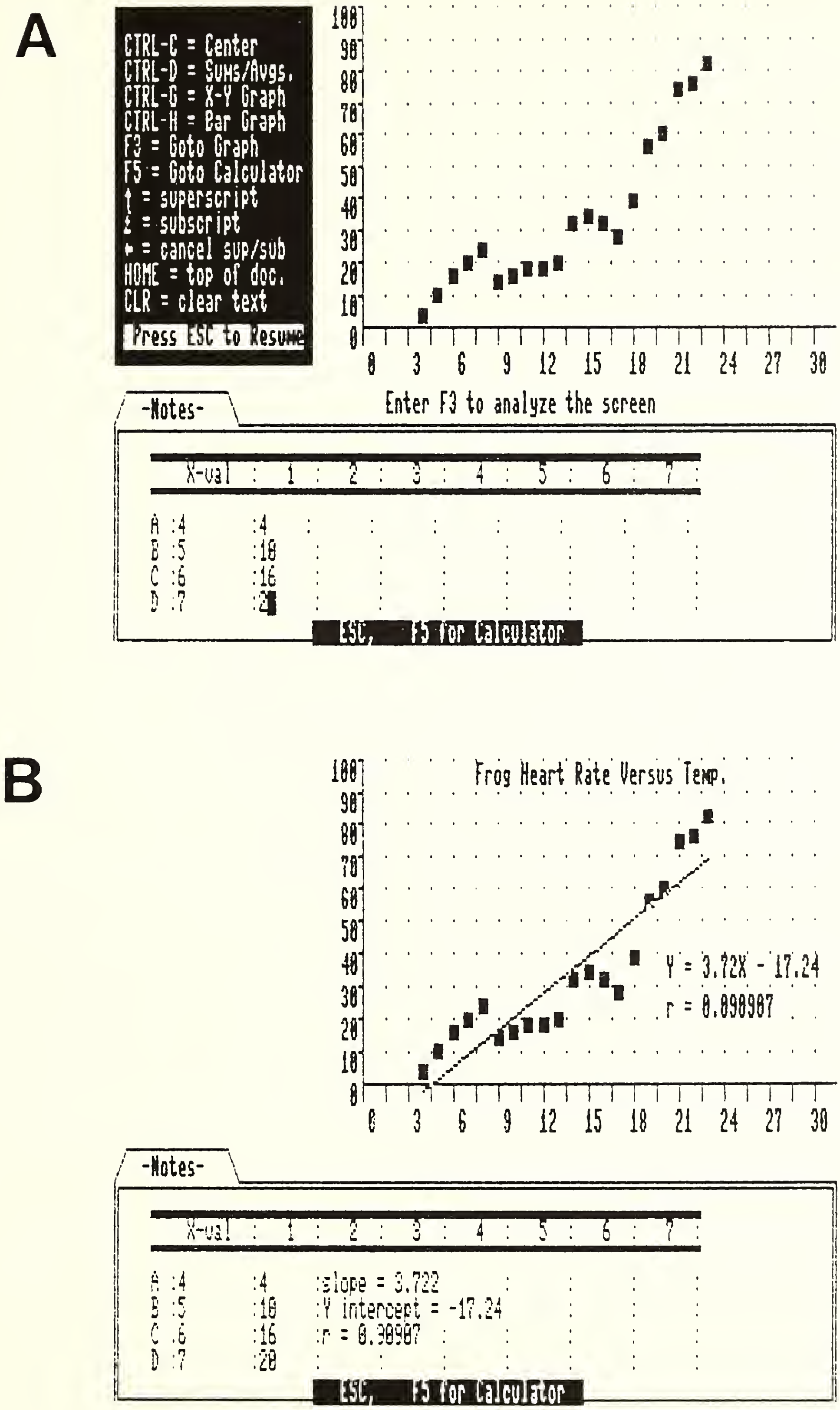

Figure 2A-B. **A.** Data entered manually using the "data sheet" is plotted using a single command. **B.** Statistical analyses and additional labels may be added.

EVALUATION OF THE PHYSIOGRAPHICS PACKAGE

The physiographics package has evolved greatly over the past five years. Initially, the program was designed solely as a data acquisition instrument (Rhodes, 1986). The earlier versions of the program have been used extensively in Anatomy and Physiology classes with excellent results. The complete computer workstation had a cost of less than $900.00 and is capable of replacing transducers, amplifiers, and chart recorders costing at least three times this amount. Since the computer offers word processing, high resolution drafting, and data processing capabilities, its value is greatly enhanced. In addition, the computer system is easier to calibrate and not prone to mechanical problems (especially with regard to ink pens!). Another advantage is the ability to collect data automatically over long periods of time, so that phenomena such as photoperiods or plant growth could be recorded remotely.

On the negative side, the computer has a limited memory and a limited viewing screen. You cannot examine "yards" of chart paper recordings with a computer screen. This can be a problem, if you are studying a phenomenon which develops over the course of several minutes. In order to condense several minutes of recording into one "screen" of data, a good deal of resolution is lost. Another problem is with "time resolution." As mentioned earlier, the computer can collect, transform, and plot data at a rate of about 120 points per second. This rate is sufficient for most biological processes but is not adequate for phenomena such as action potentials or clear resolution of an electrocardiogram (EKG). If data are collected first and plotted later, the time resolution increases to about 222 points per second which is acceptable for the EKG. However, this means that the student cannot watch the data develop on the screen in "real time."

The enhanced version of Physiographics has been used for two years in an Animal Physiology class of fifteen Juniors and Seniors. In this class, weekly lab reports with statistical analyses (generally T-tests) and two formal lab reports per semester were required. At the beginning of the course, each student was given a copy of the Physiographics package and two printed tutorials on the use of the program. The students have free access to the computers during regular working hours. Their first lab report required that they prepare graphs using the program, but for subsequent lab reports, they were free to choose the computer or manual methods of graphing and statistics. As the semester progressed, the program was used for data acquisition during five different lab periods (muscle physiology, EEG's, cardiac physiology, respirometry, and metabolism).

Initially, there was some reluctance to learn and use the program. About half of the students entered the class with "computer phobia" despite a campus-wide requirement for word processing proficiency. Several students tried to use the program without completing both tutorials. The result was frustration and confusion with the program. I tried to intervene as little as possible; when questioned, I referred the students to the tutorials. By mid-semester, all students preferred the computer system for graphing and statistical analysis and about one third used the program for preparing their complete reports (text, graphs, and statistics). Four or five students were starting to use the program for their other courses. Since we have a limited number of computer systems, in two labs, some students used the computers, while others used chart recorders. Without exception, the computer system was preferred.

However, given that I wrote the program and teach the course, I have to discount this observation.

In retrospect, the key to maximal student use of the program is to require early completion of the tutorials. The tutorials also need to be more specifically designed around preparing the lab report. Once the students fully appreciate the benefit of using the program, they learn to like it.

CONCLUSIONS

An integrated workstation for undergraduate students in the natural sciences has been developed and installed in the Franklin College physiology lab. The program provides for data acquisition, simple word processing, graphing, and statistical analysis, using a graphics, "desktop" user interface. The program was specifically designed to facilitate preparation of lab reports and to reduce the time required for the analysis of laboratory data. Hopefully, the students would be less frustrated by the mechanical aspects of preparing a report and have more time and energy for interpretation of their results. In addition, the workstation would introduce students to a practical application of spreadsheet and graphing programs which are prevalent in the science workplace. Although further analysis and adjustments will continue to be made, the "workstation" approach to undergraduate lab science seems promising and beneficial. Computer workstations are a cost-effective approach to instrumentation in the lab and provide for efficient means of data processing. User friendly programs, which can be learned rapidly, are important keys to implementation of a workstation in a lab course. Maximum benefit from such an approach would be achieved, if a consistent, campus-wide microcomputer system was in place. In this way, data collected during lab could be analyzed at any remote computer site.

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