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Aimée T. Lee
University of Southern Mississippi

Rosalina V. Hairston
University of Southern Mississippi, rosalina.hairston@usm.edu

Rachel Thames
University of Southern Mississippi, rtwalker@uiwtx.edu

Tonya Lawrence
University of Southern Mississippi

Sherry S. Herron
University of Southern Mississippi, sherry.herron@usm.edu

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Using a Computer Simulation to Teach Science Process Skills to College Biology and Elementary Education Majors

Aimée T. Lee, Rosalina V. Hairston, Rachel Thames, Tonya Lawrence, and Sherry S. Herron

Department of Biological Sciences
University of Southern Mississippi
Hattiesburg, MS 39406
Email: aimee.lee@usm.edu

***ABSTRACT**:* The *Lateblight* computer simulation (Arneson and Ticknor, 1990) has been implemented in the general biology laboratory and the science methods course for elementary teachers to reinforce the processes of science and to allow the students to engage, explore, explain, elaborate and evaluate the methods of building concepts in science. The students develop testable hypotheses and then use the program to run experiments and collect data. In addition, they research relevant background information and subsequently present their results in a poster during class.

KEYWORDS: Hypothesis testing, computer simulation, protist, constructivist teaching methods, cooperative learning

INTRODUCTION

Many students experience difficulty in science courses due to the lack of understanding of the methods of science (McPherson, 2001). Various approaches have been used to introduce students to the processes by which scientists find answers to questions about the natural world. Mulnix and Penhale (1997) successfully used the collaborative model to simulate the activities of scientists when conducting research projects, searching published literature, and communicating findings with peers.

The increasing availability of computer simulations that represent complex processes, and yet allow users to interact with the dynamics of a model system, creates a unique way of helping learners conceptualize (Windschitl, 1996). Windschitl and Andre (1998) contend that computer simulations used in a constructivist approach afford learners the opportunity to freely create, test, and evaluate their own hypotheses in a more richly contextualized environment. Furthermore, a well-designed simulation allows learners to choose their mode of informational representation on the computer screen and it allows them to develop hypotheses about phenomena that accommodate their way of solving problems (Windschitl & Andre, 1998).

Objectives of the Study

Constructivist teaching methods have been reported to be more effective in improving the learning of biology concepts, reasoning skills, and positive attitudes toward science at the college level than traditional expository modes of instruction (Windschitl & Andre, 1998; Faryniarz & Lockwood, 1992). A typical classroom using constructivist pedagogy displays students actively engaged in the learning experiences as they work individually and in cooperative groups. As mentioned earlier, computer simulations also allow students to construct testable hypotheses, thus actively applying the principles of constructivist instruction. The researchers applied Vygotsky's social constructivist view emphasizing the development of shared knowledge through social interaction and cooperative learning (Mintzes, Wandersee, & Novak, 1998). The instructional material used in this study to teach science process skills was a computer simulation, *Lateblight*, introduced by the BioQUEST Curriculum Consortium (Arneson and Ticknor, 1999). In this qualitative study, the researchers are concerned with the process by which students build abstractions, concepts, and meaning out of the experience with the computer simulation in a cooperative learning environment.

This study was conducted to answer the following questions:

- What are the students' attitudes toward learning science process skills using a computer simulation?

- Did the cooperative learning environment help students learn the science process skills while working together on the problems provided in the computer simulation?
- Were the students able to transfer their knowledge of science process skills to an open-ended, long-term investigation?

This study represents inductive qualitative research subsumed within a larger reform effort in the freshman biology program and science methods course for elementary education majors at a southeastern university. The results of this study will inform our assessment of the program, in addition to adding to the body of knowledge regarding the effectiveness of constructivist teaching methods and educational technology in enhancing student learning.

METHODS

The computer simulation was used in the second introductory biology laboratory course, *Principles of Biological Science II Laboratory* and in *Science Methods for Elementary Teachers*. The subjects were 187 freshman students majoring in biology and other science areas and 46 junior and senior students enrolled in the science methods course for elementary teachers. The objective of the biology course is to study biodiversity, comparative biology, and biology as a process of knowing in a constructivist learning environment. The science methods course emphasizes the content, attitudes, and science process skills in the context of constructivist instruction for the elementary teachers. The tasks for this activity included the following: (1) learning and using the *Lateblight* computer simulation, (2) conducting library and online searches, (3) formulating hypotheses, (4) testing the hypotheses, (5) making generalizations and conclusions, (6) preparing a poster presentation to be used in the discussion of the results of the experiment, and (7) critiquing and evaluating one another's poster presentations. The nature of the data collected in this research is not suited for quantitative measures; therefore, the approach to data collection, analysis, and interpretation follow procedures for qualitative research.

The computer simulation in this study depicts the story of the potato famine in Ireland in the 1800's. The organism responsible for the famine is a fungal-like protist, *Phytophthora infestans* (McGraw, 2000). The zoospores become airborne and attach to the potato foliage forming lesions, and then spread rapidly to the tubers. The severity of the pathogenic infestation, referred to as blight, depends upon 1) weather conditions, 2) fungicide application, and 3) placement of discarded rotten potatoes. The pathogen grows best in cool (<24ºC), moist conditions (Fry & Goodwin, 1997). When fungicide is applied to potato plants, the percentage of blighted tubers decreases (Stanley, 1997). Because zoospores rapidly disperse in moisture, spores from infected tubers that have been discarded too close to the field may easily infect new potato foliage, thus spreading the pathogen.

Library and On-line Search

Students worked in groups with the *Lateblight* computer simulation and conducted library and online searches to obtain information pertaining to late blight or *P. infestans*. The biology majors used the electronic search of the university holdings on scientific journals and the Internet during the scheduled three-hour laboratory period. Students worked in groups of four with two laptop computers. The teaching assistants serving as instructors for the course guided the students in conducting electronic searches, answered questions about searches, helped students access sites, and viewed students' search results. However, the students in the science methods course had only 70 minutes per class period two times per week. Therefore, they started the on-line search in class and continued during their own time at a computer laboratory on campus or on their own home computer. The library search was performed as an assignment. Like the biology majors, they were required to submit at least three related articles from scientific journals.

Formulating hypotheses

Utilizing the information obtained from their literature searches and the problem scenario presented in the computer simulation, students worked in groups of four to form a testable hypothesis that would enable them to obtain a high net profit. They also explained the purpose for doing the experiment. The instructor provided students with a preliminary worksheet to guide them in identifying the variables to be manipulated (weather, fungicide spray, harvest season and resistance level of potatoes). The program generated graphs and reports of completed seasons. Students interpreted the graphs to draw conclusions and related them to the hypotheses they had formed. Students then followed guidelines provided by the instructors to write a paper and create a poster presentation for the class that was evaluated by the instructor using a scoring rubric (see Appendix 1).

Poster Presentation

Students worked on their poster presentations over the span of two weeks. Each presentation contained the following sections: Introduction, Materials and Methods, Results, Discussion, and Literature Cited. During the presentations, each group of students stood by their poster while a designated reporter explained the experiment. A 15-minute time limit was enforced. The teaching assistant and their classmates asked questions about the results of the experiment and evaluated the poster presentation using a rubric. Upon completion of the presentations, students responded to a questionnaire designed to reveal their attitudes toward the use of computer simulations, poster presentations, cooperative learning, and the potential to apply what they learned about science process skills to another problem. To answer the last question posed in this study, the investigators also assessed student performance in a subsequent open-ended, long-term investigation.

Data Analysis and Findings

This study collected data on the students' perceptions about their experiences using the computer simulation, *Lateblight*, as a tool in learning the processes of science. Data sources consisted of an evaluation of the students' laboratory reports, instructor evaluations of poster presentations, group grades in the laboratory exercise, and students' responses to a questionnaire regarding attitude toward the use of a computer simulation. The investigators triangulated data from these sources (Creswell, 1994). Triangulation is a method of combining methodologies when studying same phenomena or programs (Creswell, 1994 & Patton, 1990) providing validity to students' responses. The instructors and the researchers discussed and evaluated student progress in this laboratory activity during weekly meetings. Table 1 shows the frequency of the variables selected by both groups of students.

Table 1. *A list and tally of variables in Lateblight computer simulation selected by students.**

Variables	Biology majors	Elementary education majors
Weather:		
Cool wet	63	7
Hot dry	44	20
Moderate dry	28	15
Moderate wet	26	8
Fungicide spray:		
Once a season	58	20
More than once a season	58	34
Harvest season:		
Beginning	5	12
Middle	35	15
Late	5	19
Resistance level of potatoes:		
Low	18	12
Medium	30	8
High	47	26

** The numbers did not add up to 187 or 46 for biology and elementary students respectively because in order to run the program, students had to choose a weather condition. However, some groups actually chose weather as the variable to manipulate; therefore, the number of students changing the weather condition was inflated. Other groups did not manipulate weather, but still recorded a weather condition, since that is required to get results. At the same time, a few groups manipulated other variables (i.e., fungicide spray, harvest season, etc.); therefore, the total number of variables manipulated did not equal 187 or 46 respectively for the two populations.*

Library and Web-based Searches

The biology majors performed both library and web-based searches during the three-hour laboratory period. Students liked this convenience because they were able to access the university holdings on-line, and download articles from scientific journals without physically going to the library. Fifty-two percent of the elementary education majors used the on-line library search at a site other than the library. Thirty percent used the on-line search in the library. Ten percent did both. And the remaining eight percent did not use the online search but instead used the traditional literature search at the library. When asked about the amount of materials they found related to the topic, 46% of the biology majors reported that there was more than an adequate amount of information available in journals on-line and on the web, 19% judged the amount of information available as moderate, and 4% reported that there were few materials available for the topic. However, 85% of the elementary education majors reported that more than an adequate amount of information was available to them.

Computer Simulation and Learning Science Process Skills

Student attitudes regarding the use of a computer simulation as a learning tool was generally positive. Attitude was ranked on a scale of 1 to 5, with 1 as low (less positive) and 5 as high (most positive). Using rankings 4 and 5 as an indication, 40% of the biology majors (BSC) and 85 percent of the elementary education majors (SCE) indicated that the simulation helped them understand science process skills (Fig. 1).

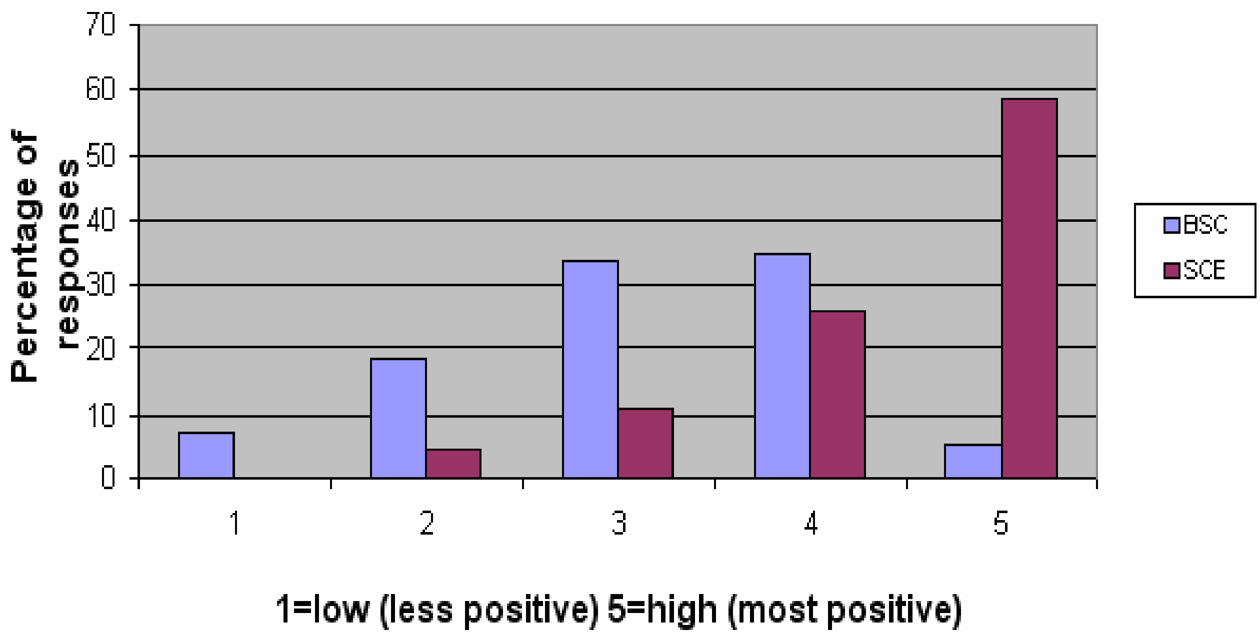

Figure 1. *Computer Simulation and Learning the Science Process Skills. Distribution of the attitude scale for both populations using the percentage of students responding on the 5-point scale attitude questionnaire administered at the end of the activity. BSC = biology majors; SCE = elementary education majors.*

Students expressed the advantages of computer simulation in the following ways:

"You get results faster."

"It allowed us to run many different variables in a short time."

"It is a form of hands-on learning on variable manipulation."

"The use of this technology is great for learning methods of studying problems in science."

Computer Simulation and Cooperative Learning

Table 2 presents the attitudes of both populations toward the cooperative learning approach used in the computer simulation. Regarding cooperative learning, 69% of the biology majors and 96% of the elementary education majors said "they enjoyed working as a team because they were able to work with more ideas contributed by members", "there was better thinking on the problem", and finally, "it built teamwork". Those who did not enjoy working in cooperative learning groups (26% of the biology majors and 6% of the elementary education majors), gave these reasons: "prefer to work alone", and "the time schedule did not allow working together, thus, one person got stuck with the work". When asked to rate the quality of their cooperative work, 72% of the biology majors and 93% of the elementary education majors expressed satisfaction. Benefits cited by students included: "more ideas are shared", "get a lot more done", "like to get others' feedback", "understood better with help from group members", "having different perspectives", and "it is a real life situation…working as a team".

Students generally gave positive responses regarding their satisfaction on the quality of the cooperative work and their poster presentations. Table 3 displays the responses of both populations when asked about the quality of their work in a cooperative learning environment.

Table 2. *Attitudes of biology majors and elementary education majors toward cooperative learning*

Attitude	Biology majors N=187	Percent response	Elementary education majors N=46	Percent response
Like	139	74.33	43	93.47
Dislike	48	25.66	3	6.52

Table 3. *Students' perception on the quality of their work in a cooperative learning environment*

Scale of 1-5 1=low, 5=high	Biology majors N=187	Percent response	Elementary education majors N=46	Percent response
1	2	1.06	0	0
2	21	11.23	1	2.17
3	35	18.72	1	2.17
4	55	29.41	8	17.39
5	74	39.57	36	78.26

Students' Attitude Toward Poster Presentation

When asked about their attitudes toward poster presentations, there was a large variation between the responses of the two populations. Fifty-six percent of the biology majors and 93% of the elementary education majors liked the presentations. Their responses included:

"Poster presentations communicate results better."

"Visuals make me learn faster."

"Poster presentations are informative because I get to know the results from other groups' experiments."

Forty-four percent of biology majors who did not like the presentations gave various reasons, such as the following:

"It is nerve wrecking."

"It is hard to schedule to work together as a group."

"I don't like public speaking."

When asked what lessons they learned when preparing their presentations, it was revealed that many students did not know how to present a scientific report despite the guidelines provided by instructors. Based on the evaluation of the poster presentation by the instructors, 87% received satisfactory performance. The high percentage may be deceiving because the assessment was made for groups rather than for individuals. This percentage does not reflect the number of students who did not comprehend the elements of a good presentation. During the evaluation when instructors gave comments about unsatisfactory presentations, some students exclaimed that, "I did not know that is what you wanted". This response accounts for the under-reporting of procedures and results of the experiment due to perceptual filters operating on students' consciousness. Students tend to use what they perceive is expected by the instructor rather than the elements of a good scientific report. Campbell et al. (2000) reported a similar problem with the communication of laboratory investigations by university students in South Africa.

Transfer of Knowledge of Science Process Skills

When questioned about subsequent investigations in which the students have to use their knowledge of science process skills, 69% of the biology majors felt they would be able to apply what they learned to another problem. These students indicated that the knowledge they gained would enable them to test different variables in an experiment and to better understand and enjoy working on an experiment. Other reasons cited were: "now I know where to begin when conducting a science investigation", and "the lab activity in the computer simulation made me focus my thinking on the problem." Using the data source from the instructors' evaluation of the individual students' report on the subsequent investigation, *Plant Growth and Development*, 75% were able to write a satisfactory report. The reports included an introduction, a statement of the problem and hypothesis, description of materials and methods, data presented in tables and graphs, accurate interpretation of the results, and citation of literature. This evaluation provides a more accurate indicator of students' ability to transfer the knowledge and skill about the processes of science learned with the computer simulation. Ninety-eight percent of the elementary education majors felt that they would be able to teach the processes of science to their students after learning from this simulation.

CONCLUSIONS AND IMPLICATIONS

Several national reports on undergraduate science education have been published since 1995, which express a strong concern and determination to improve this level of education in American universities (NSF, 1996; NRC, 1999). A common theme of these reports suggests that the instruction should go beyond improving the knowledge base to developing critical thinking, problem-solving, and decision-making skills of students. The Boyer Commission report (1998) suggests, "that the first year of a university experience needs to provide new stimulation for intellectual growth and a firm grounding on inquiry-based learning and communication of information and ideas." In this study, the use of an investigative laboratory activity delivered via computer simulation and conducted in a cooperative learning approach was used as a test case. Although it is a limited study, findings about students' attitudes toward learning science process skills using a computer simulation in a cooperative learning environment and the transfer of learning to another investigation, contribute to the knowledge base about improving undergraduate biology education.

A computer simulation is a powerful tool to enhance learning by providing opportunities for learners to develop skills in problem identification, seeking, organizing, analyzing, evaluating, and communicating information (Akpan, 2001). The choices of different variables in the problem scenario of the *Lateblight* computer simulation allowed learners to practice as cooperative learning groups with a variety of situations that resemble "real-life" problems.

Students realized the benefits of cooperative learning in promoting positive interdependence, group accountability, and social interaction. However, group work has its drawbacks. Students who did not favor group work complained of the difficulty in scheduling meeting times. In general, students became aware of the nature of the work of scientists that they emulate in solving problems in the computer simulation.

The literature search and the poster presentation in this study are testimonies to the students' diligence and understanding of the problem presented in the computer simulation. Although students were generally positive about the poster presentation, a small number suggested that they would prefer to use presentation software such as Corel Presentation or Microsoft PowerPoint. In line with the premise of multiple intelligences (Gardner, 1983), posters prepared by cooperative groups should promote the expression of students' various forms of intelligence. Those students with communication intelligence can appropriately deliver the groups' oral report, the artistic students can share their keen perception of visual spatial dimensions in the lay-out of the poster, and the student with well-developed logico-mathematical intelligence can provide the analysis and interpretation of the results. In short, the poster presentation provided many opportunities for students to express their intelligences.

Although this study is limited in scope, there are important pedagogical implications of computer simulations used in a social constructivist-learning environment. The two populations, the biology students and the elementary majors, both testified that this experience was beneficial to learning science process skills. The elementary students learned the skills so well that they felt empowered to effectively teach what they learned. On the other hand, the biology students proved that they transferred the knowledge in a similar investigation. The investigators discovered that in future use of this simulation, there is a need to require students to identify the manipulated variables versus the ones held constant. Because the computer simulation provides quick results of the experiment, students overlook the importance of designating the variables in an experiment. Despite the efficiency of computer simulations, the instructors must provide guidance in using and learning science process skills. As computer simulations mimic the problem in real-life, this instructional tool is also powerful in developing problem-solving and decision-making skills in biology issues. It is hoped that these skills will be applied when bioethical issues impact real-life context.

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Appendix 1

GRADING SCALE FOR LATE BLIGHT COMPUTER SIMULATION PROJECT

Late Blight Presentation	**Possible Points**	**Points Accrued**	**Comments**
Procedure			
Title	1		
Correct Format	2		
Each section included	2		
Introduction			
Background Information	3		
Hypothesis	3		
Materials & Methods			
Explain variables manipulated	3		
Procedure outlined	3		
Results			
Graphs and tables	3		
References to graphs	2		
Explanation of graphs	3		
Discussion			
Results Interpreted	4		
Conclusion made	3		
Literature Cited			
3 references	2		
Proper citation	2		
Sources cited in paper	2		
Proper internal citation	2		

Your score:			
Total possible points	40		

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