A Virtual Environment for Geologic Education Integrating Mathematics and Chemistry

Brian M. Slator, Donald P. Schwert, Guy Hokanson, Otto Borchert. Bernhardt Saini-Eidukat
North Dakota State University

Jeffery Terpstra
Western Michigan University

John Reber
Concordia College

Lisa Daniels
University of Central Arkansas

Sara Forness
West Fargo High School

Matti Kariluoma
WoWiWe Instruction Co.

Abstract

An experiment was performed with 26 high school environmental science students. Before playing the Geology Explorer 3D game, each student took a content quiz calling for a multiple-choice response and assessment of confidence: from total certainty to a complete guess. The students then played the game through a set of learning modules on water quality and river discharge; then the same quiz again.

Introduction

The Geology Explorer 3D (GeoEd) system is a virtual world targeting environmental science (specifically environmental geology) to juniors and seniors in high school, developed by the World Wide Web Instructional Committee (WWWIC) at North Dakota State University (NDSU).

WWWIC is an ad hoc committee of faculty, staff, and students working to advance education through the use of Immersive Virtual Environments (IVE) (Slator et al. 2006). WWWIC has implemented educational IVEs for a wide range of scientific disciplines including anthropology, biology, economics, geology, and computer science (Saini-Eidukat, Schwert, and Slator, 2001; White, McClean, & Slator, 1999; Slator and Farooque 1998; Hokanson et al., 2008). Each of WWWIC's IVEs are designed under a proven set of guidelines: they are collaborative, multi-user, are constructed with the help of content experts, employ strong cognitive and pedagogical features to assist the players in learning the content, and allow for consistent evaluation of learning outcomes (Borchert et al., 2010).

The GeoEd IVE employs authentic instruction and scenario-based assessment. GeoEd combines math and chemistry goals with geologic concepts. In this way, teachers in high school mathematics, chemistry, and environmental science can use GeoEd in their classrooms. Due to the multi-user design of the game, players can collaborate with one another while completing their tasks (Borchert et al., 2008).

Background

The Geology Explorer was originally created in 1998 as a supplement to an introductory college level geology course at NDSU. A number of studies were done to determine its efficacy as a teaching tool at that grade level (McClean, 2001). Students who played the Geology Explorer did significantly better on content and scenario-based assessment than students who completed alternative exercise covering similar topics. The software was also shown to improve student learning with no gender bias (Slator et al., 2005).

Scenario-based assessment of student learning has long been a part of formal educational evaluations. For instance, mathematical word problems, open-ended questions, and writing prompts have scenario-based components. Vocational schools have adopted scenario-based assessments, using workplace-derived measures of competent performance to assess students (Losh, 2000). Scenario-based assessments are used for training by the FBI and major business corporations (Swanson et al., 1995).

The attraction to such assessment is its effectiveness. There is little separation between "test performance" and real learning, so students cannot feign competence (Shepard, 2000). Scenario-based assessments are a part of a larger category of evaluation called "authentic assessment," where student performance on intellectual tasks is directly examined (Wiggins, 1990).

System Design

Students enter the GeoEd world and begin by taking a short tutorial to become familiar with the interface. This tutorial then leads them to a series of pre-treatment assessments. These assessments gauge student content knowledge (e.g. How are dissolved oxygen and temperature related?), confidence in that content knowledge, and attitudes towards earth science, mathematics, and computers (e.g. rate your attitude on a five point scale from "I love science" to "I absolutely hate science").

The students are asked to measure a river for levels of pollutants. These data are automatically placed into a table as the student takes measurements, and students can generate a line graph based on these data using an in-game interface. Students analyze their data and determine the location of a toxic level of any pollutants. They then answer a series of formative assessment questions related to the task.

Students then use a pygmy meter (a device used to measure river depth and velocity simultaneously) to create a cross section of the river. They then combine a lesson on significant figures with the velocity and cross sectional area to determine the discharge of the river. As with the water quality task, they are asked a series of formative assessment questions related to significant figures upon the completion of the task. Finally, students are asked to complete a series of post-treatment summative assessments to determine how their attitudes and knowledge have changed over the course of their exploration of the environment.

Experimental Results

The GeoEd software has been pilot tested for usability in a local high school with positive results. Students were able to complete their tasks in a relatively short period of time. They also expressed enthusiasm for the project and showed small gains in confidence from pre- to post-treatment.

We coordinated a user testing 'event' at West Fargo High School in the Spring of 2008. This was a preliminary event designed to test the software systems: tutorial, immersive experience, and assessment and evaluation. As part of this, we created a summative assessment exercise to gauge the effectiveness of the GeoEd IVE. Data were collected concerning student confidence in their answers, in both the pre- and post- assessments. In the same assessment we used a similar interface to determine the attitude of students towards math and science and also to gauge how important students felt math was towards geology.

Analysis of the data obtained from our pilot testing (Table 1) indicate slightly higher means in content knowledge, confidence, and attitude as a result of playing GeoEd. Although no overall statistical difference from pre- to post- treatment was found, the p-values for the confidence scores indicate promise for future research with larger sample sizes (Note: lower score indicates improved attitude).

Statistical Analysis for the Geology Explorer 3D Spring 2008 Experiment

Comparison	**Pre-Treatment Mean**	**Post-Treatment Mean**	**P-value**
Content Question 1	0.96	0.77	0.025
Content Question 2	0.73	0.85	0.317
Content Question 3	0.81	0.85	0.564
Content Question 4	0.42	0.42	1.000
Content Question 5	0.42	0.58	0.206
Content Question 6	0.46	0.5	0.655
Content Confidence 1	0.82	0.85	0.688
Content Confidence 2	0.77	0.84	0.107
Content Confidence 3	0.76	0.85	0.047
Content Confidence 4	0.61	0.79	0.003
Content Confidence 5	0.81	0.9	0.055
Content Confidence 6	0.71	0.83	0.021
Attitude 1	2.23	1.62	0.380
Attitude 2	2.61	1.31	0.538
Attitude 3	1.39	1.31	0.327
Attitude 4	0.77	0.89	0.083
Attitude 5	1.58	1.5	0.538
Attitude 6	1.19	1.35	0.103
Attitude 7	2.42	2.46	0.574
Attitude 8	1.15	1.15	1.000

Table 1: The statistical results compiled for *n*=26 high-school environmental science students

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About the Authors

Brian M. Slator is a Professor of Computer Science and Operations Research and the Director of the NDSU Computer Systems Institute at North Dakota State University.

Address: North Dakota State University IACC Building, Rm. #262E Fargo, ND 58105
E-mail: Brian.Slator@ndsu.edu

Donald P. Schwert is a Professor of Geology and Director of the Center for Science & Mathematics Education at North Dakota State University.

E-mail: Donald.Schwert@ndsu.edu

Guy Hokanson is a Research Technician for the Computer Science Department at North Dakota State University.

E-mail: Guy.Hokanson@ndsu.edu

Otto Borchert is a PhD candidate and Research Technician in the Computer Science department at North Dakota State University.

E-mail: Otto.Borchert@ndsu.edu

Bernhardt Saini-Eidukat is an Associate Professor of Geology at North Dakota State University.

E-mail: Bernhardt.Saini-Eidukat@ndsu.edu

Jeffery Terpstra is an Associate Professor of Statisitcs at Western Michigan University.

E-mail: jeffrey.terpstra@wmich.edu

John Reber is an Assistant Professor of Mathematics and Computer Science at Concordia College.

E-mail: reber@cord.edu

Lisa Daniels is an Associate Professor of Education at the University of Central Arkansas.

E-mail: LDaniels@uca.edu

Sara Forness is an environmental science teacher at West Fargo High School in West Fargo, ND.

E-mail: Forness@west-fargo.k12.nd.us

Matti Kariluoma is a software developer for WoWiWe Instruction Co. in Fargo, ND.

E-mail: Matti.M.Kariluoma@ndsu.edu