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Virtual Worlds in Large Enrollment Science Classes Significantly Improve Authentic Learning

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INTRODUCTION

An emerging pedagogy, authentic instruction (Brown et al., 1989), defines an approach that treats content as support knowledge needed to solve challenging, real-world problems. Authentic instruction places the learner in the environment of the doer, and while in that environment the learner assimilates the practices and beliefs associated with a particular discipline. This assimilation is a direct result of the learner performing activities unique to that discipline. For example, to learn cell biology, the learner would visit a lab filled with the equipment and reagents and perform authentic cell biology experiments.

Unfortunately, to offer such an experience to a large number of students is prohibitively expensive. The challenge for geology teaching is even more daunting: it is impossible to transport hundreds of students to the many physical environments necessary to perform those relatively simple, but unique experiments that are necessary to support problem solving. Without these economic limitations, authentic learning would support the active engagement of student-centered collaborative learning of the principles and practices that define science and its discipline. So what options are available to provide authentic learning in our cost-constrained educational institutions?

Properly designed computer-aided courseware that render cell biology laboratories or geological worlds can potentially support authentic instruction anywhere a monitor is available. Importantly the cost of the authentic experience is then pro-rated into the technology budget of the school. Therefore the educator is challenged to either identify off-the-shelf software that supports the authentic learning pedagogy or develop new courseware. At North Dakota State University (NDSU), the World Wide Web Instructional Committee (WWWIC) chose the latter approach. Here we provide evidence from large experiments that graphical or text-based virtual worlds designed to support authentic instruction in cell biology and geology can significantly improve the student's ability to solve authentic problems associated with those two disciplines.

DESCRIPTION OF THE STUDY

The WWWIC (**http://www.ndsu.edu/wwwic**) is a multi-disciplinary group of NDSU faculty engaged in the development of virtual/visual worlds for science education that communicate both the scientific method and discipline-specific content and are role-based, goal-oriented, learner-oriented, immersive, and exploratory (Slator et al., 1999). The worlds employ consistent elements across disciplines and, as a consequence, foster the sharing of development plans and development tools. Of particular interest for the experiments described here are two virtual worlds, the Virtual Cell (White et al., 1999) and the Geology Explorer (Schwert et al., 1999). Each is hosted on the Internet and has the capability of multi-user interactions. The common technology is a LambdaMoo (**M**UD **O**bject **O**riented; Curtis, 1998) server and database that contains the contextual material (help file and experimental output data) and controls the single and multi-user connectivity and interactivity. For the Virtual Cell (http://vcell.ndsu.edu), LambdaMoo also manages the three-dimensional display of VRML worlds representing a virtual laboratory, the interior of the cell and its organelles. The display of the world and its direct interactivity is managed by a Java applet. The version of the Geology Explorer used in the experiments described here utilized the textual interface features of LambdaMoo. A graphical version of the Geology Explorer is now available (http://oit.cs.ndsu.nodak.edu/).

The basic experimental design for the Virtual Cell and Geology Explorer experiments were nearly identical. Student volunteers were recruited from a large-enrollment introductory-level general science class (General Biology or Physical Geology) with the offer of extra credit points. The Virtual Cell experiment was performed with two sections taught simultaneously by different instructors, whereas the Geology Explorer experiment was involved a single section. Each student volunteer and non-volunteer completed a pre-treatment scenario-based assessment exercise. These exercises were problem-based questions specific to one of the disciplines. (Visit http://www.ndsu.edu/wwwic/vc/evaluation/eval2.htm for the Virtual Cell scenarios.)

Within each course, the volunteers were assigned randomly to one of two groups based on data from a student-completed survey (http://www.ndsu.edu/wwwic/vc/evaluation/eval1.htm) that characterized their computer literacy, gender, and prior laboratory experience. The Virtual Cell group completed authentic Organelle Identity and Cellular Respiration activities in the virtual world, and the WWW group performed two computer-based World Wide Web exercises that required a similar amount of time with computer-based activities. The Geology Explorer group was assigned a single authentic mineral identification activity, and the corresponding Alternative completed an exercise requiring WWW-based activities. For both experiments, non-volunteers formed the control group and performed no additional educational activities. About one month after the activities were completed and just prior to the end of the semester, students completed post-intervention scenario-based assessments. A total of 334 and 368 students participated in the Virtual Cell and Geology Explorer experiments, respectively. Multiple student graders trained against a standard approach scored the pre- and post-intervention scenario assessments. For both experiments, a score of 100 was indicative of the score a professional in the field would obtain. Because a significant correlation of scores for the Virtual Cell graders was observed, the mean score was used as the experimental observation. A separate goal of the Geology Explorer experiment was to evaluate fourteen assessment scenarios (as opposed to just one used for the Virtual Cell experiment). Because of smaller sample size per scenario, reliable correlations of grader scores within a scenario could not be obtained. Therefore, the scores of each grader were evaluated separately.

FINDINGS

Two-way analyzes of variance (ANOVA) were performed to determine if any significant Virtual Cell treatment effects could be detected. The observation that the means between the two class sections were not significant implies the teaching approaches by the instructors in the two sections did not confound the student scenario assessments scores. The ANOVA also demonstrated the post-intervention mean score of the Virtual Cell group was significantly higher than the corresponding score for the WWW and Control groups (Table 1). This large experiment

TABLE 1

Mean post-intervention scenario scores for 1999 Virtual Cell experiment with NDSU Biology 150 (General Biology) students.

	Module	
Mean	Organelle Identification	Cellular Respiration
Control[a]	17.4a	10.6a
WWW	19.7b	13.7b
VCell	22.7c	17.3c

[a]Treatment population sizes are: Control=145; WWW=94; and Virtual Cell=93. Within any column, any two means followed by the same letter are not significantly different at *P*=0.05 using the LSD mean separation test.

clearly demonstrates the Virtual Cell experience had a significantly positive effect on the ability of students to solve problems in the mode of a cell biologist. The fact that the Virtual Cell group mean was significantly higher than the WWW group strongly suggests the improved ability was not simply the result of computer-based time-on-task, but rather was directly related to the Virtual Cell experience. In addition, the results demonstrate the WWW group mean scores were significantly higher than those of the control group. Because of several confounding factors, it is more difficult to adequately explain these mean performance differences. This difficulty, though, does not diminish the significant improvement in performance demonstrated by the students who used the Virtual Cell.

For the Geology Explorer experiment, the data was analyzed by Analysis of Covariance to adjust for variation associated with pre-intervention scenario assessment score and variation associated with varying degree of difficulty of the fourteen post-scenario assessments (versus one for the Virtual Cell experiment). Consistent with the results of the Virtual Cell experiment, the mean post-intervention scores for those students completing Geology Explorer goals were significantly higher than the alternative and control groups (Table 2). Although the means of the three graders varied, the trend of Geology Explorer students performing better on the authentic assessments was consistent. Unlike the Virtual Cell experiment, the control and alternative group mean scores were not significantly different.

TABLE 2
Mean post-intervention scenario scores for 1998 Geology Explorer experiment with NDSU Geology 105 (Physical Geology) students.

	Grader		
Mean	One	Two	Three
Control[a]	25.1a	25.5a	44.5a
Alternative	29.3a	27.0a	42.6a
Geology Explorer	40.5b	35.4b	53.4b

[a]Treatment population sizes are: Control=195; Alternative=95; and Geology Explorer=78. Within any column, any two means followed by the same letter are not significantly different at *P*=0.05 using the Duncan's multiple range mean separation test.

CONCLUSIONS AND RECOMMENDATIONS

Given the consistent experimental approach we have employed, we conclude the use of virtual worlds designed as active, authentic learning environments can positively impact student learning. Although we describe a computer-based approach to authentic learning, in general we recommend authentic learning as a component of science learning. The one-time cost of the technology is expensive, but it is not a recurring cost such as annually funding laboratory exercises or transporting students to remote learning sites. For upper division courses with smaller enrollments, these traditional approaches may still be economically feasible, but we would advocate the transitioning to a virtual world approach for larger enrollment classes.

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