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ABSTRACT

Twenty-one schools from the United States and Singapore participated in this evaluation of a high-school biology multimedia CD-ROM called BioBLAST[R]. Results include a summary of teacher descriptions of their curriculum-based justifications for using this software as well as a compilation of program features that teachers describe as facilitating successful implementation of new learning technologies. Analysis of teacher reports provides a profile of three types of strategies teachers used to implement the program. Analysis of student performance on pre/posttest shows how implementation strategies were associated with student gains in particular schools and classes. A comparison of student pre/posttest scores one year later with previous pre/posttest results suggests that changes in implementation strategies, teacher incentives, or a decrease in support services had a direct impact on student performance. Students with a wide range of prior knowledge were able to use the software and show performance gains appropriate to their knowledge level and experience. (Contains 10 references.) (Author/AEF)

Evaluation of Program Impact Based on Teacher Implementation and Student Performance

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Abstract

Twenty-one schools from the United States and Singapore participated in this evaluation of a high-school biology CD-ROM called *BioBLAST®*. Results include a summary of teacher descriptions of their curriculum-based justifications for using this software as well as a compilation of program features that teachers describe as facilitating successful implementation of new learning technologies. Analysis of teacher reports provides a profile of three types of strategies teachers used to implement the program. Analysis of student performance on pre/posttests shows how implementation strategies were associated with student gains in particular schools and classes. A comparison of student pre/posttest scores one year later with previous pre/posttest results suggests that changes in implementation strategies, teacher incentives, or a decrease in support services had a direct impact on student performance. Students with a wide range of prior knowledge were able to use the software and show performance gains appropriate to their knowledge level and experience.

Introduction

This report examines technology implementation decisions made by teachers in the context of a particular multimedia high school biology software program called BioBLAST®, a computer-based, multimedia, learning environment for high school biology classes. This study examines the relationship between teacher implementation strategy and student performance. The software program described in this investigation was designed to help teachers address both NSES goals. Based on these goals, a scenario was created for a problem-based learning environment that put students in the role of NASA Advanced Life Support researchers. Student teams are challenged to use the software tools and resources to accomplish their goal: Design and test a plant-based life support system that can support a crew of six for at least three years without re-supply.

Reports from national commissions, disciplinary groups, researchers, employers, faculty, and students repeat the call for instructional innovations in science, mathematics, engineering, and technology (SMET) education[1]. Across all these reports Springer, Stanne, and Donovan (1999, p. 22) find a consistent recommendation for a shift in emphasis from teaching to learning and greater use of, "active, collaborative, small-group work inside and outside the classroom." The National Science Education Standards (NSES, 1996) recommends that teachers move away from methods of direct instruction to an inquiry-based approach to teaching. The report further recommends that teachers use alternative approaches to improving student learning that address both the method of instruction and the need to identify the content being addressed. Instruction should be student-centered rather than teacher-directed, and classroom curricula should be linked to real scientific issues and events (NSES, 1996).

An evaluation study by Cook, Habib, Phillips, Settersten, Shagle, and Degirmencioglu (1999) reports that gains in student achievement were associated with schools that have a focused academic articulation of goals for student achievement. This finding is consistent with research by Phillips (1997) and Lipsitz, Mizell, Jackson, and Austin (1997) who report that student performance improvements are most closely related to academic focus and less tied to social climate issues. Cook, et al., (1999) acknowledge that the results of their evaluation study are limited by the fact that program implementation fell short at nearly

[1] Association for the Advancement of Science, 1989, 1990; Boyer Commission, 1998; National Research Council, 1995, 1996; National Science Foundation, 1996; Peak, 1996.

all of the schools included in the study. They suggest that ways to improve and understand program implementation are greatly needed in order to understand student change.

This study examined teacher implementation strategies by adapting the issues addressed by Cook et al. (1999) and Kerr (1999) to the context of high school science teachers involved as lead teachers in the field testing of the BioBLAST software. The following research questions are examined in this study.

1. What were the academic and pedagogical goals that teachers described as their curriculum justification for using this software?
2. What strategies for implementing the software were reported by teachers?
3. How were implementation strategies expressed in student performance as evidenced in the pre/posttest scores? Are these student performance measures consistent with teacher reports?
4. What does the comparison of teacher implementation strategies and student performance during the different periods of the program cycle suggest regarding classroom application of this curriculum supplement?

Method

BioBLAST was developed by the NASA Classroom of the Future[2] in collaboration with the National Aeronautics and Space Administration (NASA) Advanced Life Support research program. The virtual reality interface of the CD-ROM draws students into a futuristic, problem-solving scenario that is situated in a simulated, lunar research facility. In the virtual lunar base environment, students use graphical simulation tools and resources to prepare for their mission goal: to design and test a model for a plant-based, life-support system that can sustain a crew of six for three years. Along with the goal of helping teachers move to an inquiry-based approach to teaching, a secondary goal of this program is for students to have access to current life science research in the process of investigating a legitimate problem.

The data collection techniques include teacher surveys, observations of teachers and students in their classroom environment, interviews with teachers, pre/posttests, and student and teacher reports. Twenty-one high schools from urban, suburban, and rural areas of the United States and Singapore participated in the classroom testing of this software. The school applications were self-selected in all but two cases. The specific schools included were selected from the group of applications based on geographic distribution, access to technology required to run software, and level of interest in learning alternative teaching techniques as expressed by teachers in their personal essays.

This study compares teacher implementation strategies with student performance during the final stage of the formative evaluation cycle (beta testing) with student performance during the pre-publication cycle when professional development support for teachers was no longer available. Participants differed in the location and level of technology available at their school and in the level of administrative support for implementation of curriculum-related instructional technology. This analysis of student outcomes based on comparison of pre/posttest scores involves a subset of the larger group who fully implemented the program and returned the completed pre/posttest materials. Table 1 provides a summary description of schools involved in the larger and subset groups.

Results

The following questions were examined in analysis of the data collected from teachers reports, surveys and interviews; student reports, pre/posttests, and surveys; and observation of on site and off site implementations of the program.

1. What were the academic and pedagogical goals that teachers described as their curriculum justification for using this software?

Many teachers described their use of BioBLAST software as offering an opportunity to change their methods of teaching to incorporate use of technology within the context of instruction and to include

[2] *BioBLAST* was produced and developed by NASA Classroom of the Future™ for the National Aeronautics and Space Administration through Cooperative Agreement No. NCC5-203. awarded to the NASA Classroom of the Future, Center for Educational Technologies, Wheeling Jesuit University, Wheeling, WV 26003.

more cooperative learning group activities. Moving to group work was cited by one third of the teachers as a greater challenge to their teaching practice than incorporating the new technology. Teachers also reported that Internet access and at least class email accounts accessible within the classroom were an important technology component of this program. These communication resources allowed students to ask questions to NASA experts and find current resources on the Web. Teachers commented that students were drawn into the QuickTime virtual reality interfaces since many video games that are popular among teenagers use this kind of interface. The "BaBS" culminating simulation was captivating to nearly all students and was the students most favorite aspect of the BioBLAST program. Students also responded favorably to the scenario link with current NASA research and laboratory exercises that had real connections with NASA experiments.

A summary of program features that teachers reported as most important to them in selecting new resources to adopt and implement is provided in Table 2. An important feature that emerges from this summary is that teachers want software/technology tools that will support their curriculum goals and help them grow. Teachers report changes in their teaching position, restructuring of existing course, the creation of new courses, and the implementation of alternative scheduling at their school based on experiences with the BioBLAST program as a "test-case" technology-integration program.

Table 1. Summary of Schools Involved in the Larger and Subset Evaluation Groups

School	Student Total	Asian	Black	Hispanic	Caucasian	Native American	Pacific Islander	School Affiliation	School location
6.12.4.6	280	11	160	36	71	2	0	public	urban
8.9.10.16	14	6	0	0	4	0	3	public	rural
8.9.5.7	35	29	0	1	1	0	3	public	urban
13.9.X	60	0	56	1	2	1	0	public	urban
13.14.6.8	101	8	1	1	90	0	0	public	urban
14.25.13.17	60	2	6	0	51	0	0	public	suburban
14.4.13.19	25	0	0	0	20	5	0	public	rural
14.10.3.4	130	7	1	4	118	0	0	private	suburban
14.13.X	25	0	0	0	0	25	0	public	rural
14.25.9.9	19	0	0	18	0	0	0	public	rural
14.25.7.11	147	16	7	7	110	0	6	private	urban
13.15.16.22	150	1	13	46	87	0	30	public	suburban
15.8.1.1	118	2	2	0	114	0	0	public	suburban
15.8.8.12	48	0	1	0	47	0	0	public	suburban
16.1.12.18	85	4	9	4	68	0	0	public	suburban
3.1.0.X	36	0	0	29	6	0	0	public	urban
22.1.2.3	119	6	36	24	54	0	0	public	suburban
21.22.11.17	36	0	0	0	35	0	0	public	rural
23.22.X	25	0	1	0	25	0	0	private	suburban
Raffles	42	22	0	0	0	0	20	private	urban
College Prep	20	1	0	0	16	1	2	private	suburban
TOTAL	1575	115	293	171	919	34	64	private - 5 public - 16	urban - 7 suburban - 9 rural - 5

Table 2. Program Features that Teachers Report Facilitates Successful Implementation:

Has administrative and department-level support;	Designed to help teachers grow
Links to real-world event(s);	Includes a description of prior knowledge required;
Includes a vision of how to makes learning more meaningful;	Includes a description of computer and laboratory access time required;
Includes guidelines for enhancing classroom learning that demonstrates effective use of technology through exposure to new methods, materials, and other	Includes a taxonomy of content and process skills addressed so that teachers can link program to school framework for basic math and science objectives;

teachers;	
Activities encourage student problem solving and facilitate cooperative group work	Addresses teacher needs for appropriate assessment material
	Applicable in small units or chunks and still effective

2. What strategies for implementing the program were reported by teachers?
Teachers used the laboratory and computer-based investigations provided by the software development team and incorporated these materials into their academic grading system. Teachers adapted the suggested sequence outlined by the project development team to suit the needs of their students, their school curriculum guidelines, and the time they had available in their course schedule. Teachers selected implementation strategies based on topics and scientific inquiry process skills that they believed their students most needed to address. The software development group suggested that teachers view their implementation of the software as having four phases much like the four phases of the problem based learning approach to teaching. The four phases of BioBLAST were presented to teachers as: Phase 1, Orientation to the problem; Phase 2, Research and analysis of the sub-units of the problem; Phase 3, the Mission in which the sub-units are integrated and combined for testing possible solutions to the problem; and Phase 4, the Report in which students present a summary of data collected, data analysis, results of initial testing, and recommendations for solutions and continued research.

Based on analysis of teacher reports, surveys, documentation of email communications, and observation of teachers in their classroom, we found that teachers implemented the software in three distinct ways. The "Lab" group focused most of their time on skill-building activities and one or more of the laboratory activities. This group allowed their students to interact with introductory materials and structured exercises embedded within the software simulation programs. Teachers using this implementation style reported that their students did not have science content and process skills required for the more advanced activities. The "Simulator" group completed the Orientation, Research, and Mission phases of the program. This group allocated at least three class periods (45 minutes each) for their students to complete the "BaBS" model building simulation in which previous plant, human, and resource recycling research is compiled and integrated and tested. The format and assessment of the Report phase were more open-ended than previous activities, and this may be why some teachers did not implement this phase. The group called the "Researcher" group completed all four phases of the project and had their students complete a project report as their culminating activity for the program.

3. How were implementation strategies expressed in student performance as evidenced in the pre/posttest scores? Are these student performance measures consistent with teacher reports?
Not all teachers submitted pre/posttest results. Teacher surveys and reports were required, but pre/posttests were not. A small percentage of the Lab group submitted their pre/posttest results, and teachers reported that they did not feel that they gave their students the full benefit of the program because they did not use the simulations. The entire Simulator group and all but one of the Researcher group submitted their
students' pre/posttests for evaluation.

The pre/posttest consisted of 16 questions, seven of which were multiple choice, the others requiring short answer and one concept-mapping responses. Analysis of pre/posttest scores on the seven multiple-choice questions indicates that student performance was significantly improved in all but two cases. The paired T-test analysis shows huge gains in nine of the eleven cases. Table 2 provides a summary of the main effect of the T-test score for each school. In one of the cases where student scores overall did not improve, the student pretest scores were already nearly perfect on the multiple choice test questions. In the other case, student scores improved, but this improvement was only significant on one question, and not all seven or on overall score. Teacher reports from the eleven participating schools expressed confidence that the program helped them successfully implement new teaching practices that incorporated student-centered and inquiry-based approaches to learning. Below are a few excerpts of teacher observations about student learning from the software program.

- "BioBLAST made student learning more meaningful; students are beginning to show more proficiency in their use of technology; the simulations encourage student thinking because they have to ask themselves why did they only survive that long, what happened?"

- "Later in the [biology] course, students would reference what they saw in BioBLAST as a reference for other bio curriculum activities; BioBLAST seemed to provide a good transfer, a good bridge, and a solid base for students to refer back to..."
- "Students were frustrated by the technology, but were also engaged by it...[through the use of this program] I accomplished the goal of incorporating more math, graphing, and research skill-building into student work; working in teams was most challenging, but in some cases most rewarding for students."

A doctoral research study (Cain, 2000) was conducted during the alpha testing of the software that analyzed student group discussions while using the Mission Phase simulation. One of the questions examined in this research study was "In what ways did the content knowledge change after the initial phase of the simulation-based learning activity?" Based on his analysis of the data, Cain reported improvements in student content knowledge in both early and later trials with the simulation. Six out of the sixteen content areas in which Cain noted deficiencies in early trials improved with continued use of the simulator. Improvements in content knowledge, similar to those noted by Cain (2000), was also evidenced in student pre/posttest scores in the following areas: [Question 2] how plants obtain nitrogen; [Question 5] understanding of the interdependence of plants and animals; [Question 8] graph interpretation of physical science concept; [Question 9] experimental design for plant science investigation; and [Question 12] in-depth understanding of human and plant respiration and photosynthesis.

Table 3. Summary of Effect Sizes for Paired T-test Scores*

Teacher Code	Effect Size for Paired T-test by Teacher - Beta Group	Effect Size for Paired T-test by Teacher - Pre-Release Group
8.9.10.16	**1.3**	
8.9.5.7	**0.91**	
13.14.6.8	0.31	
14.10.3.4	**0.4**	
14.25.9.9	**1.13**	
14.25.7.11	**0.72**	**0.43**
15.8.1.1	**0.91**	**0.64**
15.8.1.2	**1.24**	
15.8.8.12	**1.16**	
21.22.14.2	**1.06**	
19.1.0.X	0.08	
Average	**0.84**	

* Values of .4 and higher indicate a main effect. Bold numbers indicate significant effect size.

4. What does the comparison of teacher implementation strategies and student performance during the different periods of the program cycle suggest regarding classroom application of this curriculum supplement?

As Table 3 shows, teacher implementation during the Beta testing process was more successful than their implementation in the later year when there was minimal support and no in-service workshop provided. During the Beta testing, teachers received a small stipend to cover the cost of their reporting, administering, and handling of evaluation materials. Teachers also attended a 5-day off-site workshop the summer before the Beta testing in the classroom began. Weekly updates regarding the project were emailed to teachers during the beta testing, and teachers were encouraged to contact project team members if they had questions or needed assistance.

As reported in the research study by Cain (2000) and supported by analysis of teacher surveys and reports student learning improved and continued through continued use of the simulators. Later implementations of the program may not spend the same amount of time preparing the students for effective use of the simulators and may not allow time for continued trials, analysis, and comparisons of simulator trials. In addition to the professional development and incentive programs, giving students two to four separate sessions to use the simulators, analyze results, make modifications, and compare outcomes is a necessary interactive process for effective use of the simulations. More research is needed to identify what support or feature associated with the beta testing is most critical to facilitating the most successful, long-term implementation success. Since the number of pre- and posttests available for analysis were greatly reduced, it is difficult to conclude whether the trend found in the two cases documented was consistent across all implementations.

Discussion

What generalizations can be made regarding ways to improve program implementation? Can effective implementation strategies improve student achievement? Student performance improvements were statistically significant in all but two cases. The indication of reduced (although still demonstrating statistically significant improvement) student achievement in the pre-release (post-beta) test group reflects the time-sensitive nature of program implementation. The list of program features that teachers report facilitates successful software implementation (see Table 2) suggests that if any one of these eleven factors changes, the implementation strategy may be curtailed or disrupted. Teacher reports and survey data indicates that teachers want a clear set of recommendations for an activity sequence, time to allocate for each activity, and suggestions for effective use of the simulators with student groups to support their implementation strategies. This information was not available during formative evaluation, but can be made available on the Web site to new teachers using the program.

Several interesting observations from this research suggest ways in which software and other learning environment technology tools can motivate and engage students who have previously shown little or no interest in a given course. Analysis of student performance from the pre/posttest scores showed that software implementation that included use of the simulators exhibited gains for groups that were weak in fundamental content as well as for groups that were ready for more advanced concepts. By allowing multiple ways to implement the software, students with a wide range of prior knowledge were able to use the software and show performance gains appropriate to their knowledge level and experience.

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