Computers to Supplement Instruction in Science:
An Action Research Study

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ABSTRACT

The purpose of the study was to compare the results of traditional and computer-supplemented laboratory methods. Horticulture and Applied Biology and Chemistry students at a large comprehensive high school in Southeast Georgia participated in the action research study. Student attitudes, teacher attitudes and student performance were measured using journal entries, observations, surveys, and post-tests. Both groups received similar instruction and preparation for laboratory activities in plant science, but the Applied Biology and Chemistry students completed computer-supplemented labs using BioBLAST while the Horticulture students completed traditional plant science labs. Results on the data collection instruments showed favorable student and teacher attitudes to the computer-simulated experiments. Results on the post-tests did not show a significant difference from one group to the other. BioBLAST and other computer simulation programs are recommended to fulfill state objectives and national recommendations for incorporating technology into science and vocational instruction. The results of the study were communicated to the learning community through a meeting with teachers and administrators. This meeting contributed to the current organizational climate of incorporating technology into instruction and fulfilling all state objectives.

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Dedication

To my great grandmother Janiece… for the tenacity she possessed and encouraged in others.

Computers to Supplement Instruction in Science Labs

An Action Research Project

Audrey Calhoun Pickren

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Abstract

Horticulture and Applied Biology and Chemistry students at a large comprehensive high school in Southeast Georgia participated in a study comparing traditional and computer-supplemented laboratory methods. Student attitudes, teacher attitudes and student performance were measured using journal entries, observations, surveys and post-tests. Both groups received similar instruction and preparation for laboratory activities in plant science, but the Applied Biology and Chemistry students completed computer-supplemented labs using BioBLAST software while the Horticulture students completed traditional plant science labs. Results showed favorable student and teacher attitudes toward the computer-simulated experiments. Results on the post-tests did not show a significant difference from one group to the other.

Introduction

Background, Context, and Problem

For more than two decades, science educators have hoped that computers would help provide more efficient, effective instruction (Weller, 1996). Educational use of computers is not only driven by the desire of educators to improve instruction, but it is also driven by shapers of public policy, such as The President's Commission of Advisors on Science and Technology (PCAST). The PCAST developed an agenda for the use of technology in primary, middle, and secondary education. They recommended future research be based on the assumption that computers should be used in education and focused on determining the best uses for computers (PCAST, 1997; Hickey et al., 1999).

To facilitate development of my research project, I examined the organizational culture of my school, software packages available for science instruction, and studies for computer use in science. The new school administration has a greater focus on curriculum and instruction and recognizes the need for the integration of technology in instruction. Renovations are underway to replace out-of-date computers and wiring in the high school and put more computers in each classroom. Georgia Quality Core Curriculum objectives for Horticulture Technology require that I incorporate technology into instruction. I wanted to encourage the use of technology as a teaching tool while contributing to the existing body of knowledge regarding computer use in science education. Numerous articles and multiple software packages address all areas of science instruction, providing promising positive evidence for the increased use of computers to supplement traditional classroom and laboratory methods. Because I teach high school Horticulture, my main area of interest was plant science, which is also taught in Biology.

Numerous computer applications are suitable for high-school biology, and many such applications are described in the literature of the field. One study I located was very similar to the one I planned to implement. Computer simulations were used in high school microbiology courses to supplement instruction in cell growth and division. Two different laboratory approaches were incorporated within the instruction - traditional labs and simulated labs. Students in the computer-simulated labs performed better on post-tests than students in the traditional labs (Huppert, 1998). In addition, such simulations and modeling software programs have great potential to expose students to experiments that are too costly, extensive, lengthy, or hazardous to conduct in reality.

I could locate no existing research regarding computer simulations in plant science, so I modeled the design used in the cell growth and reproduction research for my study of computer supplemented instruction for science experiments. I located

BioBLAST - Better Learning through Adventure, Simulation, and Telecommunications – software which was developed for NASA's Classroom of the Future to use in the study. I worked with one Applied Biology teacher at our large, comprehensive high school to implement research comparing traditional plant science labs to computer simulated plant science labs employing a Plant Production Unit in BioBLAST (NASA Classroom of the Future, 1999).

Purpose

The purpose of this study was to evaluate the effects of computer-supplemented laboratory experiments in Plant Science units of applied biology and horticulture. The effects of the laboratory methods used to supplement instruction in plant production on student performance, the attitudes of students, and the attitudes of teachers were compared in the study. The independent variable was the instructional method, with the comparison between traditional instruction and BioBLAST instruction. Traditional instruction was defined as lecture, use of the textbook and hands-on laboratory experiments. BioBLAST instruction included similar lecture and use of the textbook, but had instruction supplemented by computer simulated laboratory experiments.

The dependent variables were student performance, student attitude, and teacher attitude. Student performance was defined as measurement of achievement of pre-set objectives and performance on laboratory reports and post-tests. Student attitude was defined as opinion of instructional method and plant production content as measured by student survey and teacher observation forms. Teacher attitude was defined as preference of instructional method and was measured by teacher survey and observation forms.

Research questions considered in the study:

1. Is there a difference between traditional instruction and supplemented instruction on:
    a. Achievement of plant production unit objectives?
    b. Attitudes of students toward instruction and content?
    c. Attitudes of teachers toward instructional methods and results?
2. What implications does supplementation of traditional instruction with computer assisted instruction have for students and teachers in biology?

Methods

School Setting and Participants

The action research was conducted at a large, comprehensive high school in Southeast Georgia with an enrollment of nearly 2,600 students. The classes involved were Horticulture and Applied Biology and Chemistry I (ABCI) during Spring Semester, 2002. Although I planned to include two horticulture classes and six biology classes, only three of the biology classes were able to participate. The second biology teacher had not reached the plant science portion of the curriculum by the time allotted for the study. I worked with one ABCI teacher who teaches three of those classes per day. Because this science teacher had planned to have all of his students complete the BioBLAST labs, I had my Horticulture students complete the traditional plant science labs.

Fifty students completed the BioBLAST labs, and fifty-four percent of them were female. Forty students completed the traditional labs, and forty-three percent of them were female. Overall, forty-nine percent of the participants were female, making the population well balanced in respect to gender. The majority of the biology students are sophomores, but a few of them are juniors who are taking ABCI for the second time. The horticulture students are a combination of sophomores, juniors and seniors. Approximately 25% of the participants were African American, 2% were of Hispanic descent, and the remaining 73% were Caucasians.

Students participated in the laboratory format conducted for their class, so they were not randomly selected. However, the majority of them are sophomores or juniors who have completed or are completing their required biology course. A few members of the Horticulture classes are seniors who have completed all of their required science courses. All students in the ABCI classes are in Technical Career programs of study, but several participants from the Horticulture classes are in College Preparatory programs of study. Each participant returned a parental consent form, and the instructional leaders for the science and vocational departments approved the study. Students were free to withdraw from the intervention at any time without penalty and were not required to complete post-tests and surveys.

Intervention

Students of high school biology and horticulture were taught plant science with two different methods of instruction: traditional and computer-supplemented. Both subject areas have access to computers and suitable laboratories within their work areas. I taught the two horticulture classes with traditional instruction using the text, teacher lecture, teacher created materials and notes, and hands-on laboratory experiments in the greenhouse. These classes spent the usual amount of time, one week, approximately seven and one half-hours in block scheduling, studying plant production. The three ABCI classes were taught by the participating science teacher with the text, teacher lecture and notes, computer-based tutorials, and computer-simulated laboratory experiments. These classes were divided between their science teacher and the horticulture teacher to conduct the computer-simulated laboratory experiments and used BioBLAST software for tutorials and simulated experiments in plant production. BioBLAST: Better Learning Through Adventure, Simulation, and Telecommunications, is multimedia software based on actual NASA research that was used to supplement one week, approximately seven and a half hours, of plant science instruction. Applied biology teachers spend approximately one week on plant science, so the Plant Production Sampler from BioBLAST fit into the curriculum efficiently. The Plant Science Sampler is one of seven units in BioBLAST. “The sequence is designed to take approximately five class periods including a launch sequence, an experiment, a simulator activity and several explanatory movie clips. The sequence also provides students with an opportunity to use the BioBLAST interface as they virtually travel throughout the simulated lunar base. The intent is to encourage student interest in computer-based tools that enhance scientific inquiry” (BioBLAST, p. 3, 1998).

Students of ABCI who participated in the study spent two full class periods using BioBLAST. We divided the students into groups of two or three to take turns using the available computers. When students were not using computers, they were in their regular classroom for traditional instruction or data compilation. It took one week to allow all the ABCI students enough computer time to complete the simulated plant production labs.

Materials and labs were selected to teach all students in the study the necessity of plant life to human life, the processes of photosynthesis and respiration, and the importance of photoperiod and carbon dioxide levels to food, water, and oxygen production by plants. Each student received textbook instruction and had a lab manual for background information, instructions, and data recording. All students in the study were given the same amount of time to conduct laboratory experiments.

Measures

The three independent variables were measured by various means of data collection. Student achievement was measured by teacher observation and student performance on post-tests. Student attitudes were measured by teacher observation student surveys. Teacher attitude was measured by teacher survey, comments on the teacher observation forms, and informal communication recorded in my journal.

Procedures

As stated, ABCI students completed BioBLAST labs and horticulture students completed traditional labs. Each group spent one week in plant production instruction and labs. During instruction, students were informed about the types of labs they would complete and given manuals to provide background information, instructions, formulas, and tables for data recording. I administered and supervised the data collection. All participating students were observed using an observation form consisting of rating scales and open-ended questions pertaining to lab performance and conduct in the labs. They also completed post-tests consisting of twenty multiple-choice questions pertaining to plant science and production.

Students completing the BioBLAST labs completed surveys consisting of ten Likert scale items and one open-ended question. I completed the teacher survey consisting of ten Likert scale items and one open-ended question, but the participating science teacher did not. Although we had planned for students to create formal lab reports to be evaluated using a lab report evaluation rubric, we did not have enough time for them to write those reports. Students analyzed their lab results by comparing them with classmates in a culminating review of the unit. The ABCI and horticulture teachers assigned grades for student participation in the group review and discussion. These grades were not analyzed in the results of the study, but the science teacher and I were very pleased with their performance on lab worksheets and their apparent understanding of the material during their contributions to class discussions. Conversations with the participating teacher and informal observations regarding students, hardware, and software were recorded in my journal.

Analysis and Findings

Observations and Journal

The applied biology teacher and I conducted observations during the experimentation and discussion portions of the study. The students seemed very motivated to complete both types of labs, but they did not like reading the instructions regarding the labs. Although introductions, background information, and instructions were given regarding the labs, the students still wanted to start conducting the labs without reading instructions. Subsequently, they had many questions that would have been answered simply by reading the information they were given. As each group rotated through the lab activities, it became more evident which instructions must be given verbally and which activities must be demonstrated physically to facilitate efficient and proper completion of the experiments.

In both types of labs, students needed continual assistance with the instructions and content. There were very few discipline problems during the labs because students stayed focused on completing the worksheets in their lab manuals. The students displayed a great deal of comfort with the equipment in both labs. As always, there were a few minor problems such as locating tools in the traditional labs or cleaning the mouse in the simulated labs, but none of these adversely affected the completion of the labs. Overall, both lab experiences were positive.

Data Collection Instruments

Student Evaluation of BioBLAST

Each student participating in the computer-simulated labs completed a survey regarding the experience. The survey consisted of ten Likert Scale items with responses that included strongly agree, agree, neutral, disagree, and strongly disagree. Numeric values of one to five were assigned to each response, starting with strongly disagree at a value of one. The following table includes the questions with the means and standard deviations for the responses.

#	Question	Mean	Standard Deviation
1	I liked the computer-simulated laboratory experiments better than other science experiments I have done.	3.29	1.08
2	I understood how to use the software and had little or no trouble completing the assignments.	3.71	.94
3	I liked the opportunity to work at my own pace and was able to finish the labs within the maximum time limits.	4.17	.92
4	I needed the instruction and interaction with my teacher to complete the assignments successfully.	3.82	1.02
5	The computer I used had enough speed and memory to run the software properly.	3.71	1.37
6	Viewing the effects of my actions on variables in the simulations helped me develop an understanding of basic plant science.	3.75	.89
7	Using the NASA research-based software that simulated a lunar base was motivating for me.	3.32	1.04
8	The simulation of producing plants in space helped me understand the environmental needs of plants	3.44	1.15

	and the necessity of plants to humans.		
9	The lab reports for these simulations were easier to write than the ones I have written for traditional labs.	3.34	1.31
10	I would like to use BioBLAST software to complete other Applied Biology experiments.	3.38	1.20

Students also responded to one open-ended question on their survey. When asked to describe their opinions of or recommendations for BioBLAST, students had a wide array of responses. Just as in the Likert Scale items, most of the open-ended responses were neutral, such as "okay" to positive, such as "cool." There were a few negative responses about the hardware we had to use and the graphics in the program. Some particularly helpful responses included; "good, but not every day," "have computer give directions at the same time as the teacher," and "use for horticulture and science."

Student Observation Form

The student observation form contained a rating scale of one to five, five being highest for student behavior, work ethic, and performance. The table below shows the means and standard deviations of the ratings for the groups. Ratings for each item improved throughout implementation of the study.

Item: Mean of 3.0 = Neutral	Mean	Standard Deviation
Student Behavior	5	0
Student Software Operation (BioBLAST)	3.25	.96
Student Computer Operation (BioBLAST)	4.25	.96
Student Use of Lab Equipment (Traditional)	4.5	.58
Student Work Ethic	4.25	.96
Student Comprehension	3.25	.96
Progress through Lab Activities	3.5	1.29
Overall Classroom Environment	4.5	.58
Current Ranking of Plant Production Unit	3.5	1.29

Teacher Survey

I used a survey instrument to guide my responses and reactions to BioBLAST, but I did not receive a survey from the participating science teacher. My opinions of the Plant Production Unit range from neutral to positive. The most positive aspects of the unit were its suitability to one week of instruction and the ability of our computers to run the software. Content was appropriate for the courses and was aligned with the objectives for the State of Georgia. Students stayed on task during the activities, and I would use the software again.

My opinion of the instruction for preparation for the graduation test is neutral. Having to relocate students to classrooms with more computers was a little inconvenient, but did not adversely affect instruction. Because students needed so much assistance, I don't think the labs could be truly self-paced. I do think that students were more motivated to complete the computer-simulated labs than traditional labs. The software could be improved by providing instructions for functions as they are selected for use.

Post-Test

Each student in the study completed a post-test to measure academic achievement in plant science and production. The table contains means and standard deviations of those scores by laboratory experiment method and by gender.

Group	BioBLAST	BioBLAST Male	BioBLAST Female	Traditional	Traditional Male	Traditional Female
Mean	39.58	41.82	37.69	46.19	46.96	45.26
Standard Deviation	12.83	14.76	10.88	17.94	18.20	18.06

On average, the traditional group scored higher than the BioBLAST group. However, while the traditional group had a higher mean score, the variability in traditional group scores was much greater than the variability in the scores of the BioBLAST group. Mean scores of the groups were compared using a t-test. Results indicated no significant difference. Because seniors and College Preparatory students were included in the traditional group and not in the BioBLAST group, I compiled post-test data without their results to achieve a more homogenous group comparison. As expected, the t-test comparing the mean scores of this more homogenous group showed an even less significant difference.

Group w/o Sen. & CP	BioBLAST	BioBLAST Male	BioBLAST Female	Traditional	Traditional Male	Traditional Female
Mean	39.58	41.82	37.69	42.43	42.75	42.06
Standard Deviation	12.83	14.76	10.88	15.57	15.43	16.21

Discussion

Purpose and Research Questions

The purpose of the study was to determine if there is a difference between traditional instruction and computer-supplemented instruction on accuracy and thoroughness of lab experiment reports, achievement of plant production unit objectives, attitudes of students toward instruction and content, and attitudes of teachers toward instructional methods and results. I also attempted to identify implications computer-supplemented lab instruction might have for students and teachers in biology.

Accuracy and Thoroughness of Lab Reports

I created a Lab Report Evaluation Rubric to be used in grading students' lab reports from the laboratory activities. The ABCI classes had to start studying other objectives and did not have enough time to complete lab reports for the BioBLAST labs in addition to their other lab reports. Because I had no BioBLAST lab reports to compare them to, I did not have the traditional group complete lab reports. Instead, students from both groups reported their findings to their classmates in class discussions of the labs and were assigned participation points for the labs and discussions. Students were allowed to keep the worksheets and graphs they created in the labs for their notebooks. The participating science teacher and I were very pleased with students' completion of the lab and their apparent comprehension of the material as indicated by performance on the lab worksheets and in the class discussions.

Achievement of Plant Production Objectives

As stated in the discussion of the Post-Test, students participating in the traditional labs scored an average of one test item higher than the students participating in the computer-simulated labs. However, it appears that use of the BioBLAST software resulted in a more homogeneous set of final scores. That is, it appears using the computer simulation results in less variability in the content message delivered and hence the learning measured. One of the benefits touted for computer-assisted learning is students' consistent experience with the content. Also, students are able to repeat sections of the labs over and over to reinforce their understanding of the effects of variables in their experiments. The laboratory method may not be the only factor affecting consistency in the BioBLAST group scores. Students in the BioBLAST group were predominantly sophomores or juniors who are in a technical career program of study, but the traditional group included seniors and students who are in a college preparatory program of study.

In addition, I taught the entire traditional group, and I developed the post-test. Although I wanted the experimental group to perform better than they did, I am sure my selection of post-test items and the objectives I stress in instruction directly influenced the better performance of the traditional group. Naturally, the test items I chose from the sample tests would be the ones I feel are most important to students' understanding of plant science and the ones I would put more emphasis on when I teach. A third-party, more neutral post-test is recommended to test this assertion. Also, the traditional group is in Horticulture every day, so they were exposed to information about plants and plant science much more frequently than the computer-simulated group. Examining student lab reports would also have shed light on the effectiveness of the two laboratory methods. Although a true experimental design was not possible in this action research study, it would be necessary to statistically support a hypothesis regarding instructional method.

Attitudes of Students

Attitudes of students were measured through the student survey and were inferred from their conduct and work ethic in the laboratory experiments. Means of responses from the student surveys and means of teachers' ratings on the observation forms indicated positive attitudes and motivation in relation to the computer supplemented labs. All responses on the student survey had means above three or neutral. In other words, all items on the survey had a positive response indicating that students have a high opinion of the computer-simulated labs and that they would like to use similar software for science labs again.

Attitudes of Teachers

Attitudes of teachers were inferred from the ratings and comments they made on student observation forms, responses to the teacher survey, and conversations and activities recorded in my journal. The participating teacher made positive comments regarding BioBLAST on his student observation forms and in our conversations before, during, and after the intervention. The study required his students to be placed in other classrooms for four days, so it is evident he supported the computer-simulated activities by allowing them to participate. He said he feels the computer-simulated labs are a nice change to the traditional labs and are a good way to apply theories studied in the course. He also stated his discouragement with the existing support materials for Applied Biology and Chemistry, and indicated he would be interested in using the software again.

Incidental Findings

The main incidental finding I see is students' unwillingness to read instructions regarding computer based experiments. I assume that their previous experience with computers makes them feel that they don't need to read the instructions for the lab. A couple of students mentioned it would be helpful for them if the instructions were presented on screen rather than on paper. It is possible to view instructions in the program, but that requires toggling back and forth from the simulator to other parts of the program. Less teacher input might be necessary if the software could be upgraded to include scripting that appears when the cursor hovers over an object or a helper that appears when a function is selected.

Future Action Planning and Implications

Though student performance was nearly the same from one laboratory method to the other, BioBLAST and other computer simulation software should still be considered for incorporation in science and vocational courses. This action would contribute to the fulfillment of state requirements and federal recommendations for integrating technology into science and vocational instruction. Such simulations also make it possible to complete activities that are too costly, complex, hazardous, or lengthy to conduct in our high school laboratories. These benefits may be reason enough to consider using simulation software.

The intervention I planned was for a short period of time and a small amount of content. Future research should include a more lengthy and thorough implementation of computer-simulated labs. The BioBLAST software would be best used throughout a biology course and fully integrated into the program of instruction and coordinated with traditional labs. The materials that come with the software actually included many such activities. A more thorough integration of the software may have shown positive achievement gains. It may also be the case that traditional content tests do not fully assess the benefits of such software and a long-term implementation would allow other benefits to be examined.

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Computers to Supplement

Science Instruction

Camden County High School is a large comprehensive high school in Southeast Georgia. Enrollment for the 2001-02 school year is just under 2600 students. The school was constructed in the early nineties, and opened for the 1994 – 95, school year. Two additional wings were opened in 1999, and a Ninth grade center was opened in 2000. The increase in population caused by Kings Bay Naval Submarine Base and supporting industries necessitated the construction of numerous schools within a short period of time.

The need for space was a greater priority for the existing administration than the need for technology. Subsequently, schools were built and furnished without up-to-date wiring, hardware, and software. The new administration has a greater focus on curriculum and instruction and recognizes the need for the integration of technology in instruction. Renovations are underway to replace out-of-date computers and wiring in the high school and put more computers in each classroom.

Because leaders in the school system were not focused on technology, teachers were unable to make it a priority. The school formed a technology committee in Fall, 2001, to develop a technology plan. The current focus on technology creates the optimum environment for experimenting with various instructional software packages and encouraging teachers and administrators to participate. In addition, it is textbook adoption year for the science department. The applied biology curriculum is the area of greatest need for more useful materials. The workbooks that have been used for the last five years do not correlate well to state standards, and the teachers have been using Georgia High School Graduation Science Test workbooks.

The action research will be conducted with horticulture and applied biology I classes during Spring Semester, 2002. Two horticulture classes and approximately six applied biology classes are taught each semester. One horticulture teacher and two applied biology teachers will conduct those courses during Spring Semester. The horticulture classroom has five computers capable of running the BioBLAST software, and the two science classrooms each have three to five computers. BioBLAST: Better Learning Through Adventure, Simulation, and Telecommunications, is multimedia software based on actual NASA research. The participating teachers have agreed to rotate students among the available computers in their classrooms and in other rooms to complete the simulated labs.

Area of Focus Statement

The purpose of this study is to evaluate the effects of computer simulations on student attitudes and performance in Plant Science units of applied biology and horticulture. A review of the literature shows promising results from the use of computer assisted instruction in supplementing traditional instruction in science. The President's Commission of Advisors on Science and Technology has recommended that research in science education focus on determining the best uses of computers for that subject area (Hickey et al., 1999). No studies were located pertaining to the use of computer-aided instruction in secondary plant science, so results of the study will add to the body of knowledge related to computer use in science education. Although Camden County High School is relatively new and considered “state of the art,” the number of computers in the school and the degree of integration of technology are very low. Hopefully, the technology integration modeled in this action research will be successful and will encourage teachers and administrators to further facilitate the integration of technology into the curriculum.

Biology Literature Review

For more than two decades, science educators have hoped that computers would help provide more efficient, effective instruction (Weller, 1996). Educational use of computers is not only driven by the desire of educators to improve instruction it is also driven by the makers of public policy, such as The Presidents Commission of Advisors on Science and Technology (PCAST). The PCAST developed an agenda for the use of technology in primary, middle, and secondary science education. The report calls for research in typical classrooms with ordinary teachers and without unusual financial, technical, or research support. The commission recognized the necessity of computer use in education and recommended that research be based on the assumption that computers should be used in instruction and focused on how they are best used (Hickey et al., 1999).

Hyper-models and simulations are two types of software that have real potential in the science laboratory. Hyper-models combine stored or web-based information with manipulable computer models. A hyper-model, such as GenScope for studying genetics, supports student development of higher level reasoning skills (Horwitz, 1999). Simulations are interactive computer representations of real experiments, such as dissections or chemical reactions, which can be used when time, hazard, cost, cruelty or workability of the real experiment is prohibitive (Soyibo & Hudson, 2000).

Numerous computer applications are suitable for high-school biology. As stated, GenScope is hyper-modeling software for studying genetics. In a test conducted in 40 high school classrooms over four years, GenScope-supplemented instruction produced better gains for general and applied students than traditional instruction alone. College preparatory students performed equally well with either method of instruction. The main advantage of the software is that it links the entire range of biological organization. Any genetic change made in the cell, organism, species, or evolution is reflected in every other level. Fanciful creatures such as dragons as well as real organisms such as dogs and cats are used to help students work through their preconceptions about genetics. The software permits students to analyze their own thoughts and the consequences of their actions in the model while providing numerous, low-risk opportunities for students to practice altering the genetic make-up of the organisms. These opportunities to make changes and visualize the effects help students develop an understanding of genetic concepts (Hickey et al., 1999).

Simulations have been used in high school microbiology to supplement traditional instruction in cell growth and division. One study compared traditional biology labs with computer simulation labs for 82 biology students in Israel. Girls who used the simulation performed much better than girls in the traditional labs. Girls using the simulation performed more in line with the performance of the boys who completed either type of lab. Traditional labs generally manipulate one variable at a time at the high school level. The simulation allows the manipulation of more than one variable at a time, so the simulation can cover more material in less time. The software was used to model yeast cells like those used in the traditional lab, but the simulation students don’t have to wait for the cells to grow and divide like the traditional lab students do. Students are constantly and actively involved with the simulation and work at their own pace. Low to average ability students showed significant improvement over traditional instruction and labs, but honors and college preparatory students performed the same under both teaching methods (Huppert, 1998).

Simulations, such as the interactive laser video to teach the functional anatomy of the rat, can supplement or replace dissection labs in secondary biology. The software provides a practical dissection that is highly interactive. It covers five areas of rat dissection and can interchange gender of the specimen, so students can study all organs. The teacher can edit, extend, or customize the activity as necessary, and the learner controls the display of information. Use of dissection simulations can solve a number of moral, ethical, and financial problems. Students are more vocal about animal rights issues related to animal use in science, and animal specimens are very expensive. The simulation allows repetition of the lab and review, and the software can be used with unlimited numbers of students at a fixed cost, year after year. It is also much cleaner and safer than traditional labs (Quentin-Baxter, 1995).

Although computers have been around for a long time, their use in education has not reached full potential. More comprehensive evaluation – formative and summative – is necessary to determine the best uses of computers in education. According to the Presidents Commission of Advisors on Science and Technology, existing problems with sufficient computer use and application should be solved before new problems are identified and addressed. (Hickey et al., 1999) Designers, content experts, and technicians need to collaborate to develop materials that utilize computers in ways that maximize technological capabilities and model recognized effective teaching practices. Technologies should be judged on their ability to really improve working and learning conditions. (McNaught, 1999)

Promising software packages exist to help teachers at all levels and in all areas of science support their instruction. Computer assisted learning should not be used to replace traditional instruction but should be used to supplement that instruction where real experiments are too difficult, expensive, dangerous, or inhumane. Simulations and modeling software have great potential to expose students to experiments they might never be able to conduct in reality. The improvements in performance of general and applied level students using many of the tools reviewed is strong evidence for incorporating these tools in instruction. Although higher level students did not always show significant improvement in test scores, they did show improvement in higher order thinking skills and depth of knowledge. Future studies could be devoted to the evaluation of more difficult and inductive tools for higher aptitude students and the continued improvement of instruction for all students.

Variables

The effects of the instructional method used to teach the theories of plant production on student performance and the attitudes of students and teachers will be compared in the study. The independent variable is instructional method, with the comparison between traditional instruction and BioBlast instruction. Traditional instruction will be defined as lecture, use of the textbook and hands-on laboratory experiments. BioBlast instruction will include similar lecture and use of the textbook, but will have instruction supplemented by computer tutorials and will use computer simulated laboratory experiments.

The dependent variables are student performance, student attitude, and teacher attitude. Student performance can be defined as measurement of achievement of pre-set objectives and success on laboratory reports and post-tests. Student attitude can be defined as opinion of instruction and content as measured by student survey and teacher observation forms. Teacher attitude can be defined as preference of instructional method and is measured by teacher survey and observation forms.

Research Questions

1. Is there a difference between traditional instruction and computer-supplemented instruction in:
    a. Accuracy and thoroughness of lab experiment reports?
    b. Achievement of plant production unit objectives?
    c. Attitudes of students toward instruction and content?
    d. Attitudes of teachers toward instructional methods and results?
2. What implications does computer-supplemented instruction have for students and teachers in biology?

Intervention

Students of high school biology and horticulture will be taught plant science with two different methods of instruction: traditional alone and computer supplemented. Both subject areas have a maximum class load of 28 students and have access to computers and suitable laboratories within their work areas. Half of the 120 biology students and half of the 50 horticulture students will be taught with traditional instruction using the text, teacher lecture, teacher created materials and notes, and traditional, hands-on laboratory experiments. These classes will be taught by their regular science or horticulture teacher and will spend the usual week studying plant production, approximately seven and a half hours in block scheduling,

Half of the 120 biology students and half of the 50 horticulture students will be taught with the text, teacher lecture and notes, computer-based tutorials, and computer-simulated laboratory experiments. These classes will be taught by their regular science or horticulture teacher and will use BioBLAST software for tutorials and simulated experiments in plant production as a supplement to the text and teacher instruction. BioBLAST will be used to supplement one week of plant science instruction, approximately seven and a half hours. Applied biology teachers stated that they spend approximately one week on plant science, so the Plant Science Sampler from BioBLAST will fit into the curriculum efficiently.

The Plant Science Sampler is one of seven units in BioBLAST. “The sequence is designed to take approximately five class periods including a launch sequence, an experiment, a simulator activity and several explanatory movie clips. The sequence also provides students with an opportunity to use the BioBLAST interface as they virtually travel throughout the simulated lunar base. The intent is to encourage student interest in computer-based tools that enhance scientific inquiry” (BioBLAST, p. 3, 1998).

Action Research Group

The two instructors of applied biology for Spring Semester, 2002 at Camden County High School have agreed to participate with the instructor of horticulture in this study of computer-supplemented instruction in plant science. The Vocational Supervisor, who is responsible for the instruction in horticulture and in applied science, has also agreed to assist in the study. Members of the thesis committee will be part of the action research group as well.

Negotiations

Negotiations will be made to determine which students will be taught with each laboratory method based on teacher preference and the availability of computers to facilitate the intervention. Students may have to relocate to other classrooms to complete the simulation activities based on a schedule of rotation for available computers. Participating teachers will negotiate the schedule of rotation. Timing of the actual intervention will depend on course schedules and may require some negotiation. Hopefully the unit can be taught when it is normally taught in the course sequence. Parental permission will be obtained for all students in the study.

Timeline

Start	**Finish**	**Activity**
1/7/02	1/31/02	❑ Acquire and distribute software. ❑ Review and refine research proposal. ❑ Review and refine tests and laboratory activities. ❑ Develop detailed timeline for intervention.
2/1/02	2/8/02	Conduct lab activities for group A.
2/11/02	2/15/02	Post test group A and conduct lab activities for group B.
2/18/02	2/22/02	Survey group A, post test group B, and conduct lab activities for group C.
2/25/02	2/28/02	Survey group B, and post-test and survey group C. Survey teachers.
3/1/02	3/8/02	Collect, compile, and analyze data for article manuscript.
3/11/02	3/15/02	Write and refine article manuscript.
3/18/02	3/22/02	Submit article manuscript, celebrate with participants, and write LCR.
3/25/02	3/29/02	Submit LCR, Learning Community Report and revise Article Manuscript.
4/1/02	4/5/02	Re-submit article manuscript.
4/8/02	4/12/02	Write thesis abstract and create all supporting pages.
4/15/02	4/19/02	Submit all supporting files and forms.

Resources

BioBLAST web site and literature obtained with the software will be used as resources for implementing the instructional supplement. Camden County High School applied biology instructors and the Vocational Director will be used as resources for the applied biology curriculum and the state objectives the applied biology students must meet. The Georgia Learning Connections web site will also be used to identify state objectives in the Georgia Quality Core Curriculum that apply to plant science in applied biology. Sample questions from the Georgia High School Graduation Test and the pilot-tested, state, end-of-course test for biology will be used to develop the post-test.

Camden County High School science and horticulture classrooms and labs will be used to teach the classes. If possible, computer labs will be used to allow entire classes to complete the simulation experiment at the same time. Manuals for applied biology and the Georgia High

School Graduation Test for science are used as texts for the applied biology course, so they will be used as resources for the study. Horticulture classes use Introductory Horticulture textbooks, so they will be used as well.

Data Collection

All instruments will be used for all students and teachers. Instructors will keep a daily log in each class to record observations of students during instruction and labs to assess understanding and attitudes. Student performance rubrics will be used to grade lab reports to evaluate accuracy and depth of knowledge regarding plant science. At the end of the instruction, students will take a unit test that will serve as the post-test for the study. Instructors will complete surveys to assess their opinions of the instructional methods and student performance. Students will complete surveys to assess their opinions of plant science and the instructional method employed to teach them the content.

Correlation of Research Question to Instrument Question

Abbreviations: HT - Horticulture Teacher, Q - Question

Research Question	**Data Collection Method**	**Instrument and Appendix**	**Instrument Question #**
1a. *accuracy and thoroughness of lab experiment reports	Observation by HT	Field Notes	
	Teacher evaluation	Lab Report Rubric (Appendix D)	Q 1-22
1b. *achievement of plant production unit objectives	Observation by HT	Field Notes	
	Teacher evaluation	Post-Test (Appendix D)	Pre Q 1-20 Post Q 1-20
	Teacher Observation	Student Observation Forms (Appendix C)	Q 1-12
1c. *attitudes of students toward instruction and content	Observation by HT	Field Notes	
	Teacher Observation	Student Observation Form (Appendix C)	Q 1-12
	Self Report	Student Survey Form (Appendix F)	Q 1-12
1d. *attitudes of teachers toward instructional methods and results	Observation by HT	Field Notes	
	Teacher Observation	Student Observation Form (Appendix C)	Q 1-12

	Self Report	Teacher Survey Form (Appendix G)	Q 1-12
2. *implications of computer supplementation for students and teachers of plant science	Observation by HT	Field Notes	
	Self Report	Teacher Survey Form (Appendix G)	Q 1-12

Data Analysis and Interpretation

The horticulture teacher is conducting the study and will keep field notes of all activities to be reduced, coded, and displayed. All teachers participating in the study will keep logs composed of student observation forms. Teachers are expected to note student activities, questions, attentiveness, motivation, confidence, and comprehension on the forms to be analyzed by the horticulture teacher. Teachers will also complete a self-report survey to assess opinions of the instructional supplementation and the use of computers in instruction in general.

Range, distribution, central tendency, and standard deviation of the post test scores will be analyzed to assess student achievement. Students will complete lab reports, as they do with all science labs, to be graded using a scoring rubric that ranks the accuracy and thoroughness of each section of the report. Scores on the rubric will be analyzed to determine students' comprehension of the content under both methods of instruction. Students will also complete self-report studies for analysis of attitudes toward the method of instruction they were taught with and toward plant science in general.

Correlation of Research Question to Instrument Question			
Abbreviations: HT – Horticulture Teacher, Q – Question			
Research Question	**Data Analysis Method**	**Instrument & Appendix and Question Number**	**Interpretation**
1a. *accuracy and thoroughness of lab experiment reports	Data reduction, data coding, data display	Field Notes	Possible patterns, themes, and/or deviations in accuracy and thoroughness of lab reports.

	Range, distribution, central tendency and standard deviation of scores. Item analysis.	Lab Report Rubric (Appendix)	Possible patterns, themes and/or deviations in scores and item analysis.
1b. *achievement of plant production unit objectives	Data reduction, data coding, data display	Field Notes	Possible patterns, themes, and/or deviations in comprehension or response to items.
	Range, distribution, central tendency and standard deviation of scores. Item analysis.	Post-Test (Appendix D)	Possible patterns, themes, and/or deviations in pre and post-instructional knowledge and item analysis.
	Data reduction, data coding, data display	Student Observation Forms (Appendix)	Possible patterns, themes, and/or deviations in student behavior during/after instruction.
1c. *attitudes of students toward instruction and content	Data reduction, data coding, data display	Field Notes	Possible patterns, themes, and/or deviations in students' attitudes during/after instruction.
	Data reduction, data coding, data display	Student Observation Form (Appendix)	Possible patterns, themes, and/or deviations in students' behavior during/after instruction.
	Frequencies and means of responses. Central tendency & standard deviation.	Student Survey Form (Appendix)	Possible patterns, themes, and/or deviations in students' responses to surveys.
1d. *attitudes of teachers toward instructional methods and results	Data reduction, data coding, data display	Field Notes	Possible patterns, themes, and/or deviations in teacher behavior throughout study.

	Data reduction, data coding, data display	Student Observation Form (Appendix)	Possible patterns, themes, and/or deviations in teacher notes throughout study.
	Frequencies and means of responses. Central tendency & standard deviation	Teacher Survey Form (Appendix)	Possible patterns, themes, and/or deviations in teachers' responses to surveys.
2. *implications of computer supplementation for students and teachers of plant science	Data reduction, data coding, data display	Field Notes	Possible patterns, themes, and/or deviations emerging during/after the survey.
	Frequencies and means of responses. Central tendency & standard deviation	Teacher Survey Form (Appendix)	Possible patterns, themes, and/or deviations emerging regarding future use of innovation.

Communication of Findings

"Thank-you" tokens will be presented to all participating students. A "Thank-you" celebration will be held to convey the communication of findings to participating instructors, administrators and available members of Thesis Committee. The horticulture teacher will develop a web page devoted to the study and its findings and will make postings to the BioBLAST discussion forums on the BioBLAST web site for other users/researchers to view. Copies of the thesis and supporting video and photos will be submitted to the entire thesis committee.

Appendix A

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Appendix B

Plant Production Unit Student Observation Form

Instructor: ____________________________ Class: ______________ Date: ______________

Rank the following on a scale of 1 to 5, with five being the highest:

	1	**2**	**3**	**4**	**5**
Student motivation					
Student behavior					
Student software operation (if in BioBLAST instruction)					
Student computer operation (if in BioBLAST instruction)					
Student use of lab equipment (if in traditional instruction)					
Student work ethic					
Student comprehension as determined by questions/progress					
Progress through lab activities					
Overall classroom environment					
Current ranking of plant production unit					

Positive observations: ____

Negative observations: ____

Student comments: ____

Questions/points to consider: ____

Appendix C

Plant Science Lab Report Evaluation Rubric

Student: ____________________ Date: _______ Class/Teacher: ___________

Section	**A**	**B**	**C**	**F**
Purpose				
Accuracy				
Thoroughness/Critical Thought				
Spelling/Grammar				
Background				
Accuracy				
Thoroughness/Critical Thought				
Spelling/Grammar				
Materials				
Accuracy				
Thoroughness/Critical Thought				
Spelling/Grammar				
Hypothesis				
Accuracy				
Thoroughness/Critical Thought				
Spelling/Grammar				
Procedure				
Accuracy				
Thoroughness/Critical Thought				
Spelling/Grammar				
Results				
Accuracy				
Thoroughness/Critical Thought				
Spelling/Grammar				
Conclusion				
Accuracy				
Thoroughness/Critical Thought				
Spelling/Grammar				
Overall				

Comments: ____

Appendix D

Plant Science Post-Test

Name: ___________________________ Date: _________ Teacher/Class: ___________

1. The xylem, or wood of a stem
   a. conducts manufactured food down to the roots
   b. stores food
   c. is green in color
   d. conducts water and minerals up to the leaves

2. The major function of root hairs on roots is to
   a. grow into larger roots
   b. absorb water and minerals from the soil
   c. protect the root as it pushed through the soil
   d. keep the root warm

3. Pollination is a sexual process in which pollen is deposited on the stigma of the plant. It starts the process of fertilization and
   a. growth of the pollen tube
   b. seed formation
   c. production of a fruit or seed coat
   d. all of the above

4. As the outside temperature increases, plant growth normally
   a. increases if moisture is available
   b. decreases because plants become too hot
   c. decreases because the plant cannot receive moisture fast enough
   d. increases because humidity always increases with the temperature

5. Green plants cannot live without light because
   a. it is necessary for the manufacture of food
   b. they need light to breathe
   c. light helps to warm them to the optimum temperature for growth
   d. none of the above

6. Transpiration is a process where plants
   a. lose water through stomata in the leaf
   b. lose water through the leaf epidermis
   c. breath through the leaves
   d. none of the above

7. An autotroph is an organism that
   a. does not depend on the sun for energy
   b. does not require energy
   c. obtains energy by eating other organisms
   d. obtains energy by making its own food

8. Which of the following is characteristic of gymnosperms?
   a. seeds are produced in cones
   b. produce flowers in spring
   c. leaves are deciduous
   d. are usually monocots

9. Plants with fewer stomata would most likely occur in which type of environment?
   a. rain forest
   b. desert
   c. coniferous forest
   d. grassland

10. The female reproductive structures of a flowering plant include all of the following EXCEPT
    a. the stamen
    b. the ovary
    c. the pistil
    d. the stigma

11. Angiosperms produce a seed that contains a leaf, which provides food for the emerging plant. This seed leaf is called
    a. a conifer
    b. a cotyledon
    c. a monocot
    d. a stem

12. The stage in a plants life when germination and growth occurs is the ______ phase.
    a. vegetative
    b. reproductive
    c. dormant
    d. pollination

13. In photosynthesis, ___ and ___ are converted in the presence of light to sugar and _____.
    a. oxygen, water, carbon dioxide
    b. sunlight, oxygen, water
    c. sunlight, water, carbon dioxide
    d. carbon dioxide, water, oxygen

14. The chemical in the leaf which aids in photosynthesis is
    a. chlorophyll
    b. chloroplast
    c. phototropism
    d. chlorosis

15. Plants raised using hydroponic methods
    a. have completely controlled nutrients
    b. have a greater yield per unit area
    c. have a smaller root area
    d. all of the above

16. Chlorophyll occurs in organelles called
    a. vacuoles
    b. chloroplasts
    c. chlorates
    d. vacuplasts

17. Organisms in the soil that aid plant roots in water and nutrient absorption are called
    a. mycorrhizae
    b. plastids
    c. meiosis
    d. mycelium

18. A plant has leaves with parallel veins and a seed with a single seed leaf. How would it be classified?
    a. conifer
    b. fern
    c. monocotyledon
    d. dicotyledon

19. Two main functions of plant stems are
    a. to store food and convert it to starches
    b. movement of materials and support of plant parts
    c. to manufacture food and store it for future use
    d. to furnish food for human beings and other animals

20. Which of the following is not a function of roots?
    a. storage of food
    b. absorption of water
    c. anchoring of plants
    d. manufacture of food

Appendix E

Student Evaluation of BioBLAST Plant Production Unit

Respond to the following by marking one of the boxes to the right.

	Evaluation Item	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
1	I liked the computer-simulated laboratory experiments better than other science experiments I have done.					
2	I understood how to use the software and had little or no trouble completing the assignments.					
3	I liked the opportunity to work at my own pace and was able to finish the labs within the maximum time limits.					
4	I needed the instruction and interaction with my teacher to complete the assignments successfully.					
5	The computer I used had enough speed and memory to run the software properly.					
6	Viewing the effects of my actions on variables in the simulations helped me develop an understanding of basic plant science.					
7	Using the NASA research-based software that simulated a lunar station was motivating for me.					
8	The simulation of producing plants in space helped me understand the environmental needs of plants and the necessity of plants to humans.					
9	The lab reports for these simulations were easier to write than the ones I have written for traditional labs.					
10	I would like to use BioBLAST software to complete other Applied Biology experiments.					

11. Describe your opinion of or recommendations for BioBLAST. ________________

____

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____.

Appendix F

Teacher Evaluation of BioBLAST Plant Production Unit

Respond to the following by marking one of the boxes to the right.

	Evaluation Item	**Strongly Agree**	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
1	Content was appropriate for high school applied biology students.					
2	Content was aligned with quality core curriculum (QCC) standards of Georgia for high school applied biology.					
3	The unit sufficiently prepares students for Georgia High School Graduation Test Items pertaining to photosynthesis and respiration.					
4	The unit was well suited to one week of instruction in block scheduling - 7.5 hours.					
5	Computers available had sufficient speed and memory to run the labs.					
6	It is acceptable for students to complete the lab in a computer lab or other classroom instead of in the science lab and classroom.					
7	It is acceptable for students to complete the labs at different times throughout the week at their own pace.					
8	Students stayed "on-task" during the self-directed activities.					
9	Students were more motivated to complete the computer-based labs than traditional labs.					
10	I would use BioBLAST software to teach applied biology units again.					

11. Describe your opinion of or recommendations for BioBLAST. ________________

____
____
____
____
____
____.

Appendix G

Parental Consent Form

I, ____, parent or legal guardian of ____, give my consent for him/her to participate in an experimental study of computers in plant science instruction. The study will consist of two instructional methods, traditional and computer supplemented, and will contain the same content. I have been informed that the study will last for one week of Spring Semester, 2001and that I may withhold or withdraw the student from the study at any time without penalty.

____ ________________

Parent or Legal Guardian Date

Questions or comments may be directed to:

Audrey Calhoun
Horticulture Instructor
Camden County High School
1545 Laurel Island Parkway
Kingsland, GA 31548
(912) 729-7352
amcalhou@hotmail.com

Appendix H

Simulated Laboratory Activities

Background to the Plant Production Simulator
By: Arthur W. Galston, Ph.D.
Professor Emeritus, Department of Biology
Yale University

This Plant Production Simulator is based on actual investigations now being conducted by scientists at NASA's Kennedy Space Center. The "challenges" in this simulator are designed to increase your understanding of plants in an ALS. If you feel you already know enough about this subject, you may want skip this exercise and proceed directly to the BaBS simulation, where you may start selecting your crops.

Plant's Role in the Earth's Ecosystem

In the process of photosynthesis, green plants absorb light energy to combine carbon dioxide and water into carbohydrates and other food products. This process also liberates gaseous oxygen. Animals reverse this flow. They breathe in the gaseous oxygen and eat the plants, then expel carbon dioxide gas. They also excrete various minerals and nitrogen compounds, which eventually make their way back into the plants.

On earth, these chemical interchanges between plants and animals are largely in balance, producing a stable complex of ecosystems.

Advanced Life Support (ALS)

When humans are removed from their natural ecosystems for short periods of time--for sea voyages or brief space flights--it is practical to carry along all the food, oxygen, and water that will be needed and to dispose of waste upon completion of the mission. However, when humans leave their natural ecosystems for prolonged periods--for months in a submarine or years in a spacecraft--artificial systems must be devised that can substitute for the natural world in providing its life-sustaining amenities. All food, water, oxygen, and recycling capabilities must be generated from within the artificial system itself.

For these long missions, an Advanced Life Support (ALS) system is essential.

ALS System

A typical ALS system uses artificial lighting and human-produced carbon dioxide and wastewater to sustain green plants, which in turn, produce oxygen and food for the crew. The system also depends on plants to transpire enough collectable pure water to meet the crew's needs.

Waste materials from plants and humans are decomposed by microbes and physical devices. This process eventually yields carbon dioxide and water that are again recycled into the plants.

These processes must be constantly monitored to ensure that they are in balance. Otherwise the artificial, enclosed ecosystem may "crash," dooming its occupants. Monitored information is usually processed and integrated by a central computer, which can then adjust the rates of individual reactions to achieve the necessary long-term balance.

Kennedy Space Center

At NASA's Kennedy Space Center, advanced technology has been used to construct plant production chambers that yield large quantities of food and oxygen from such crops as dwarf wheat, soybeans, potatoes, and lettuce. These chambers use artificial light and hydroponically supplied minerals to grow plants efficiently. Physical probes constantly measure and record temperature, light intensity, air flow, oxygen gas, carbon dioxide gas, pH of the nutrient solution, mineral composition of the nutrient solution, and additional measurements such as concentrations of ethylene and other volatiles that can affect plant growth. Periodic observations are also made on microbial contaminants in the nutrient solutions and on the plants.

Based on these measurements, parameters affecting growth and plant health can be adjusted automatically or by hand to achieve stability of the system.

Much to Do

At present, the technology of recycling wastes lags behind that of plant growth. Thus, the ideal of a stable closed system has not yet been achieved. Yet it must be achieved if astronauts are to be sent on a three-year mission involving a round-trip to Mars, or for extended residence on the Moon. These NASA research programs must be accelerated to meet the needs of humans on extended missions in space.

Important Notice

Although the Plant Production Simulator can be very useful in understanding plant production, remember that it is only a simulator. Like all simulators, its outputs are only as good as the assumptions used to create it. Its outputs should constantly be questioned and challenged in a scientific manner.

Plant Production Overview

If we take a closer look at Earth, our home planet, it's easy to see that it is a rather complex model of a biological life support system. In this terrestrial biosphere plants, animals, and microorganisms interact to produce dynamic cycles of exchange that make all life possible. Plants consume carbon dioxide produced by animals and microorganisms and produce oxygen, the vital ingredient for animal and microbial life. Often these cycles of change and growth go on virtually unnoticed by the casual observer. Life in a lunar Advanced Life-Support System (ALS) will bring these processes to a central focus. In the case of an ALS beyond the boundaries of Earth's atmosphere, it will be man, and not nature, who will monitor and, when necessary, mediate these cycles of change. In the enclosed system humans become facilitators, responsible for understanding and directing complex levels of interaction between the components of the system. All waste products become resources, a key factor in the continued success of the operation.

Plant production research plays a vital role in the ALS mission. Mission specialists will be responsible for selecting and conducting experiments and research that will design a bioregenerative life support system capable of maintaining a continuous supply of recycled resources from an assortment of plants used for food. As members of the research team, you will address these critical issues related to the ALS mission:

• Can your crops produce enough oxygen to sustain human life from the carbon dioxide exhaled by the crew?

• Can these crops provide the crew with an adequate amount of water that is fit to drink ?

• Can the plant growth system provide 80% of the crew's nutritional needs?

As members of the team you will be responsible for developing a plant growth and production system capable of maximizing the crops' potential for providing the essential requirements for a sustainable life support system. Key requirements related to the design of your mission objectives include:

• Developing an efficient and reliable schedule of seed germination, growth, and harvest;

• Selecting crops that specifically provide calculated oxygen, water, calorie, and nutrient requirements for individual crew members;

• Controlling the system to provide optimal conditions at each stage of development for a variety of crops.

Experimentation and Data Analysis

Throughout the mission, team members will provide contributions for the design of a functional bioregenerative life support system. The team will be engaged in a variety of experiments and activities addressing specific issues (e.g. light and temperature requirements) which will affect the final design and operation of the system.

As members of the team, you will gain a new appreciation for the basic requirements of seed germination, and an increased awareness of the essential requirements for crop growth. Your work will involve both experimentation and extensive research.

Many of the issues that you will face have been the topic of research conducted at various NASA facilities. Basic processes at work in plant germination, growth, and reproduction will have to be re-examined in the context of the lunar-based system.

Lab Activities

As research scientists, you will conduct experiments designed to guide you as you develop in-depth research investigations. Some of the experiments may lead to a new generation of questions contributing to life support.

Some of the topics that you will explore in the Plant Production Laboratory include investigating:

• farming in space;

• the effects of imbibition (water absorption) on the germination of seeds;

• the effects of light intensity on plant growth; and,

• the effects of the hormone gibberellic acid on plant growth.

Do You Have What It Takes?

Walking in the footsteps of the pioneers who braved danger in the Apollo missions, you have the unique opportunity to pave the way for a new generation of pioneers, the first solar system explorers. Do you have what it takes to meet the challenge?

Student Name: ______________________

Living Off the Land

Which Plants Are Most Productive?

Student Objectives

In this activity you will have an opportunity to

- familiarize yourself with the Plant Production Simulator,
- use the Plant Production Simulator to investigate the growth of several candidate crops for advanced life support (ALS) systems,
- collect data from the simulator runs and analyze the data using a spreadsheet, and
- select the best advanced life support (ALS) crops based on their production of oxygen, potable water, and edible biomass.

Background Information

In an ALS system the majority of the oxygen, clean water, and food resources will likely be produced by plants. It will be important for designers of an ALS system to know which plants are the best producers of these resources.

Most plants produce more of one resource (relative to a human's needs) than another. For example, Plant A may produce 50% of the oxygen a human needs, but only 30% of the water and 25% of the food, while Plant B may produce only 35% of the oxygen, but 45% of the water and 10% of the food a human needs.

Adequate amounts of all resources must be produced on a continual basis. It is not acceptable for the ALS system to produce plenty of food but not enough oxygen. So, a mixture of plant types must be used in the ALS system.

Problem to Be Investigated

In this activity, you will simulate growing each of the ALS candidate crops using the Plant Production Simulator. You will record each crop’s total output (for one harvest cycle) of oxygen, water, and food. Using this data, you will determine each crop’s average daily output, the number of humans supported by one square meter of each crop, and the planting area required to support one human with oxygen, water, and food.

Materials

Plant Production Simulator

Computer spreadsheet program

Spreadsheet template (Excel version: **Most Productive-XL**, ClarisWorks version: **Most Productive-CW**), located in the Spreadsheet template folder on the CD

Procedure

Run 1

The following run will give you practice setting up and running the simulator. (If you are already on the main input screen for the Plant Production Simulator, you can skip to Step (5).)

1. Find the computer monitor (hot spot) in the Lunar base laboratory that has Plant Production Simulator on the screen and click on it.
2. Click on the Plant Production Simulator button to enter main menu screen

for the simulator.
3. If your teacher instructs you to, select Background and read it. (You may have already done this as homework.)
4. Return to the main menu screen and select Start Simulation
5. Enter the following conditions in the Set screen.
• **Length of Experiment: 28 days**
This is how long the simulator will generate data. A longer experiment will allow you to collect more data, but will also take longer to run. For this investigation always set the Length of Experiment to one harvest period. The harvest period, along with other useful data, can be found by clicking on the database button at the bottom of the screen.
• **CO_2 Level: 1200 ppm**
The level of carbon dioxide (CO_2) in the plant growth chamber can affect the rate of growth of the plants. The level of CO_2 in the earth's atmosphere is approximately 300 ppm. NASA often uses CO_2 levels near 1200 ppm in their plant growth studies.
6. Click on the growth chamber labeled Crop 1.
7. Select Lettuce, and enter the following values:
• **Growing area: 1 square meter**
• **First planting day: 1**
If you are planting several chambers of crops, it may be useful to stagger their planting schedules so that they are not all harvested at the same time.
• **Harvest/plant every: 28 days**
The simulator will automatically replant the chamber with crops every time they are harvested for as long as the simulation is running. Although some variation in harvest time for a particular crop can be tolerated, it is usually best to harvest the crops when they are at optimum yield. The ideal growing period for each crop is listed in the database.
• **Photoperiod: 24 hours**
Adjust the slide bar to give the desired period of light (photoperiod) that the crop will receive each day. Some plants can tolerate continuous lighting (24 hour photoperiod) while others must have some period of dark each day. Check the database to find the maximum photoperiod for each crop.
6. Close the Crop Settings window.
7. Click on Run.
8. During (or after) the run, look at the four graphs. You won't be using them directly in this investigation, however, it is important to become familiar with the daily outputs from the plants. If your teacher instructs you to, print or save some or all of the graphs.
• To print the graphs, click the Print button and select the graphs you want printed.
• To copy a graph, make sure the graph is displayed on the

simulator's run screen. Click the Copy button. Select your journal
or toggle to your word processor using the Program Select button
, and paste in your graph. You must use this procedure for
each graph you want to copy.

9. Click on Analyze and record the following information in the data table provided at the end of this investigation:

- Total Potable Water Produced
- Total Oxygen Produced
- Total Edible Biomass Produced
- Length of Experiment

10. Close the Analysis screen.

Runs 2, 3, and 4

Repeat this process for wheat, soybean, and potato, using the following procedure for each run:

1. Click on Set.
2. Enter the following conditions in the Set screen.

- **Length of Experiment: Use the growing period for each crop from the database.**
- **CO_2 Level: 1200 ppm**

3. Select the growth chamber labeled Crop 1.
4. Select the appropriate crop, and enter the following values:

- **Growing area: 1 square meter**
- **First planting day: 1**
- **Harvest/plant every: Use the growing period for each crop from the database.**
- **Photoperiod: Use the maximum photoperiod for each crop from the database.**

5. Close the Crop Settings window.
6. Click on Run.
7. During (or after) the run, look at the four graphs. If your teacher instructs you to, print or save some or all of the graphs.
8. Click on Analyze, and record the following information in the data table provided with this investigation:

- Total Potable water Produced
- Total Oxygen Produced
- Total Edible Biomass Produced
- Length of Experiment

9. Close the Analysis screen.

Results

Switch to your spreadsheet software. Create a spreadsheet similar to the data table at the end of this investigation. A template for this spreadsheet (in

Excel and ClarisWorks) is available on the CD. Record your outputs in the spreadsheet. Use the math functions in your spreadsheet software to make the calculations listed below.

1. Find the average daily output of each resource for each crop by dividing the total output for each resource by the number of days the simulation ran (**Length of Experiment**),

Average daily output per square meter =

Total output produced by one square meter

Length of experiment

Find the number of humans supported by one square meter of each crop by dividing the average daily output of each resource by the daily requirements for one human. According to NASA, one human requires 19 liters of water per day, 0.83 kilograms of oxygen per day, and 0.75 kilograms of food per day.

For each of the resources, find the planting area needed to support one human by dividing the daily requirements for one human by the average daily output for one meter of each resource.

Discussion of Results

From the table you produced in the Results Section, select the best crops for production of water, oxygen, and food.

Why would you want to have as many different crops as possible in an ALS system? What if some of the crops were not good producers of water, oxygen, or food?

Some shorter plants can be stacked within the growth chambers. How might your choices change if you could grow twice as much soybeans, and three times as much lettuce in the same space?

Does the shorter life span of lettuce offer some special benefits? What about the fact that potatoes, soybeans, and wheat all have similar growth periods?

Journal Entry

Make an entry in your research journal. Comment on what additional experiments, with or without the simulator, might be useful for helping to complete your mission.

What other crops do you think may be good ALS crops? Why? What experiments would you perform to test a crop’s usefulness in an ALS system?

Suggested Readings

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Mitchell, C. A. (1981). Candidate species selection--cultural and photosynthetic aspects. *Controlled Ecological Life Support Systems:First Principle Investigators Meeting* (pp. 21-22). NASA Conference Publication: 2247.

Student Name: ______________________

LIVING OFF THE LAND
Using the BaBS "Farm"
to Supply Your Crew's Food

Student Objectives

In this activity you will have an opportunity to

- use the Plant Production Simulator to mimic the planting conditions on the *BioBLAST* Lunar Base,
- determine the amount (in kilograms (kg) and 100-gram (100-g) servings) of edible biomass (food) produced by one plant growth chamber in the *BioBLAST* lunar base, and
- develop a planting system that will grow enough edible biomass to supply your crew's diet.

Background Information

In your first Plant Production Simulator activity, you determined the average amount of edible biomass that one square meter of each crop could produce in a day. This will be very useful information for designing your lunar-base advanced life-support system. The next step towards completing your mission and surviving on the moon will be to determine how much of each crop must be planted in your lunar "farm" to supply your crew's diet. (You may have noticed in the first activity that if you planted enough of a crop to supply the crew's food, more than enough oxygen and water would also be produced.) Before tackling this activity, there are a few things you need to know about your farm. First, since there is no atmosphere on the moon to sustain plant life, the plants in BaBS must be grown inside the lunar base. Second, you will be growing your plants hydroponically. NASA is currently investigating growing plants both hydroponically and using soil. And third, the overall size of the Plant Production Area had to be decided ahead of time so that it could be constructed on the moon before your ship arrived.

The BaBS Plant Production Area is divided into ten growing chambers. Each chamber is three meters wide, five meters deep, and three meters high. On the lunar base, space is expensive and must be used as efficiently as possible. To save space, you will be using growing trays (called plant growth units (PGUs)), which can be stacked on top of one another in the chambers. Each PGU is three meters by five meters and contains a hydroponics system and a bank of lights.

The crops you will be growing have a variety of heights ranging from 25 cm for lettuce to 65 cm for wheat. To accommodate these differences, three different PGU heights will be used. Table 1 below gives the crop height available for each of the three PGU sizes and the number of each PGU size that can be stacked in a chamber. For each crop you select, you will need to chose the shortest PGU that will still allow enough room for the plants to grow.

One final piece of information: In order to make controlling the environmental conditions of each chamber manageable, only one type of crop can be planted in each chamber.

Problem to Be Investigated

In this exercise you will use the Plant Production Simulator to determine how much food (edible biomass) can be produced by one plant growth chamber on the lunar base for each of your crops. You will then use this information to determine how many chambers of each crop must be planted to supply your crew's diet.

Materials

Plant Production Simulator
Computer spreadsheet program

Procedure

Initial calculations

1. For each crop, record the following information from your first investigation into Table 2.

• Crop growth period (This period can be found in the database. It is the same period you used for the Length of Experiment in the first Plant Production Simulator activity)

• Photoperiod

2. Look up the height for each crop in the database, and record in Table 2.

3. Use the crop height and the information given in Table 1 to determine how many PGUs can be stacked in a chamber for each crop, and record in Table 2.

4. From the number of PGUs and the PGU area, calculate the total area of each crop that can be planted in a chamber.

Simulator runs

You can now use the simulator to determine the amount of edible biomass that one chamber can produce for your crew.

For each of the four crops, run the simulator using the following setings for the chamber labeled **Crop 1**.

• **Length of Experiment: Use each crops growth period**

• **CO_2 Level: 1200 ppm**

• **Growing area: Use the area for one full chamber of each crop**

• **First planting day: 1**

• **Harvest/plant every: Use each crops growth period**

• **Photoperiod: Photoperiods from first activity**

At the end of each run, click on Analyze. Record in Table 2 the Total Edible Biomass Produced for the run and the Average Edible Biomass Produced per day. You should only collect data for one crop at a time using the **Crop 1** chamber of the Plant Production Simulator.

Results

Knowing the kilograms of biomass produced by your crops is important, but what you really need to know is how many servings of food your crops will provide. Because most nutritional information is given in terms of 100-g servings, you will probably have developed your crew's diet using 100-g servings. Calculate the average number of 100-g servings produced per day by one

chamber of each of your crops, and record this value in Table 2.
*Remember, this is the total number of servings produced on average each day. The amount available to each crew
member will depend on the number of crew members.

Discussion of Results

The necessity of using the chambers for growing your crops limits your selection of a diet for your crew. The final diet for your crew must be a multiple of the amount of food produced by one chamber. For instance, what if you decided that each crew member will consume three 100-g servings of soybeans per day? If one chamber of soybeans produces four 100-g servings per day, this means that for a crew of six, one chamber supplies 0.67 100-g servings (4 divided by 6) per day for each crew member.

Journal Entry

Make an entry in your research journal. Comment on what additional experiments, with or without the simulator, might be useful for helping to complete your mission.

Additional Investigations and Activities

1. In BaBS you cannot select a CO_2 level because the amount of CO_2 in the atmosphere changes depending on how well you have balanced your system. Plants need CO_2 for photosynthesis, and varying levels of CO_2 may have an effect on your crops' food production.
Use your Plant Production Simulator to determine the effect of CO_2 on your food production. Select one of the crops, and perform several runs using different CO_2 levels. Make sure you use the highest and lowest levels available, along with several other levels. Record the average daily edible biomass production from the crop at each CO_2 level. (You can use the data for 1200 ppm CO_2 from the first part of this activity.)
Make a graph of biomass production vs. CO_2 level, and discuss any trends.
2. Can your crops' growth also be affected by light? Use the Plant Production Simulator to test the effect of photoperiod on plant growth. Perform approximately 5 runs, varying the photoperiod from 5 hrs to 24 hrs. Do this with one of the crops that has a 24-hour maximum photoperiod and with one that has a 14-hour maximum photoperiod. Graph and compare your results.
3. Once you begin to work with the complete lunar base simulator (BaBS), you may find it useful to return to the Plant Production Simulator to develop possible crop planting schedules. For example, run the Plant Production Simulator with all four crops, using the planting areas you have chosen for BaBS.

Suggested Reading

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Running Head: COMPUTERS TO SUPPLEMENT SCIENCE INSTRUCTION

Computers to Supplement Instruction in Science: A Review of the Research

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Computers to Supplement Instruction in Science Experiments

For more than two decades, science educators have hoped that computers would help provide more efficient, effective instruction (Weller, 1996). Educational use of computers is not only driven by the desire of educators to improve instruction, but it is also driven by makers of public policy, such as The President's Committee of Advisors on Science and Technology (PCAST, 1997). The PCAST developed an agenda for the use of technology in primary, middle, and secondary education (Hickey et al., 1999). The purpose of this review is to examine the organizational culture, software packages, and existing studies for computer use in science instruction. A fairly large body of knowledge exists in this area, providing promising positive evidence for the increased use of computers to supplement instruction. Much of the existing research qualifies as action research because the teachers or professors conducted the research with their own students and used the results to improve instruction in their classrooms and institutions.

State of Technology in Science Education

Opinions and Policy

According to Bigum, (1998) educators have four general views of computer use in instruction. Some have a utopian view, in which computers remedy all the problems in education, while others view computers in a dystopian manner, thinking computers would replace teachers in instruction. Some educators have critical views, considering computers a waste of time and money, but others view computers in a humanistic sense, seeing technology as a method of support for human activities, like instruction and learning. The PCAST, the President's Committee of Advisors on Science and Technology, made the recommendation that future educational research regarding science and technology be based on the assumption that computers should be used in education and that studies should focus on determining the best uses of technology in the regular classroom. The report calls for research in typical classrooms with ordinary teachers and without unusual financial, technical, or research support. The report also allays the fears expressed in the dystopian view that computers would replace teachers in instruction, noting the importance of supplementing traditional instruction with existing and emerging technologies (PCAST, 1997; Hickey et al., 1999).

Challenges

One of the major challenges to integrating technology in education is convincing the teachers to adopt the innovations and use them in their classrooms. Teachers often have more fear of and far less experience with technology than students. Many teachers were trained before the use of computers in education, so a “teachers first” principle should be adopted to focus on increasing their level of comfort and competence (Bigum, 1998). Teachers need training in how to use technology, integrate it into their instruction, and select software that supports specific instructional objectives (Hughes, 1998). Colleges and universities are increasing instructional technology requirements for new teachers, but in-service teachers need training as well. Studies of 205 teacher-preparation institutions were conducted in 1984 and again in 1992. As expected, the requirements for technology skills preparation increased from the time of the first study to the time of the second. In 1984, only 25% of those institutions required future science teachers to take a computer course. In 1992, 77% of the colleges required science education graduates to take a course or demonstrate competency in computer use, with nearly a quarter requiring a course solely for secondary science educators. Almost half of those required courses were taught by science teacher educators, not computer teachers (Lehman, 1995).

For technology to be fully integrated into education, students also need training. (Bigum, 1998). They also need training in how to learn from technology and relate the computer applications to their learning (Hughes, 1998). A twelve-year, three-way comparison of traditional instruction alone, traditional instruction supplemented by computer-assisted instruction, and computer instruction alone, provides strong evidence supporting the effective use of computers in science education. Students taught with a combination of traditional and computer-assisted instruction performed as well as or better than those taught with only one of the methods. The percentage of combination method students that performed better than those taught with other methods declined slightly from the original 57% over the twelve-year study, but remains significant enough to support the use of computers to supplement instruction. The initial, more positive results for the combination method are attributed to a Hawthorne effect – increased motivation due to the newness and novelty of the computer assisted instruction. (Christmann & Badgett, 1997).

Software and Methods

Computer use in education initially started with drill and answer software, with the computer simply functioning as a set of electronic flash cards. Since then, much progress has been made in the development of educational software that does not automate instruction but helps develop deeper levels of knowledge and higher levels of critical thinking. Hyper-models and simulations are two types of software that have potential in the science laboratory. Hyper-models, such as GenScope for genetics study, allow students to manipulate variables, which supports student development of a higher level of reasoning (Horwitz & Christie, 1999). Simulations are interactive computer representations of real experiments that can be used when time, hazard, cost, cruelty, or workability of real experiments, such as dissection, is prohibitive (Soyibo & Hudson, 2000).

Chemical Science

Post-secondary school.

Computer assisted learning has been used with success in secondary and post-secondary chemical science. Faculty at the University of Wittwatersand in Johannesburg have used computers in instruction for over 20 years and view technology as one of the four most important areas for students to master. Use of computers has progressed from simple data analysis to complex simulations. The three most successful software packages that the students of the program used were a chemical reaction “card game” for supplement or review, a graphical analysis program for spreadsheets and graphs, and computer generated, three-dimensional, teaching aids (Glasser, 1996).

Secondary school.

Three-dimensional teaching aids have also been very helpful in secondary chemical science education. It is difficult for students to envision molecular structure and expensive to purchase models of molecules to represent their structure. An interactive digital videodisc was developed to remedy those problems. Students using the software as a learning tool in an experimental study performed 21% better than the control group for which the instruction was not supplemented. Those using the software supplement also performed better at higher levels of knowledge. Not only were their overall scores better, but they were more likely to respond correctly to items that were more difficult or required more critical thought. Despite these successes, student surveys of the software indicated that they still wanted and needed teacher explanations and support (Vrtacnik, 2000).

Physical Science

Computers have been used in physical science education to help students solve physics problems and grasp concepts of physics. Hayward (1996) developed software that provides a format for solving physics problems. Students choose their topic and identify the knowns and unknowns. If they provide sufficient data, the computer will solve the problem, if not, the program prompts them to supply more data. The biggest advantages of this software are that it offers variety and is non-judgmental of the student. When an instructor might get frustrated with the student's inability to understand a problem, the computer continues to prompt the student to supply the information needed to solve the problem.

Another study involving 353 science students was conducted to measure the effectiveness of computers for teaching physical science concepts by comparing deductive and inductive learning strategies. Deductive methods used instructional systems design principles while inductive strategies used constructivist principles. The deductive group completed a computer based physical science tutorial and a computer-simulated lab before taking the post-test. The inductive group completed the computer-simulated lab and the post-test. A control group completed only the post-test and performed as well as the inductive group. The deductive group had the highest post-test scores, supporting computer use in science education as a supplement to instructional systems design strategies (Rieber, 1995).

Earth Science

Computers can also be used in earth science. Meteorologists, astronomers, hydrologists, and other earth scientists in weather stations, space stations, and laboratories gather mass quantities of data every day. Teachers can access much of this information to use in the classroom, but the volume of data makes it difficult to filter and apply. Two models have been developed to help teachers use this real scientific data in the classroom. The learning cycle model focuses on student knowledge acquisition through the social experience of gathering and studying data. The experimentation model attempts to model the tasks and experiments of real scientists and focuses on student knowledge acquisition through real experimentation (Slater & Fixen, 1998). Similar models exist for post-secondary use in geology and geomorphology. Interactive software programs are available that help students learn concepts, and Global Information System (GIS) technology can be used to conduct real-world studies (Wentz et al., 1999).

Biological Science

Post-secondary school.

As described, a large body of technology-based resources is available for the physical sciences. However, resources are even greater in the biological sciences. Very specific and advanced tools have been developed for post-secondary use. BIOTOL software was developed to assist the decision-making process in biotechnology. It is a simulation based in a real-world industrial environment and is not meant to substitute for lab time, but makes the available lab time more efficient. Biotechnology requires small, specialized labs that are not often available at universities because of the high cost. Biotechnology experiments are often highly specialized and require different equipment, so they are difficult to conduct in labs where other students and courses are taught. The BIOTOL simulator requires students to record and track data as they would in real experiments. Outcomes of using the software include students' more efficient assembly of real lab equipment and better comprehension of complex problems due to the use of animations and simulations (Jenkins, 1997). Increased achievement due to computer-assisted instruction in biotechnology content as a whole needs more study (Klemm, 1998).

The Welsh School of Pharmacy used computer simulations to replace required animal-based laboratory experiments. Authorware, an icon-based programming tool, was used to develop simulations for frog heart dissection and sciatic nerve/calf muscle preparation labs. Ninety-two of 93 pharmacology students completed the simulations without assistance, and 89 of 93 completed them in the allotted time. Non-finishers returned to finish later – a practice not possible with real specimens. Students also returned voluntarily to study and review the process. Participants were more enthusiastic about the experiments than before, and extended study showed no Hawthorne effect for the simulations. Students with biology backgrounds liked the experiments with real specimens more than students with math backgrounds did, but both groups liked the simulated experiments. Those with biology backgrounds normally perform much better than those with math backgrounds on the experiments with real specimens, but both groups performed equally well using the simulations (Sewell et al., 1995).

Secondary school.

Numerous computer applications are suitable for high-school biology as well. GenScope is hyper-modeling software that was developed for studying genetics. In a test conducted in 40 high school classrooms over four years, GenScope supplementation produced better gains for general and applied students than traditional instruction alone. College preparatory students performed equally well with either method of instruction. The main advantage of the software is that it links the entire range of biological organization. Any genetic change made in the cell, organism, species, or evolution is reflected in every other level. Fanciful dragons and real organisms like dogs and cats are used to help students understand genetics. The software permits students to analyze their own thoughts and evaluate the consequences of their actions in the genetics of the simulated animals. The computer also provides numerous opportunities for students to practice without penalty. These benefits allow the student to build confidence and work through their preconceptions to develop knowledge regarding genetics (Hickey et al., 1999).

BioLogica software is an improved model of GenScope. It includes scripting that supports the learning process by responding to student actions in the simulation. GenScope and BioLogica include a performance assessment called WORM that provides an easy application for complex genetics problems. Both tools could be used in high school and entry-level post-secondary genetics courses (Hickey et al., 1999).

Simulations were used in high school microbiology courses in Israel to supplement instruction in cell growth and division. Two different laboratory approaches were incorporated with instruction - traditional labs and simulated labs. Girls who used the simulation performed much better than girls in the traditional labs. Girls using the simulation performed more in line with performance of the boys that completed both types of labs. At the high school level, labs generally manipulate only one variable at a time. The simulation allows manipulation of more than one variable at a time, so more material can be covered in less time. Students are actively involved in the simulation and work at their own pace. This software modeled yeast cells, like those used in the traditional lab, only the simulation students did not have to wait for the cells to grow and divide as students conducting the traditional lab did. Low to average students showed significant improvement over traditional labs, but honors and college preparatory students performed the same under both laboratory methods (Huppert, 1998).

Students are more vocal about animal rights issues related to use in science, and specimens are very expensive, so the use of dissection simulations could solve a number of problems for schools. Simulations like the interactive laser video to teach the functional anatomy of the rat could supplement or replace dissection labs in secondary biology. This software provides a practical dissection that is highly interactive. It covers five areas of rat dissection and can interchange the gender of the specimen, so students can study all organs. The teacher can edit, extend, or customize the simulated activity as necessary, but the learner controls the display of information. The simulation allows repetition of the lab and review and can be used with large numbers of students at a fixed cost year after year. It is also much cleaner and safer than traditional labs (Quentin-Baxter & Dewhurst, 1995).

Conclusions

Although computers have been around for quite a while, their full potential in education has not been realized. More comprehensive formative and summative evaluations of computer use in science courses are necessary. According to the PCAST (1997), existing problems with computer use and application should be solved before new problems are identified and addressed. Designers, content experts, and technicians need to collaborate to develop materials that maximize the strengths of the technologies while modeling recognized effective teaching practices (McNaught, 1999). Technologies should be judged on their ability to really improve working and learning conditions (Schack, 2000).

Accessibility is another of the major issues to be addressed. To maximize effectiveness, the technology needs to be in the regular classroom – not in multiple-use computer labs. One solution to accessibility is the purchase of portable, wireless labs that can be moved from room to room. If technology is not accessible enough to be effective, its purchase is a waste of money.

Promising software packages exist to help teachers at all levels and in all areas of science supplement their instruction. Computer-assisted learning should not be used to replace traditional instruction but should be used to supplement that instruction where real experiments are too difficult, expensive, dangerous, or inhumane. Simulations and modeling software programs have great potential to expose students to experiments they might never be able to conduct in reality. The improvements in performance of general and applied level students using many of the tools reviewed is strong evidence for incorporating these tools in instruction. Although higher level students did not always show significant improvement in test scores, they did show improvement in higher-order thinking skills and depth of knowledge. Future studies could be devoted to the evaluation of more difficult and inductive tools for higher aptitude students along with the improvement in science achievement for all students.

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Learning Community Report

One of the goals of action research is to reduce the gap between research and practice, so action researchers are encouraged to share their results with members of their learning community. This report describes the ways I shared the results of my action research study of Computers in Science with members of my organization and learning community. In the study, I compared traditional instruction to computer-supplemented instruction in relation to student achievement and student and teacher attitudes toward instructional methods.

My celebration consisted of three parts:

- Presentation to the science and vocational faculty of my school.
- Distribution of brochures to the faculty and administrators of my school.
- Dissemination of information via the Internet.

Members of the science and vocational departments were invited to attend a presentation that included a demonstration of the BioBLAST software, description of the study, and discussion of findings. BioBLAST, Better Learning through Adventure, Simulation and Telecommunications, software was developed by NASA's Classroom of the Future to help students understand the requirements of human life. The software simulates a self-contained lunar base where students must maintain a homeostatic environment for a team of six scientists using three different simulators. Faculty of the science and vocational departments were able to view and use the various functions in the software to help them understand the experiments that students conducted in the simulations. The intent of the demonstration was to show the teachers the potential of computer simulation software to enhance instruction by allowing us to conduct experiments that are too costly, extensive, lengthy, or hazardous to conduct in reality.

I described the study we conducted to compare BioBLAST experimentation to traditional experimentation in plant production including the activities we conducted, worksheets the students completed, and instruments we used to answer the research questions. We discussed the findings of the study including responses to surveys, scores on the post-tests, and the limitations of those findings. Participants were able to see the forms, lab packets, worksheets, surveys, and evaluation instruments used in the study. Participants in the celebration asked questions and made comments related to the software and to the limitations of the study created by the whole group design, possible bias in the post-test, and availability of hardware and software for other interventions.

I developed a brochure to distribute to the faculty and administration of my school that briefly describes my study, its findings, and the possible implications of computer-supplementation to instruction in science and vocation labs. A copy of that brochure is included in Appendix A of this report. Faculty and administration are invited to make comments regarding the study or review the thesis or software.

NASA's classroom of the future has a web site containing access to information of software packages available to supplement instruction. Part of the BioBLAST site is a discussion board containing postings regarding the use of the software in instruction. Although we did not use BioBLAST as a fully integrated part of instruction, I made postings to the discussion board to notify current or potential users of BioBLAST of my study, its findings, and the location of my thesis and online journal article.

Appendix A, pages three and four, is the brochure that was provided to faculty and administrators of Camden County High School.

BioBLAST: A computer-Supplemented Laboratory Experience

As partial fulfillment of my Specialist's Degree in Instructional Technology, I conducted a study to analyze the effects of computer supplemented laboratory experiments on student achievement and student and teacher attitudes of laboratory methods in plant science. Jeremy Spencer generously allowed his students to complete the computer-supplemented laboratory experiments in addition to their regular instruction and experiments in plant science.

NASA's Classroom of the Future developed BioBLAST (Better Learning through Adventure, Simulation, and Telecommunications) software. http://www.cotf.edu/ It simulates a self-contained lunar base where a crew of six scientists will live. The software contains three simulators for maintaining a homeostatic environment on the base. We used the Plant Production Simulator to grow enough lettuce, wheat, potatoes, and soybeans to produce enough oxygen and food and purify enough water to support the crew.

I had hoped to include all Applied Biology and Chemistry I classes as well as my two Horticulture classes and alternate the laboratory method by teacher and class. Due to the short time available, we were only able to use the computer-supplemented labs with three ABCI classes. My Horticulture classes conducted traditional plant science experiments for the study. Both groups took post tests to measure their achievement of plant science objectives from Applied Biology and Horticulture. The students also completed surveys regarding their opinions of the simulation software.

Although students did not write formal lab reports for the experiments, they shared data with classmates and discussed lab results with their classes. Some topics covered in the labs included photosynthesis, respiration, CO2 levels, photoperiod, and plant characteristics such as height, life span, cultural requirements, and life stages. Mr. Spencer and I were pleased with the students' conduct in the labs and were satisfied with their apparent comprehension of the material through their performance on lab worksheets, graph interpretation, and class disussions.

I developed the post-test from the Science study guide for the Georgia High School Graduation Test, the pilot-tested, end-of-course-test for Biology, and Horticulture objectives and materials. I wish that I had used a standardized plant science test from other Biology or Horticulture sources, because I think I included too many specific items regarding plant structure and function. Although laboratory time was the same for both groups in the study, the Horticulture students inevitably had more background in plant science theory and terminology creating a bias for them on the post-test.

The BioBLAST group was predominantly sophomores and juniors who are in a Technical/Career Program of Study. The Traditional group is a mixture of sophomores, juniors, and seniors with a few students in a College Preparatory program of study. This creates a bias for them because they might have more existing knowledge in plant science than the BioBLAST group. I analyzed the data without the scores of the seniors and college prep students in the traditional group. The difference between groups is less than one test item, and the higher standard deviation for the traditional group reduces the significance of that difference.

10th and 11th Tech/Career Post-Tests		
Lab Method	Mean Raw Score	Standard Deviation
BioBLAST	7.94	2.54
Traditional	8.59	3.09

Students in the study completed attitudinal surveys regarding BioBLAST. Darkest items were most significant, but all were positive.

BioBLAST Survey 3.0 = Neutral	**Mean**	**St. Dev.**
Preferred BioBLAST	3.29	1.08
Understood the software.	3.71	.94
Liked working pace.	4.17	.92
Needed teacher's help.	3.82	1.02
Computer was sufficient.	3.71	1.37
Experiments were helpful	3.75	.89
Software was motivating.	3.32	1.04
Learned plant processes.	3.44	1.15
Lab reporting was easier.	3.34	1.31
Would like to use again.	3.38	1.20

Teacher attitudes to the computer-simulated experiments were favorable as well. Student behavior, software operation, and comprehension improved throughout the study. I think the software would be most beneficial if it were used in conjunction with traditional instruction and laboratory experiments throughout a course. BioBLAST was designed for this and includes a great deal of information and supplemental activities to support the software.

State course objectives require that we incorporate technology into instruction, and the President's Committee of Advisors on Science and Technology recommends the same. I think that simulation software has a great potential benefit to science and technical instruction. With simulations, it is possible for us to conduct activities that are too costly, extensive, lengthy, or hazardous to conduct in reality. I would like to thank Jeremy Spencer for his assistance and you for you interest. My thesis and the software are available if you want further information. Journal article can be viewed at http://teach.valdosta.edu/.

Computers to Supplement Instruction in Science: An Action Research Study

Incorporating:

BioBLAST

A NASA Sponsered Project

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Valdosta State University
Department of Instructional Technology
Spring, 2002

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