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ABSTRACT

A series of computer-based activities were integrated into the laboratory portion of a two-semester university biology course for elementary teaching majors. The purpose of the project was to address the biology instruction provided to the students while at the same time providing examples of appropriate uses of computers in instruction, applicable to elementary teaching, and involving the students in the use of computer-based science teaching materials. Groups completing supplemental computer-based activities were compared to non-computer groups on regular class measures of achievement and on measures of attitudes towards computers, biology, and the supplemental activities. There were few apparent achievement differences between the computer and non-computer groups. However, there were instances where students gave more favorable evaluation to the computer-based activities, and students showed significantly more positive attitudes towards computers as a result of the project. The findings suggest that the integration of computer-based instruction in preservice elementary teachers' science coursework may be an effective means of incorporating computer education in preservice teacher education. (Author)

Integrating Computers in the Biology Education of Elementary Teaching Majors

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A series of computer-based activities were integrated into the laboratory portion of a two-semester university biology course for elementary teaching majors. The purpose of the project was to address the biology instruction provided to the students while at the same time providing examples of appropriate uses of computers in instruction, applicable to elementary teaching, and involving the students in the use of computer-based science teaching materials. Groups completing supplemental computer-based activities were compared to non-computer groups on regular class measures of achievement and on measures of attitudes towards computers, biology, and the supplemental activities. There were few apparent achievement differences between the computer and non-computer groups. However, there were instances where students gave more favorable evaluation to the computer-based activities, and students showed significantly more positive attitudes towards computers as a result of the project. The findings suggest that the integration of computer-based instruction in pre-service elementary teachers' science coursework may be an effective means of incorporating computer education in pre-service teacher education.

INTRODUCTION

The purpose of this National Science Foundation - Purdue University project was to develop a model approach for the integration of advanced technology in an introductory science course for pre-service elementary teachers. During the 1986-87 academic year, a total of 12 computer-based activities were integrated into the laboratory component of the course, Biology for Elementary Teachers, at Purdue University. A variety of activities were employed; these included drill and practice, tutorials, simulations, computer-based data pooling, interactive video, telecommunications, computer software evaluation, and even limited software development. In most cases, techniques for utilizing limited numbers of computers were employed in an effort to conform to the situation found in the typical elementary classroom. The effects of project activities on student attitudes and achievement were assessed.

BACKGROUND

The impetus for the project derived from several different but interrelated sources. These sources included: well publicized problems in science education, elementary teachers' reported lack of preparation to teach elementary science, the potential of computers and other high technologies to address educational problems, the dearth of computer hardware in elementary schools, elementary teachers' lack of preparation to use educational technologies, and limited access to computer course electives in the college elementary teaching curriculum.

A major focus of this project was the improvement of science education. Clearly, reports such as "A Nation at Risk" (1983) have raised public awareness about the problems facing U.S. education in general and science education in particular. At a time when the demand for a scientifically and technically literate populous is growing, declining student performance creates real concern. A push for educational improvement has become part of the national agenda.

There are some especially acute problems at the elementary school level. While the elementary school years are an ideal time to interest young people in science and to lay solid educational foundations, the educational system often fails to do well in these regards. There is a need to improve science education at the elementary level.

Unfortunately, many elementary teachers report feeling inadequately prepared to teach science, and elementary science often gets short shrift compared to "more basic" parts of the curriculum. Reports such as "A Nation Prepared: Teachers for the 21st Century" from the Carnegie Task Force on Teaching as a Profession (1986) and "Tomorrow's Teachers" from the Holmes Group (1986) have focused on teachers and teacher preparation as both a part of the problem and an avenue toward solution of educational difficulties. Changes in teaching and in teacher preparation have the potential to effect positive changes in the education of students throughout the country. Specific to the project reported herein, it is clear that for improvements to be made in elementary science teaching, the preparation of elementary teaching majors for the teaching of science must be addressed.

Another major focus of this project was technology. While many approaches and factors may help to improve education, the effective use of educational technology is often cited as an important element in improving today´s and tomorrow´s instruction. For example, "Transforming American Education: Reducing the Risk to the Nation" (1986), a report of the National Task Force on Educational Technology commissioned by then Secretary of Education T. H. Bell, argues that computers and allied technologies have the potential to go beyond educational reformation to educational transformation.

Computers are now widespread in U.S. schools, and a second national survey of school uses of computers conducted by The Johns Hopkins University in 1985 shows computer use to be up substantially over the first national survey done in 1983 (Becker, 1986). Meta-analyses by Kulik and his associates (1980, 1983, 1985, 1986) as well as other reviews (e.g. Niemiec and Walberg, 1987) indicate that computer-based instruction tends to: be somewhat more effective than traditional instructional methods, be more efficient than traditional methods, and promote positive attitudes towards the instruction. The greatest effects on achievement are seen at the elementary level. Thus, evidence exists that suggests that computers might be a significant factor in improving elementary instruction.

Of course, effective use of educational technology at the elementary level requires both availability of the technology and teachers trained to use it. Unfortunately, the levels of hardware available in the typical elementary school are low. According to a recent national survey, a typical public elementary school in the United States has about 9 computers, while a typical secondary school by contrast has about 26 computers (Market Data Retrieval, 1987). This low number in the elementary school often translates into 1 or 2 computers in a single elementary classroom. While the numbers certainly need to increase, elementary teachers also need to be aware of methods for utilizing limited hardware in the classroom.

As with the teaching of science, effective use of educational technology at the elementary level requires knowledgeable teachers. Unfortunately, the situation parallels that in science education in that many teachers are inadequately prepared to use educational technologies in the classroom. According to the second Johns Hopkins survey (Becker, 1986), although a much higher proportion of elementary teachers make use of computers in an average week than do secondary teachers, those elementary teachers who do use computers are far less expert than corresponding secondary teachers in: using instructional programs, knowing a variety of programs, using computers as professional tools, and writing useful programs.

The lack of necessary skills among elementary teachers creates an impediment to the integration of computer technology in the elementary curriculum. Yet, integration and individual teacher development have been cited as areas of critical concern in an overview of computer-based projects in science education (Watson, 1983) and in a recent national teleconference on educational technology (Oklahoma State University, 1985). According to the first national survey conducted by Johns Hopkins (Becker, 1984), computer integration is most successful when a group of teachers initiates and organizes the use of computers. To accomplish successful integration, better elementary teacher preparation in the use of technology is needed.

But, the situation at Purdue University, like many other universities, makes it difficult to incorporate computer education in the elementary education curriculum. Because of the large number of required courses, many elementary teaching majors now take more than the traditional four years to complete their degrees and obtain elementary teaching certification. Although computer education courses are available, only about one in three pre-service elementary teachers elect to enroll in one. Computer education elective courses represent one more demand on limited time. One viable solution is to integrate computer use and computer education into existing courses. Indeed, Battista and Krockover (1982) suggest a model for the computer education of pre-service elementary teachers that focuses on the development of positive attitudes through the use of computer-based instruction in coursework.

The factors noted above all contributed to the conceptualization of this project. The basic idea was to incorporate technology-based activities into a science course for elementary teaching majors in such a way as to: enhance the basic science instruction provided to these college students, demonstrate ways that a variety technology-based activities can be integrated into the curriculum, illustrate techniques for utilizing limited numbers of computers in the classroom, raise the students' awareness of the educational uses of technology and the types of software available for use in elementary science teaching, and promote more positive student attitudes towards educational technologies through their use in the college classroom.

METHODS AND MATERIALS

Subjects

The subjects consisted of students enrolled in Biology 205 and Biology 206, Biology for Elementary Teachers, at Purdue University during the 1986 fall and 1987 spring semesters. All of the students were elementary education majors. Most were in their freshman and sophomore years, and the great majority were female. Students who failed to complete a course were not included in the data pool.

During the project's first semester (Biology 205), the total number of subjects was 202. Of these, 189 were female and 13 were male. A total of 71 were freshmen, 98 were sophomores, 30 were juniors, and 3 were seniors. The mean age at the beginning of the semester was 20.3 years.

During the project's second semester (Biology 206), the total number of subjects was 195, consisting of 182 females and 13 males. A total of 58 were freshmen, 88 were sophomores, 47 were juniors, and 2 were seniors. The mean age at the beginning of the semester was 20.7 years. Of the 195 students enrolled in Biology 206, 136 were enrolled in Biology 205 during the previous semester and, therefore, were exposed to the project for the entire academic year.

Description of the Courses

Biology 205-206, Biology for Elementary Teachers, is a two-semester sequence of basic biology for elementary teaching majors. As noted above, course enrollees are all elementary education majors, mostly female, and mostly in their freshman and sophomore years. While most students complete the course sequence in the intended order (Biology 205 in the fall and Biology 206 in the spring), the courses are sufficiently independent that students can and do elect alternative approaches. As a result, during a given academic year, the class make-up from fall to spring does change somewhat.

The curriculum and organization of the Biology 205-206 sequence is designed to provide the students with an overview of the major organizing principles and concepts of the biological sciences while providing hands-on experiences with materials and methods appropriate for the teaching of biology in the elementary school. The course foundations derive from the curriculum reforms of the 1960s, the work of cognitive psychologist Jean Piaget, and the approaches of renowned University of Washington science educator Arnold Arons.

Each week, students receive one hour of lecture and participate in four hours of laboratory work. Depending upon enrollments, six or seven laboratory sections of 20 to 32 students each typically are scheduled. During the project period, enrollments in the fall semester (Biology 205) were sufficiently large to require seven laboratory sections, while only six were scheduled in the spring (Biology 206).

In the laboratory, students practice observation and problem solving skills using materials appropriate for elementary teaching. Activities concentrate on developing students' reasoning abilities in a discovery environment. Throughout the course, the methods and materials used are applicable, directly or indirectly, to the elementary classroom.

The fall semester, Biology 205, is devoted to the major concepts of ecosystem and population. In the laboratory, students construct and observe an aquarium-terrarium system that models an actual ecosystem. Additional experiments allow students to investigate organisms, their interactions with the environment, and population growth patterns. Near the end of the semester, each student must write a major paper, the most significant influence on the laboratory grade, summarizing his/her understanding of ecosystems and populations based upon evidence accumulated in the laboratory investigations. The spring semester, Biology 206, is devoted to organismal biology and genetics. In the laboratory, students carry out a long-term genetics experiment with Drosophila, examine elementary teaching materials and techniques, and wind up by coming full circle to again consider organisms in their natural environments. Near the end of the second semester, each student must write a major paper, again the most significant influence on the laboratory grade, summarizing his/her understanding of genetics based upon the laboratory investigations.

Instructional Materials

A total of 12 computer-based activities were developed and integrated into Biology 205 and 206, 6 per course. Each of these activities was supplemental or adjunct in nature. The intent of this project was not to replace the students' hands-on and problem solving activities. Rather, the idea was to use the computer-based activities to reinforce or provide a different perspective on important laboratory concepts and activities while demonstrating classroom uses of computer technology.

The intervention activities for Biology 205 are summarized in Table I. To understand the nature of the computer-based activities integration, consider the first activity. This laboratory activity dealt with metric measurement and graphing. As part of the regular laboratory activities, teams of students measured the circumferences and diameters of a variety of circular objects. Each team then constructed an appropriate two dimensional graph of the data and determined the relationship between circumference and diameter (thereby "discovering" pi). The student objectives for this activity included: accurate collection of the data using metric measurements, accurate construction of a two dimensional graph, and accurate interpretation of the graph.

The computer-based portion of this activity involved the use of a data collection and graphing program that was produced in-house. Students in the sections assigned to the computer-based treatment for this activity used the program as an integral part of the laboratory. As each team completed its measurements, the data were entered into the computer. The program first assessed the accuracy of the measurements. If any of the data points fell outside acceptable error limits, the students were instructed to re-measure. This feature circumvented later interpretation problems that might have arisen from erroneous measurements. Once a complete set of acceptable data was entered, the program "walked through" the construction and interpretation of a graph using a graphical representation of the students' data. At the end of the construction of the graph, the students' graph was compared to an ideal graph of circumference vs. diameter to stimulate discussion of experimental error, a topic of recurring importance in the course. Finally, the computer maintained each team's data, and, after all of the teams had finished, it produced a graph of the entire class' data.

This example illustrates the important components of the computer-based activities. First, the computer-based activity supplemented the regular laboratory activity. Despite the fact that the computer was used in a supplemental fashion, every effort was made to make the activity an integral part of the laboratory relevant to the students' objectives. In this case, the program was designed to help the students construct and interpret their graph. Second, the program illustrated one way to use a computer in the science classroom. In fact, this particular program encompassed several useful features, including: data pooling, error checking, graphical representation of data, and aspects of a tutorial. Finally, the use of the program in the laboratory also illustrated simple but effective means of utilizing limited hardware, in this case, teams of students in rotation. These characteristics marked nearly all of the computer-based integration activities.

The students in the laboratory sections that did not receive the computer-based activity learned via a "traditional" instructional approach. In the case of the example given above, the measurement and graphing laboratory, the students in the comparison sections also completed the basic activities of measuring objects and constructing a graph. Instead of using the computer program, however, these students were instructed in the manner which heretofore had been the norm in the class. The laboratory instructor conferred individually with each group to discuss the group's

TABLE I.
Biology 205 (Fall Semester) Integration Activities

Week	Integration Activity
2	Laboratory: Measurement and Graphing. Computer-Based Activity: Graphing Computer Program - student groups of 5-6 in rotation entered data into the computer, and the computer used a graphical representation of the data to provide a tutorial on graphing and interpretation of the data. Comparison Activity: group discussion.
4	Laboratory: Effects of Variation of Environmental Factors. Computer-Based Activity: Isopods Computer Program - upon completing the experiments, groups of about 3 students in rotation went through the program that simulated the types of experiments just performed. Comparison Activity: group discussion.
7	Laboratory: Ecosystems Review. Computer-Based Activity: Food Webs Computer Program - groups of about 3 students in rotation went through the program, an upper elementary level tutorial that summarized important concepts about ecosystems and food webs. Comparison Activity: food webs hand-out.
9	Laboratory: Scientific Notation. Computer-Based Activity: Scientific Notation Drill - individual students in rotation completed the computer program which provided drill and practice on scientific notation. Comparison Activity: independent practice, if desired.
11	Laboratory: Yeast Population Growth. Computer-Based Activity: Population Growth Simulation - pairs of students in rotation used the program to simulate and graphically depict several models of population growth. Comparison Activity: group discussion.
15	Laboratory: Current Events. Computer-Based Activity: CompuServe - with instructor guidance, teams of students logged onto CompuServe to search databases, such as the ones in the Science and Mathematics Education Forum, to supplement their library research. Comparison Activity: library research only.

TABLE II.
Biology 206 (Spring Semester) Integration Activities

Week	Integration Activity
2	Laboratory: Human Systems. Computer-Based Activity: Cell Tutorial Program - pairs of students in rotation completed a tutorial which reviewed the important cell structures and functions. Comparison Activity: cell review hand-out.
7	Laboratory: Experimental Study of the Transmission of Inherited Variations (Drosophila experiment). Computer-Based Activity: Drosophila Simulation Program - pairs of students in rotation used the program to simulate the actual crosses made to verify their experimental results as well as to simulate other crosses to practice interpretation of data.. Comparison Activity: independent study.
12+	Laboratory: Elementary Teaching Materials Evaluation. Computer-Based Activity: Software Evaluation - after receiving instruction in software evaluation, students evaluated two pieces of elementary science software. Comparison Activity: elementary textbook evaluation.
13	Laboratory: Genetics Review. Computer-Based Activity: Genetics Problem Solving Practice Program - students worked one on one at computers using a program that presented four genetics crosses and required the students to apply their model of Drosophila inheritance to predict cross results. Comparison Activity: independent practice.
14	Laboratory: Elementary Teaching Materials Development. Computer-Based Activity: Computer "Shell" Game - students developed questions, from course content but at a level appropriate for elementary students, and built them into a computer "shell" game. Comparison Activity: non-computer game development.
15	Laboratory: Organisms in Their Natural Environments. Computer-Based Activity: Interactive Videodisc Program - in large groups, the students went through a computer-based interactive video program that reviewed major concepts from the entire year and oriented the students to some of the flora and fauna they were likely to encounter on an up-coming field trip. Comparison Activity: inquiry activity and viewing of wildflower slides.

data, the construction of the graph, and the interpretation of the graph. Obviously, this approach was intended to achieve the same ends as the computer program, but it was more time intensive for the instructor. In other instances, the "traditional" activity was pencil-and-paper or another activity deemed appropriate for the particular laboratory.

In addition to the measurement and graphing activity mentioned above, the Biology 205 computer-based activities illustrated a number of different classroom uses of computers. The students were introduced to an in-house produced problem solving computer program with their experiment investigating the effects of variation of environmental factors on isopods (pill bugs). A commercial tutorial about food webs, Food Webs (Lehman, 1984), was used to help students review important ecosystem concepts. An in-house drill and practice program was used to supplement the scientific notation unit. A commercial computer-based simulation, Popgro (Lehman, 1982), was used to help students investigate population growth. Finally, telecommunication in the form of on-line sessions on CompuServe was used as part of the students' current events activity.

The integration activities for Biology 206 are shown in Table II. In concept, these activities paralleled those used in Biology 205. However, because Biology 206 dealt with different content, the activities necessarily were different. In Biology 206, the students used a commercially available tutorial about cell structure and function, Biology: The Cell

(Encyclopaedia Brittanica, 1983), to review important concepts about the cell. A commercial simulation of Drosophila genetics, Flygen (Lehman, 1982), was used in support of the students' Drosophila experiment. An in-house produced genetics problem practice program was used to help prepare the students for writing their major genetics papers. The latter program represented the only departure from the limited hardware model employed in the project; the nature of this program dictated one student to one computer use in a computer laboratory. Finally, an in-house produced, computer-based, interactive videodisc program was used prior to an end of the semester field trip to review important concepts from the entire year and to orient the students to things that could be observed on the field trip.

In addition to these, two of the integration activities in Biology 206 dealt directly with instructional concerns. During the semester, the students spend some time considering elementary teaching methods and materials through study of videotapes of elementary teaching and examination of actual materials for the teaching of elementary science. To complement these activities, a unit was developed on the evaluation of software for elementary science teaching. In addition, in another integration activity, the students used a commercially available "shell" game, Biology Mind Game (Lehman, 1984), to construct content review games based on content that they had learned in the course but at a level appropriate for elementary students.

Thus, over the course of the project, students were exposed to a wide variety of instructional applications of computers, including: drill and practice, tutorials, simulations, telecommunications, and interactive video. The methods of use included: individuals one on one with the computer, small group use, and whole class use. In addition, students had a chance to preview and evaluate commercially available software for elementary science teaching and even to participate, through the use of the "shell" game, in the development of computer-based science teaching materials.

In most cases, print-based supplements to the usual laboratory hand-outs were developed to help guide students in the intervention or comparison activities. In the case of the computer-based activities, these supplemental hand-outs indicated how the students were to use the computer as part of the laboratory. Other supplemental hand-outs were provided for comparison groups. During the project, these were color coded to make it easier for the course staff to dispense the proper hand-out supplement.

Instruments

To assess students' attitudes towards computers and biology, an attitudes instrument was constructed. This measure consisted of 20 Likert-type items related to attitudes towards computers taken from the work of Anderson, Hansen, Johnson, and Klassen (1979), and 14 Likert-type items related to attitudes towards biology taken from the work of Russell and Hollander (1975). The items were of mixed type; some of the statements were positive and some were negative.

For each statement on the attitudes survey, the student was asked to mark a blank on the answer sheet corresponding to "strongly agree", "agree", "undecided", "disagree", or "strongly disagree". Each item received a score of 1 to 5, where the highest score was awarded for "strongly agree" on a positively worded item or "strongly disagree" on a negatively worded item. The item scores were summed for the computer items and for the biology items to yield an overall computer attitudes score of 20 (low) to 100 (high) and an overall biology attitudes score of 14 (low) to 70 (high). The Spearman-Brown split-half reliability of the computer scale was determined to be .82, and the Spearman-Brown split-half reliability of the biology scale was determined to be .92.

To assess student attitudes towards the instructional methods and materials used in each intervention unit, a short unit evaluation form consisting of 12 likert-type items and 3 open-ended questions was constructed. As with the major attitudes instrument, each Likert-type item was scored from 1 to 5 and the item scores were summed to yield a unit evaluation score, from 12 to 60, for each of the instructional units. The open-ended questions asked the student to indicate what he/she liked most and least about the instruction unit and to make any desired comments. These were examined separately and frequently made comments were noted. The

Spearman-Brown split-half reliability of the Likert portion instrument was determined to be .88.

To assess the impact of project activities on achievement, the results of the usual course achievement measures were collected. These included: student laboratory report scores for all of the laboratories involving intervention activities, laboratory quiz scores, course exam scores, scores on the major paper of each semester, and the students' final course grade averages. These achievement measures were not pure measures of the effects of the project's activities. In virtually every instance, they measured content unrelated to as well as related to project activities. For both practical and philosophical reasons, no attempt was made to glean from the achievement measures those portions that related directly to the intervention activities. From a practical standpoint, the task would have proven very difficult and too time consuming. From a philosophical standpoint, the project staff was interested in learning if the intervention activities could affect the scores on the usual course achievement measures as such.

Procedure

In order to assess the impact of project activities, the basic experimental design called for a comparison of intact laboratory sections completing computer-based activities with laboratory sections completing comparison activities. Because the make-up of laboratory sections is determined by the Purdue class scheduling computer, there is a degree of randomness involved although the scheduling of students into laboratory sections cannot be said to be truly random. As a result, the basic experimental design was a quasi-experimental, non-equivalent control group design (Campbell and Stanley, 1963).

Initially, it was expected that there would be 6 laboratory sections each semester. The basic design plan called for 3 sections to receive supplemental computer-based instruction and 3 sections to receive traditional discussion or paper/pencil instruction for a given laboratory. Further, to provide students in every section with some exposure to the computer activities, the plan called for rotating those sections receiving computer-based instruction with those receiving traditional instruction over the semester such that different sections received different treatments. The net result was to be that 2 of the 6 sections would receive 4 computer-based and 2 traditional activities during the semester, 2 sections would receive 3 computer-based and 3 traditional activities, and the remaining 2 sections would receive 2 computer-based and 4 traditional activities. This design approach would permit direct comparisons of computer and non-computer sections for particular laboratories as well as gradated comparisons on whole semester measures such as the final exam and student grade averages.

Although this plan was used for the spring semester, the enrollment for the fall semester, Biology 205, dictated a slight change in the design. Because of high enrollments, a seventh laboratory section was added in the fall. During the summer of 1986, the project staff, including the course instructors, consulted regarding the seventh section. In order to provide a more rigorous test of the effects of the computer activities, it was decided that the seventh section would receive no computer-based activities while the remaining six sections would adhere to the original plan. The laboratory sections were randomly assigned to the treatment conditions according to the specified plan, and the project proceeded.

The laboratory section assignments to the treatment conditions are shown in Table III. During the fall semester, Biology 205, sections 3 and 4 received a total of 4 computer-based instruction activities and 2 traditional activities; sections 5 and 6 received a total of 3 computer-based and 3 traditional instructional activities; sections 1 and 2 received a total of 2 computer-based and 4 traditional instructional activities; and, section 7 received traditional instruction for all 6 activities. During the spring semester, Biology 206, sections 3 and 6 received 4 computer-based and 2 traditional activities; sections 1 and 2 received 3 computer-based and 3 traditional activities; and, sections 4 and 5 received 2 computer-based and 4 traditional activities.

At the beginning of each semester, the computer and biology attitudes measure was administered to all of the subjects. To determine if there were any apparent pre-intervention differences between sections, the pre-test

Table III.
Laboratory Section Assignments to Treatment Conditions

Fall Semester (Biology 205)

Laboratory	Computer-Based Activity Sections	Traditional Activity Sections
Measurement & Graphing	3,4,6	1,2,5,7
Variation of Environ. Factors	2,3,5	1,4,6,7
Ecosystem Review	1,2,4	3,5,6,7
Scientific Notation	1,5,6	2,3,4,7
Yeast Population Growth	3,4,5	1,2,6,7
Current Events	3,4,6	1,2,5,7

Spring Semester (Biology 206)

Laboratory	Computer-Based Activity Sections	Traditional Activity Sections
Human Systems	2,3,5	1,4,6
Experimental Study of Inheritance	1,2,6	3,4,5
Elementary Materials Evaluation	1,2,6	3,4,5
Genetics Review	1,3,4	2,5,6
Elementary Materials Development	3,5,6	1,2,4
Organisms in Environments	3,4,6	1,2,5

computer and biology attitudes scores as well as student self-reported SAT scores were submitted to one-way analyses of variance (ANOVAs) by section. The ANOVAs failed to detect any significant differences between sections at the .05 alpha level. Therefore, the laboratory sections were assumed to be equivalent at the beginning of each semester. Because section variances were equivalent and the intervention instruction was largely independent of instructor influence, sections receiving like treatments were pooled for comparison tests.

The computer and biology attitudes measure was administered on a pre-test/post-test basis at the beginning and end of each semester. The data were analyzed for evidence of changes in attitudes based upon the number of computer-based activities per semester. Unit evaluations were administered to all subject immediately following the completion of each laboratory involving an intervention activity. The data were analyzed for evidence of differences between computer-based and traditional activity groups. Finally, achievement data were collected and analyzed for evidence of differences between computer-based and traditional activity groups and, where appropriate, for evidence of differences among groups receiving different numbers of computer-based activities during a semester. All of the analyses were conducted using procedures in the PC-SAS statistical package. Students missing a score were omitted from the analyses involving that measure.

RESULTS AND DISCUSSION

To assess the impact of the project activities on achievement in the courses, data from the usual course achievement measures were collected. It was expected that those course measures most closely related to the intervention activities, usually laboratory reports, would be the most sensitive to any achievement effects. For these measures of laboratory unit achievement, the results from the computer sections were pooled as were the results from the comparison, traditionally taught, sections and one-way analyses of variance (ANOVAs) were performed to test for possible differences between the computer group and comparison group means. The means and standard deviations by group, as well as the F values resulting from the ANOVAs, for the laboratory unit achievement measures are summarized in Table IV.

As noted in Table IV, there were 6 unit achievement scores collected for the fall semester corresponding to the 6 intervention activities. In 5 of the 6 cases, the achievement measure was a laboratory report or worksheet. In the sixth case, the ecosystems review activity, the most direct measure of the intervention activity's impact was the score on the semester's major paper on ecosystems. F the spring semester, only 4 measures of laboratory unit achievement were collected. Of these, 2 were laboratory reports and 2 related most directly to the semester's major paper on genetics. For the remaining 2 intervention activities used during the spring semester, the cell review (the first intervention activity of

TABLE IV.
Laboratory Unit Achievement Summary

Fall Semester (Biology 205)

Laboratory Activity/ Achievement Measure	n	Computer Group Mean	SD	n	Comparison Group Mean	SD	ANOVA F	Prob F
Measurement & Graphing Lab. Report (25 pts)	88	19.03	4.16	114	19.54	3.86	0.81	0.369
Variation Env. Factors Lab. Report (30 pts)	86	25.60	5.14	116	25.63	4.01	0.00	0.970
Ecosystems Review Major Paper (120 pts)	86	101.37	10.32	116	95.59	17.56	7.41	0.007
Scientific Notation Worksheet (10 pts)	88	9.81	0.56	111	9.67	1.05	1.26	0.262
Yeast Pop. Growth Lab. Report (20 pts)	87	14.61	4.66	115	15.24	4.65	0.92	0.339
Current Events Lab. Report (25 pts)	88	21.89	5.42	114	22.05	4.45	0.06	0.806

Spring Semester (Biology 206)

Laboratory Activity/ Achievement Measure	n	Computer Group Mean	SD	n	Comparison Group Mean	SD	ANOVA F	Prob F
Transmitted Variations Major Paper (180 pts)	97	146.75	30.90	96	150.98	17.64	1.36	0.245
Genetics Review Major Paper (180 pts)	99	149.55	21.65	94	148.13	28.60	0.15	0.697
Materials Evaluation Lab. Report (30 pts)	98	26.51	5.80	96	28.20	2.19	7.12	0.008
Materials Development Lab. Report (25 pts)	96	24.22	1.16	98	23.50	4.63	2.18	0.141

the semester) and the organisms in their natural environments activity (the last intervention activity of the semester), no direct measures of laboratory unit achievement were collected.

The results in Table IV show little evidence of any achievement impact of the intervention activities. The F values from the ANOVAs revealed statistically significant differences between group means in only two instances. During the fall semester, the computer group significantly ($p < .01$) outscored the comparison group on the major paper on ecosystems. In this instance, the computer group reviewed ecosystems topics by completing a computer tutorial dealing with ecosystem topics such as food webs while the comparison group reviewed using print-based materials. During the spring semester, the comparison group significantly ($p < .01$) outscored the computer group on the elementary materials evaluation laboratory report. In this case, the computer group evaluated elementary science teaching software while the comparison group evaluated elementary science textbooks. The failure of the computer group to perform as well as the comparison group on this task might be attributable to the relative unfamiliarity of software and software evaluation or to differential grading of the laboratory reports.

ANOVAs comparing the mean scores of the computer and comparison groups were also conducted for class quiz scores, exam scores, and student averages. These ANOVAs failed to show significant differences between groups at the .05 alpha level and so are not reported here.

Taken as a whole, the results of the analyses of the achievement data indicate very little impact of the project on the usual course measures of achievement. Even in the case of the laboratory unit achievement measures, which were more sensitive to the treatments than the quizzes and exams, only one instance of a significant positive effect of a computer-based activity was noted. The lack of significant achievement differences between groups is not particularly surprising. The measures used to assess achievement were the usual course achievement measures and were not very sensitive to the effects of the project's intervention activities. All of the activities were supplemental in nature, and most were of short (roughly 15 minutes) duration. In addition, the comparison activities in many cases probably delivered instruction comparable to the computer-based activities. Clark (1985) has argued that computer-based instruction has no inherent advantages for achievement over other forms of instruction and that the positive effects attributed to computer instruction are often the result of elements of the instructional design.

The one instance where the computer group significantly outscored the comparison group was on the major paper of the first semester. In this case, the chances for detection of an achievement effect were much better than for most of the activities. The computer group reviewed ecosystems concepts using a tutorial program while the comparison group used print-based review materials. The computer instruction was much more lengthy than the norm (about 40 minutes). The content of the tutorial matched very closely that which was measured by the major paper. And, the interactive computer tutorial offered clear instructional design advantages (clear presentation of content, graphics, embedded review questions, etc.) over the comparison print-based materials.

Student attitudes towards the intervention activities themselves were assessed using the unit evaluation survey instruments. The mean unit evaluation scores of computer and comparison groups were compared using one-way ANOVAs. The results of these analyses are summarized in Table V.

During the fall semester, the students in the computer group gave significantly higher ratings to the instructional materials for the ecosystems review ($p < .001$) and yeast population growth ($p < .05$) activities than did students in the comparison group. The computer-based activities in these cases corresponded to the food webs tutorial and population growth simulation programs, respectively. During the spring semester, significance was approached ($p = .076$) in favor of the computer group for the genetics review activity.

In one case, the scientific notation activity during the fall semester, the comparison group gave a significantly ($p < .001$) higher unit rating than did the computer group. This result may be reflective of student dissatisfaction with the drill and practice format of program used. Alternatively, it may reflect students´ feelings towards the subject matter itself. The students´ written comments about this unit reflected overwhelmingly negative feelings towards mathematics

TABLE V.
Laboratory Unit Evaluations Summary

Fall Semester (Biology 205)

Laboratory Activity	n	Computer Group Mean	SD	n	Comparison Group Mean	SD	ANOVA F	Prob F
Measurement & Graphing	87	39.68	8.37	107	39.98	8.09	0.07	0.799
Variation Env. Factors	83	42.51	7.76	113	42.77	6.52	0.07	0.797
Ecosystems Review	84	46.29	5.77	114	42.74	7.29	13.62	<0.001
Scientific Notation	83	40.01	8.81	108	45.48	7.28	22.03	<0.001
Yeast Pop. Growth	80	39.48	9.56	113	36.15	9.36	5.80	0.017
Current Events	72	45.14	6.98	100	43.93	8.99	0.91	0.342

Spring Semester (Biology 206)

Laboratory Activity	n	Computer Group Mean	SD	n	Comparison Group Mean	SD	ANOVA F	Prob F
Human Systems	93	43.35	5.90	98	43.64	5.64	0.12	0.731
Transmitted Variations	81	40.69	7.75	93	40.14	8.31	0.20	0.653
Genetics Review	97	39.42	9.25	86	36.83	10.42	3.19	0.076
Materials Evaluation	88	39.88	10.72	91	38.10	8.59	1.50	0.222
Materials Development	84	40.60	6.72	85	41.26	8.32	0.33	0.569
Organisms in Environ.	83	46.11	6.60	79	45.85	6.60	0.06	0.802

and scientific notation. The students in the computer group may have rated this unit lower simply because they were required to do more of something that they disliked in the first place.

In comparing the unit evaluation ratings, Table V shows that the highest overall rating of the fall semester was given by the computer group to the ecosystem review activity. Once again, the computer activity in this case corresponded to the food webs tutorial program. This finding is especially encouraging because this activity was the only one which showed a clear achievement effect as well. In the spring semester, the highest overall rating was given by the computer group to the organisms in their environments activity. The computer-based activity in this case corresponded to the interactive video review program.

The results of the unit evaluations analyses suggest more positive student attitudes towards the instructional units as a result of some of the computer-based intervention activities. The examination of the students' written comments verified this. On a positive note, students in the sections receiving the computer-based activities frequently cited the computer as their favorite part of the laboratory activities. Interestingly, however, the written comments also showed evidence of some frustration with the limited hardware approach employed in the study. While few students indicated that they disliked the computer activity itself, a number complained of having to wait their turn to get access to the computers. Limited computer hardware may be a reality in the elementary classroom, but it is certainly not the optimum.

The effects of the project on overall attitudes towards computers and biology were assessed using the attitudes instrument that was administered on a pre-test/post-test basis at the beginning and end of each semester. The results were broken down by number of computer-based activities per semester. Pre-test and post-test means were compared using paired samples t-tests. The results for the computer attitudes are shown in Table VI, and the results for the biology attitudes are shown in Table VII.

The results of the analyses of the computer attitudes data given in Table VI show clear evidence of a positive impact of the project on the students' attitudes towards computers. In the fall semester, the groups receiving 2, 3 and 4 computer-based activities showed mean pre-test to post-test gains of 2.75, 4.02 and 1.17 points, respectively. The gains for the 2 and 3 computer-based activities groups were statistically significant at the .05 alpha level or better. The group receiving no computer-based activities actually showed a mean decline of 1.08 points, although this was not statistically significant. In the spring semester, the groups receiving 2, 3 and 4 computer-based activities showed mean pre-test to post-test gains of 2.10, 2.02 and 2.57 points respectively. The mean gains for the 2 and 4 computer-based activities groups were statistically significant at the .05

TABLE VI.
Computer Attitudes Results Summary

Fall Semester (Biology 205)

Number of Computer Activities	n	Pre-test Mean	Post-test Mean	Mean Change	Std. Error	t-value	Prob t
0	28	69.80	68.72	-1.08	1.90	-0.57	0.574
2	57	70.46	73.21	2.75	1.09	2.53	0.015
3	59	65.70	69.72	4.02	1.30	3.09	0.003
4	58	72.03	73.20	1.17	1.11	1.05	0.297

Spring Semester (Biology 206)

Number of Computer Activities	n	Pre-test Mean	Post-test Mean	Mean Change	Std. Error	t-value	Prob t
2	63	72.73	74.83	2.10	0.81	2.60	0.012
3	65	72.00	74.02	2.02	1.89	1.89	0.064
4	67	71.78	74.35	2.57	0.91	2.81	0.007

TABLE VII.
Biology Attitudes Results Summary

Fall Semester (Biology 205)

Number of Computer Activities	n	Pre-test Mean	Post-test Mean	Mean Change	Std. Error	t-value	Prob t
0	28	43.08	46.00	2.92	1.83	1.60	0.123
2	57	45.75	46.46	0.71	1.22	0.58	0.567
3	59	47.04	43.62	-3.42	1.31	-2.62	0.012
4	58	46.59	46.75	0.16	1.23	0.13	0.899

Spring Semester (Biology 206)

Number of Computer Activities	n	Pre-test Mean	Post-test Mean	Mean Change	Std. Error	t-value	Prob t
2	63	46.30	48.18	1.88	0.98	1.91	0.062
3	65	44.38	46.67	2.29	1.22	1.88	0.067
4	67	46.40	48.38	1.98	0.87	2.27	0.028

alpha level or better, and the gain for the group receiving 3 computer-based activities approached statistical significance.

These results indicate that the infusion of computer-based activities into a teacher preparation course can effect positive attitudes towards computers as suggested by Battista and Krockover (1982). From its initial administration at the beginning of the fall semester to its final administration at the end of the spring semester, the mean score on the computer attitudes instrument rose about 4.5 points. Further, in terms of attitudinal changes, there seemed to be little difference in gains among the groups receiving 2, 3 and 4 computer-based activities.

The results from the biology attitudes measure, shown in Table VII, are less clear. In the fall semester, only the group receiving 3 computer-based activities showed a significant pre-test to post-test change, and that was a decline of 3.42 points. Although it is difficult to be certain, this result may have been due to negative student attitudes towards one of the laboratory assistants. An inexperienced laboratory assistant worked in one of the sections that received 3 computer-based activities and numerous negative comments were received about this individual on the unit evaluation forms. In the spring semester, all of the groups showed pre-test to post-test gains near the .05 alpha level of significance. Taken as a whole, however, these results do not suggest a clear pattern of improved biology attitudes resulting from the computer-based activities.

Rather, it seems likely that students attitudes towards computers and towards biology are independent of one another.

SUMMARY AND CONCLUSIONS

A total of 12 computer-based activities were integrated into the laboratory component of a two-semester biology course for elementary teaching majors at Purdue University. The intent of these activities was to address the basic biology instruction provided to these college students while providing examples of the uses of computers and allied technologies in classroom instruction. Groups receiving computer-based activities were compared to groups receiving "traditional" instruction on regular class measures of achievement, attitudes towards the instructional activities, and attitudes towards computers and biology.

The project results showed little evidence of an impact of the computer-based activities on achievement as measured by the usual class laboratory reports, quizzes, exams, and papers. In almost every instance, there was no significant achievement difference between the computer and comparison groups. The lack of significant achievement differences between groups is not really surprising. The achievement instruments were not particularly sensitive to the effects of project activities, the intervention activities were supplemental in nature and typically short in duration, and the comparison activities often delivered comparable instruction. The one clear instance of an achievement impact, the effect of a food webs tutorial on students' performance on an ecosystems paper, diverged from this pattern. In this case, the computer activity was closely related to the content measured by the paper, of longer duration than most of the activities, and offered considerable instructional benefits compared to the comparison activity.

The results of the students' evaluations of the instructional activities showed several instances where the computer-based activity was significantly preferred to the comparison activity and only one instance where the comparison activity was preferred to the computer-based activity. Students in the computer-based sections frequently cited the computer activity as their favorite part of the laboratory. However, a number of students also indicated frustration with having to wait to use one of the two available computers.

The project activities showed a clear, positive impact on students' attitudes towards computers. Significant pre-test to post-test gains in computer attitudes were recorded for both semesters. Clearly, the approach used in this project can effect positive student attitudes towards computers. Biology attitudes results were mixed. It is not clear that the computer-based activities had any direct impact on students' biology attitudes.

Taken as a whole, the results of this project suggest that integrating computer-based activities into the science coursework of pre-service teaching majors may be a useful way to introduce computer education into the pre-service teaching curriculum. This project showed improved student attitudes towards computers. It is hoped that these improved attitudes will result in increased interest in and willingness to use computer technology in teaching. Further, positive attitudes resulted whether the students received 2, 3 or 4 computer-based activities. Thus, as few as 2 computer-based activities may be of benefit, although it would not be possible to demonstrate the full breadth of possible applications with so few activities.

Although this project was successfully conducted using a limited hardware model to simulate a typical elementary classroom, it is not the most desirable approach. For most activities, only 2 computers were available and strategies such as small group use and rotations were employed. Although many of the students liked the computer activities, there was considerable frustration expressed at the waiting involved. The project staff estimated that a student to computer ratio of 5:1 instead of 15:1 would have proved far better. However, until schools begin to exhibit such a ratio, prospective teachers will still need to be aware of ways to use limited hardware in the classroom.

Finally, although this project failed to demonstrate significant achievement advantages of computer use when compared to "traditional" instruction, it is important to recognize that other factors must be considered. Clark (1985) has argued convincingly that comparisons of computer-based and traditional instruction are of limited utility. It is of more value to examine effective use of the peculiar attributes of computer instruction and ways to integrate that instruction into the curriculum. This project represented an attempt to carefully integrate computer instruction into one course. In addition, there are clear societal reasons for incorporating computer use in instruction. The future will be highly computer oriented, and students must become accustomed to computer use. For students to receive proper computer exposure, their teachers must be able to use computers. The approach utilized in this project represents one way to provide better computer training to future teachers.

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