A Model for Incorporating & Evaluating Use of a Computer Laboratory Simulation in the Nonmajors Biology Course

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In spite of the fact that well over one million computers are currently in use in U.S. classrooms and continued exponential growth has been predicted, science teachers, particularly biology teachers, regularly fail to employ them in their classes (Baird 1989, Becker 1987, Ellis & Kuerbis 1988, Lehman 1985). One explanation offered for this is lack of prior exposure to examples of computer use in the curriculum (Ellis & Kuerbis 1988, Klopfer 1986, Lehman 1985). The purpose of this paper is to describe how one program was used with a nonmajors biology course at the undergraduate level and to provide information on its subsequent effect on student learning in the hope of providing a model for implementing and validating the use of software, particularly programs that incorporate tutorials with laboratory simulations.

Definition of Objectives & Program Choice

The guidelines established in 1984 by the National Science Teachers Association indicate that the first step in adding a computer component to any class is identification of the instructional criteria the program is to fulfill. This involves definition of the students' needs, the learning expectations of the instructor and the type of program best suited to meet the constraints imposed by each of these (Kingman 1984, Klopfer 1986, Okey 1985, Smith 1988).

In the case discussed here the class consists of nonmajors taking an undergraduate Life Science course. Since enrollment is not limited to first year students, the population is quite heterogeneous, approximately 60 percent freshmen, 30 percent sophomores, and 10 percent juniors and seniors. Overall enrollment at our university is comprised of 74 percent Hispanic, 5 percent black, and 16 percent Caucasian students, with the remainder being of various other ethnic backgrounds.

Many of these students encounter impediments to learning because of unfamiliar vocabulary and style of English usage within science (AAAS 1990, Lemke 1990, Mikulecky 1988, Ryan 1989). In addition, as nonmajors they are likely to express apprehension about enrollment in a science course (Brown & Cranson 1989; Chipman & Thomas 1987; Jegede, Alaiyemola & Okebukola 1990; Mallow 1986; Mallow & Greenburg 1983). Maslow (cited in Schunk 1991) classifies such anxiety as an intervening factor to successful learning which needs to be addressed before students can function properly within the educational environment. The first goal in this approach, then, was to facilitate learning by providing increased opportunity to become familiar with and review terms encountered in introductory biology, working at a relaxed and self-determined pace, thus addressing any language difficulties and initial anxiety about the class.

The tutorial aspect was to be accompanied by interesting visual presentations to clarify concepts for the students and to help excite those whose previous experiences in science courses may have been limited or negative. We also wanted a program that offered a learning opportunity not otherwise afforded by the traditional first week laboratory exercise. Almost every introductory biology course we have reviewed begins with a description of *The Scientific Method of Study* (Arms & Camp 1991; Enger, Kormelink, Ross & Smith 1991; Postlethwait & Hopson 1991; Starr 1991). It is a concept that underlies all the experimental presentations that follow. While students are capable of rote listing of requirements involved in experimental design, in our experience, many repeatedly fail to apply these requirements to their own laboratory work and to recognize problems with the work of others who have made similar omissions. An experiment that could be done at the onset of the course to demonstrate the importance of an organized approach to investigations in biology and to fix firmly the concepts underlying what is known as the Scientific Method in the student's mind was needed. Because laboratory periods are short, software that included an experimental simulation was an appropriate choice. This also offered the administrative advantage of allowing individual makeup should the first laboratory session be missed due to inevitable first week enrollment changes.

The final requirement was that there be significant emphasis on data handling and proper evaluation of results. These are areas that we have found students frequently overlook when describing biology experiments. Even students skilled in mathematical operations and graphing do not recognize the need to bring these methods to the biology class; such failure in lateral transfer has been described by cognitive psychologists and learning process theorists in a multitude of situations. Furthermore, the ability of the student to understand scientific concepts can be linked to their ability to properly prepare and interpret

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graphs (Mokros & Tinker 1987; Shaw, Padilla & McKenzie 1983).

With these requirements in mind the hunt for an appropriate computer program began. The one selected was Disk I: Biological Principles from *Introduction to General Biology* (COMPRESS).

Program Implementation

The software was installed on the university's computer network and assigned to the branch housed in the Science Building which consists of 30 computer terminals available for both individual use and classroom reservation. The first laboratory session of the term was scheduled to meet in this facility where the students could work individually on the program and also have the assistance of teaching staff and peers. Students were given the entire 2½-hour laboratory period to work on the program. They were encouraged to return later if they found the need to review or repeat parts of the program. No effort was made to monitor the time.

Three separate sections of the disk were used: The Scientific Method, Running an Experiment and Interpreting Results. The first of these provides the basic vocabulary needed and explains the steps to be followed. It includes extensive question and answer review to test both acquisition of terminology and conceptual understanding. The second section provides additional examples of experimental design and introduces the simulation on plant growth. The student sets up control and experimental treatments and directs the computer to perform the experiment, one day at a time, in response to keyboard input. Ten days of plant growth occur on screen. Each repetition of the identical treatment generates slightly varied mathematical results. The third section of the program describes how to accumulate and graph mathematical observations made during the course of an experiment and discusses the validity of observations when presenting support for a hypothesis. It provides plots of the experimental results for two trials.

Also, each student received a four-page study guide which outlined the learning expectations, explained how to use the computer facility, discussed any difficulties with the software and established the initial evaluative criteria for the learning experience. The latter consisted of a written paper/lab report accompanied by the final page of the study guide containing 20 questions on the Scientific Method.

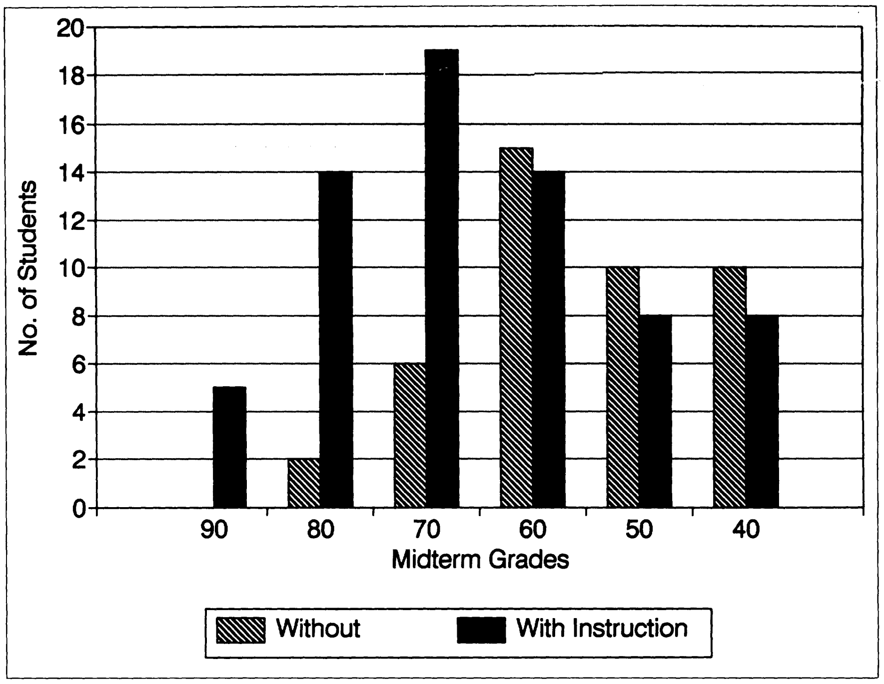

Figure 1. Comparison of two classes without vs. with computer instruction.

The effectiveness of the experience would be tested further, throughout the semester, in three ways:

1. Formal examination through midterm testing
2. Inspection of future written reports on actual laboratory exercises for evidence of continued application of learned principles
3. Day-to-day subjective observation of performance in actual laboratory exercises.

However, to assure the validity of the observed effects, no additional lecture or laboratory time was spent on this material.

Assessment of Program Use

Since the Life Science course is taught each semester, information on the past performance of students who had been presented the same material by the more traditional method is available. We used records and observations of 43 students taught in the Fall 1990 class to compare to those of the 67 students with whom the software was first used in the Spring of 1991. Figure 1 shows the grade distribution obtained for 10 of the questions on the midterm laboratory examination devoted to this topic. It should be noted that the type and general content of the questions used with the two groups being compared were similar but not identical.

The graph shows a marked shift to the left. Since both curves are nonparametric yet equally skewed and the sample size is large, the Student's t-test can be used to measure the normal approximation and significance of change between the two groups (Glantz 1991). Table 1 presents the comparative data. The improvement in grades is significant ($t = -4.249$ with 108 degrees of freedom; $P = 0$).

To measure continued application of acquired skills, grades were compared for a written report on identical laboratory exercises performed by the

Table 1. Evaluation of grade distribution midterm questions on Scientific Method.

Group	*N*	*Mean*	*Std Dev*	*SEM*
Without	43	59.72	10.27	1.57
With	67	70.06	13.66	1.67
Difference		−10.34		2.43

(95% confidence interval for difference: −15.16 to −5.52)

Table 2. Evaluation of grade distribution follow-up laboratory work—four weeks later.

Group	N	Mean	Std Dev	SEM
Without	43	70.88	5.54	0.85
With	67	85.88	11.98	1.46
Difference		−14.99		1.95

(95% confidence interval for difference: −18.86 to −11.13)

two classes approximately four weeks later. Table 2 summarizes the data. Again the change in grades is significant ($t = -7.688$ with 108 degrees of freedom; $P = 0$). To verify that the change was due to exposure to the program and not to differences in performance of the later laboratory exercise or complications in understanding that experiment, the papers were reviewed to pinpoint errors. In the initial group, 11 out of 43 students had not retained data handling and/or graphing skills that were presented as part of the analytical techniques involved in the use of the scientific approach; in the computer-instructed group only six out of 67 students failed to retain these capabilities: 25.5 percent to 8.9 percent, respectively.

Additional qualitative evidence of the success of the computer program is also available. The students who had the computer introduction to the course appeared to use a more sophisticated approach throughout. Their use of the concepts began immediately as they worked on the program, viewing each other's on-screen simulations and helping each other work on any software problems that arose as they went through the tutorial. Later in the semester, when the students were required to visit the laboratory outside prescribed times and record information about the progress of an ongoing experiment of their own design, they were heard speculating and arguing over differences in treatments, even challenging validity of comparisons. They appeared to be practicing science.

Finally, the students were asked to complete anonymously a survey evaluating the experience with the software. The survey questions and results are reprinted in Tables 3 and 4. Several of these deserve special comment.

Question 13 brought a unanimous reply: 100 percent of the students agreed that they liked using the computer because they could progress at their own pace. In fact, 82 percent indicated that they repeated the tutorial more than once—a fact confirmed by systems records of the computer laboratory manager. Better confirmation that the students' needs for additional, directed study were met cannot be offered.

Table 3. Survey regarding use of computer tutorial/experimental simulation.

1. The tutorial section of the computer program helped me learn new scientific terms.
2. The question section helped me fix the terms in my memory.
3. The questions helped clarify ideas explained in the preceding parts.
4. The graphics were easily understood.
5. The graphics helped me understand the tutorial section better.
6. Even though the tutorial was understandable, the study guide was necessary to help me pick out important ideas and terms.
7. Without the study guide, I would not have taken notes.
8. I can write a better laboratory report as a result of the tutorial.
9. I would welcome having access to other tutorial programs to study other topics in this course.
10. I would like the tutorial programs to include graphics.
11. I would probably use the computer lab only if it were required and would not use it to study on my own.
12. I would like a few more experimental simulations.
13. I liked using the computer program because I could work at my own pace and repeat parts I did not understand or wanted to write down.
14. I did do the tutorial section of the program two or more times.
15. I still remember what I learned from the program.

Seventy percent of the respondents acknowledged that the Study Guide was an essential part of the program and that without it they would not have taken notes (Questions 6 and 7). This is quite important since few software packages for undergraduate use come with any study guides. We have noticed students consequently approach tutorials as an interesting diversion from the normal routine. They "play" the tutorial game and do not recognize the need to take away the information. From the time of its initial publication in 1962, educators have accepted the model of instruction set forth by Mager which clearly indicates that all effective teaching techniques rely on the student being apprised of the expected outcomes at the beginning of the experience. This was the primary purpose for preparation of the Study Guide.

The last comment to be made is with regard to the student responses to Question 5. These indicate that most students felt the visual presentations/animations were highly important. Penned comments asked for future software that would offer similar presentations of structures and processes described in lecture to use as study aides. The students were not satisfied with tutorials consisting of only question and answer reviews of presented materials.

Conclusion

Inclusion of the computer software with its experimental simulation as an introduction to the laboratory exercises and for teaching the scientific method of inquiry to the Life Science students at our university has proved to be an effective addition to the overall course. Student experimental techniques, mathematical performance and attitude toward the class have improved. The software has also generated interest in biology. Several students who plan to be elementary school teachers indicate that they hope to perform the actual plant growth experiment that was simulated with their future classes. For the majority of the nonmajors, this course is among the last formal encounters they have with scientific topics. We believe this technique has given them a degree of success and understanding within the science classroom, a result consistent with the goals for the Life Science course.

Table 4. Results of student survey regarding use of computer simulation in Life Science course.

No	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
1	22.2%	68.2%	3.2%	6.4%	
2	18.2%	71.0%	3.6%	7.2%	
3	19.7%	62.3%	13.1%	4.9%	
4	55.0%	36.7%	3.3%	5.0%	
5	39.3%	52.5%	6.6%	1.6%	
6	24.2%	46.8%	17.8%	9.6%	1.6%
7	23.8%	34.9%	9.5%	28.6%	3.2%
8	24.6%	42.6%	24.6%	8.2%	
9	59.0%	34.5%	4.9%	1.6%	
10	61.7%	33.3%	3.4%	1.6%	
11	11.5%	27.8%	13.1%	27.8%	19.8%
12	39.3%	50.8%	6.6%	3.3%	
13	77.0%	23.0%			
14	37.1%	45.2%	4.8%	12.9%	
15	16.0%	64.0%	16.0%	4.0%	
16	21.4%	32.7%	13.1%	26.2%	6.6%

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