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ABSTRACT

As technology developments seek to improve learning, researchers, developers, and educators seek to understand how technological properties impact performance. This paper delineates how a traditional science course is enhanced through the use of simulation projects directed by the students themselves as a means to increase their level of knowledge comprehension and application. To facilitate the learning of geophysical fluid dynamics, faculty at a midwestern university infused the use of simulations to help students better understand the theory and application of this domain. Three areas were targeted for class restructuring: (1) students' physical understanding of the complicated mathematical structure discussed in class; (2) learning the techniques necessary for turning new physical understanding into concrete results; and (3) ability to use their simulations to drive understanding of the physical system being modeled. In this approach, students are divided into groups based on their pre-existing computer skills and areas of interest. The course lectures are integrated with each step of the simulation. At the end of the simulation experiment, a class discussion analyzes the physical nature of the differing systems and the strengths/weaknesses of the simulations. The final step allows each group to add an additional physical process. (AEF)

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STUDENTS AS SIMULATION DESIGNERS AND DEVELOPERS— USING COMPUTER SIMULATIONS FOR TEACHING BOUNDARY LAYER PROCESSES

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1. PURPOSE

As technology developments seek to improve learning, researchers, developers, and educators seek to understand how technological properties impact performance. This paper delineates how a traditional science course is enhanced through the use of simulation projects directed by the students themselves as a means to increase their level of knowledge comprehension and application.

2. INSTRUCTIONAL GOAL

A common goal for educators is the development of thinking skills (Stolberg, 1956). The National Education Association Research Division (1994) has established that the acquisition of higher order thinking skills for students is now an important national goal. If students are to be competitive in the years ahead, faculty need to provide students with the cognitive strategies that will enable them to make decisions, think critically, and solve problems (Pogrow, 1994).

One goal of science education is not only to get students to memorize and repeat facts but to teach them how to investigate new areas, while being able to place their results in context of what is currently known. Within the small subject area covered in this class, students learn general methods of application of knowledge and new ways of expanding their knowledge.

Due to the increased accessibility of technology, educators are studying the impact of the computer in developing higher-order thinking skills. Computers are thought to have great potential for assisting the development of problem solving skills (Thornburg, 1986). Research on computer-assisted instruction and simulations suggest that computers are effective in reaching deeper understandings of information being learned (Salomon & Gardner, 1986). Quinn (1993) showed that simulations enhance students' problem solving skills by providing them a practice environment whereby they can refine their higher-order thinking strategies. Other studies have also shown instructional benefits by using computer simulations for development of higher-order thinking strategies (Gokhale, 1996; Lieberman & Linn, 1991; Rivers & Vockell, 1987; Thomas & Hooper, 1991).

3. INSTRUCTIONAL PERSPECTIVE

Traditionally, geophysical fluid dynamics has been very difficult for undergraduate and graduate students to learn. From an instructional point of view, this knowledge domain is extremely complicated due to the nature of the content: the components of the system are highly interrelated, and the system is highly mathematical. To facilitate the learning of this scientific domain, faculty at a midwestern university have infused the use of simulations to help students better understand the theory and application of this domain.

The traditional method for teaching and learning geophysical fluid dynamics has been to gain a physical understanding of fluid dynamics by using differential equations to represent the actual system. Students investigate the meaning of differential equations by asking what is happening in the equations. This is accomplished by deriving the equations and looking at examples by using the data and determine the meaning of the data. Through this instructional strategy, students demonstrate knowledge comprehension at a theoretical level. Yet few students were able to transfer the theoretical knowledge to an application level.

4. METHOD

4.1 Enhanced Simulation

In trying to meet the goal of helping students reach deeper understandings of information being learned, the class was re-structured to include the use of simulations to enhance their understanding of fluid dynamics as well as to assist students in the application of their theoretical knowledge.

Three areas were targeted for re-structuring:

One: we wanted the students to gain a physical understanding of the complicated mathematical structure that we spent time deriving and discussing in class. In atmospheric and oceanic processes, as in many areas of science, mathematical complexity is necessary for fully describing a system. However, in previous years it had been apparent that although students could describe the meaning of the pertinent equations, it was not clear to them how these equations were actually describing the physical system.

Two: we wanted students to learn the techniques necessary for turning new physical understanding into concrete results such as better predictions of physical variables. In essence, this is providing one methodology for assimilating new information into a computer model and improving understanding.

Three: we wanted the students to be able to use their somewhat simplistic simulations to in turn drive understanding of the physical system that was being modeled. With these simulations, students can now investigate the differences between different systems, and can also determine what components of the model contribute to these differences. By using a consistent set of graphical outputs and web pages, students are able to interact with other students evaluating other simulations and increase their ability to understand other systems and models.

4.2 Rationale for Simulation

There are several reasons why we chose to use simulations as the instructional strategy used to guide the course re-structuring. From a theoretical perspective, constructivist learning theories provide the strongest support for using simulations as a method to help students meet the course objectives. Instead of the traditional use of computers where they are used as "conveyors of information, communicators of knowledge, or tutors of students" (Jonassen & Reeves, 1996, p. 693), Jonassen and Reeves recommend the use of computer-based cognitive tools to function as intellectual partners to enable and facilitate critical thinking and higher-order learning.

Constructivism and its accompanying principles establish a strong rationale for using technology as cognitive tools. This rationale includes:

- Computers as cognitive tools focus on the application of technology
- Technologies are used as media for representing and expressing what learners know
- Technologies are not used to constrain students' learning processes through prescribed learning
- Learners function as designers using technologies as tools for analyzing the world, accessing information, interpreting and organizing their personal knowledge, and representing what they know

As a specific cognitive tool, simulations offer many learning benefits that are supported by Constructivism. Simulations provide a simplification of reality, constrain the learning, decrease learning variables and decrease confusion. Students will generally learn faster if details are eliminated at the beginning of instruction (Alessi & Trollip, 1991). By adding detail, simulations bring the student closer to reality as the student becomes increasingly competent in dealing with simple cases. Further, simulations are better instructional tools than other methodologies because "learning by doing" is recommended (Anzai & Simon, 1979; Bruner, 1973; Papert, 1972, 80), and motivation is increased through active participation in the learning situation.

4.3 Simulation Design/Development Activity

Students are divided into groups based upon their pre-existing computer skills, and areas of interest. The course lectures are integrated with each step of the simulation. First, the general physical principles for each component are discussed, and then methods for utilizing those principles in the simulations are outlined. The students then integrate those principles into their particular simulations. Each group has a different set of data which needs to be analyzed by the simulations; each group produces graphs of their results based upon their simulations. These graphs are then displayed across the Web, and the groups then provide feedback on their physical understanding of their data and the comparisons of their results with the other groups. Finally a class discussion results in which both the physical nature of the differing systems are analyzed and then the strengths/weaknesses of the simulations are identified.

The final step in the course allows each group to add an additional physical process. Each group gets to choose what type of process they would like to study, and the final discussion is a sharing of ideas as to the impact of the physical processes on the simulations. Thus the students have started from a very simple conception of the physical system, and have grown to the point of addressing issues with which they are concerned by using their own knowledge and knowing how to expand it.

4.4 Simulation Activity Challenges

One of the difficulties accounted for in having students design and develop their own learning simulation is that the students must learn the software needed to design and develop the simulations. In this course, we allowed students to use whichever programming language they were familiar with (one of the prerequisites in the major is at least one programming course), and pre-programmed the graphing and web-based tools to minimize the time spent by students on learning the development tools.

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