4.3 A VIRTUAL EXPLORATORIUM TO SUPPORT INQUIRY -BASED LEARNING IN GEOSCIENCE COURSES

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1. INTRODUCTION

Over the past decade, the challenges facing undergraduate science education have been well articulated in a number of national documents. The reports were prompted by the national crisis of a scientifically literate citizenry, the rising concern about inadequate preparation of pre-service teachers, and the expanding expectation of a technologically literate student population. These reports recommend that science education become more inquiry-based, focus on fundamental principles, and give students the opportunity to experience "doing science" (Shaping the Future, Geoscience Education).

Doing science has undergone dramatic changes in the past decade. Scientists routinely use high-performance computer models, large data sets, and high-end visualizations. At the same time, the field of education has been transformed through major insights in the areas of cognition, learning theory, and educational technology. Although both education and science have evolved substantively, undergraduate science education, particularly at the survey level, has not kept pace. Most undergraduates are still passively absorbing the products of science, with no opportunity to explore or inquire. This experience does not adequately foster understanding of the complex relationships that are the foundation of scientific literacy.

Today's desktop computers are capable of supporting three-dimensional visualization of complex phenomena at a level that, until very recently, was available only on costly visual supercomputers. Advances in technology and software make it feasible to deliver a 3D virtual world to students; one they can explore, learn from, ask questions of, and from which they can derive new spatial/temporal visualizations.

The emergence of computer-based learning and research tools on the desktop, greater understanding of learning and cognition, and the pressure to integrate technology on many campuses have prompted repeated and urgent calls for assistance from the geoscience education community.

2. VIRTUAL EXPLORATORIUM

A new NSF/CCLI funded project, the "Virtual Exploratorium" (VE) is being launched to address these concerns about undergraduate science education and respond to the mandate of the geoscience education community. The VE exploits recent advances in information technology to design an environment that promotes deeper understanding through scientific exploration. It will provide learners with a set of inquiry-based projects and curricular elements and a well-supported, computationally sophisticated environment that allows learners to engage in the "tools of practice" of modern scientific inquiry. Among the unique features of the VE will be the testing of a learning model that reflects contemporary notions of cognition and student's use of interactive models and advanced visualizations to explore and understand geoscience principles, building blocks, processes, and phenomena.

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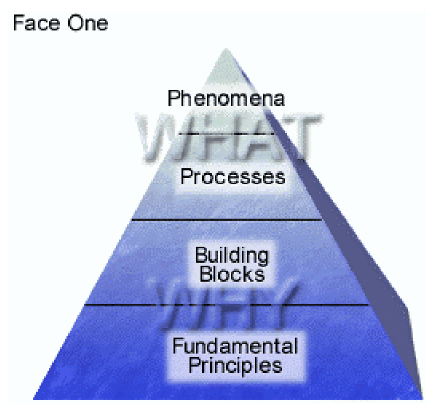
2.1. A Conceptual Approach

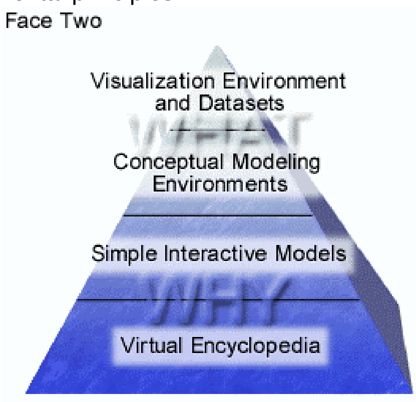
We use the metaphor of a three-sided pyramid to represent the structure of the learning model, the curricular elements we are developing, and the anticipated understanding students will construct in the VE. At the apex of the pyramid is the description of the natural phenomena, or *what*. This apex can accommodate significant student exploration before leading to the *why* and the lower tiers of the pyramid. The lower tiers of the pyramid look to explaining *why*, and focus on developing relationships between fundamental principles.

Face One of the pyramid outlines our conceptual approach and represents a progression of scientific knowledge that can be used to recognize and understand the natural world. At the base of the pyramid are fundamental principles, basic immutable physical



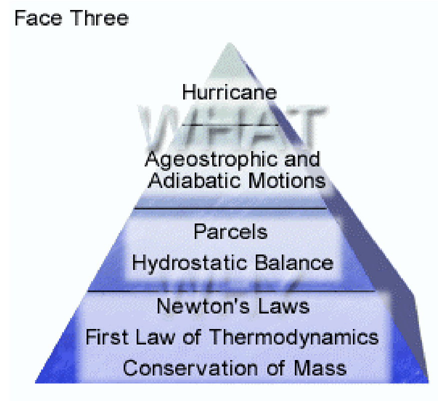
laws applicable to all of nature. An example of a fundamental principle is Newton's laws of motion. Building blocks occupy the next level of the pyramid. Building blocks are combinations of fundamental principles that scientists can apply in diverse contexts. An example of a building block in atmospheric science is the notion of buoyancy, which exploits Newton's laws (as well as the equation of state and gravity) to explain vertical motion in phenomena as diverse as ocean currents, mantle convection, and thunderstorms. A key strength of this learning model is its ability to leverage a variety of phenomenological contexts to direct student inquiry toward fundamental principles of value across the geosciences.

Processes occupy the tier above building blocks. Processes are sequences of or relations between building blocks that contribute to a resulting phenomenon. In the example of thunderstorms, the process of adiabatic motion is built with the building block of buoyancy. Finally, at the apex of the pyramid we have the observable phenomena itself, the thunderstorm in this example. The phenomena is the result of a complex interplay between many processes, each leading to a number of building blocks. The building blocks, however, converge to only a few fundamental principles.



In the apex of the pyramid, the primary student activity will be investigation of phenomena. We will develop specific data sets and a learner-centered visualization environment. This part of the pyramid will differ from existing web-based visualizations of phenomena (e.g. El Niño) because it will allow the students to actively construct the visualizations. In the process level of the pyramid, we will adapt research level models for student use. Students will be able to investigate hypothesis and formulate theories using authentic tools of modern science. The building blocks and fundamental principles will be archived in a virtual encyclopedia, an extensively cross-indexed and hyperlinked collection of definitions, applets, streaming video, simple interactive models etc.

The final face of the pyramid indicates how the pyramid approach might inform learning. Although the pyramid offers flexibility in pedagogy, we will consider a scenario motivated by student curiosity about the eye of a hurricane. A brief overview is presented here; a more complete scenario is presented at http://www.atmos.uiuc.edu/go/ccli. Students will begin by exploring and describing satellite imagery of a recent hurricane. Emphasis here will be placed on the opportunity to create and compare techniques of visualization as well as observations. A number of questions arise from such an exploration, among which might be the question of "why is there an eye?" Students, using powerful visualization tools, explore the region of the eye and discover the eye is a region of downward motion. Students can then move to the modeling tools and determine if the correlation between downward motion and the eye has physical significance, The relation of the downward motion to the eye is investigated with building blocks and processes using idealized models, visualizations, etc. within the virtual encyclopedia. Here the student's prior experience and



the instructor's guidance can significantly influence the exploration.

2.2. Identifying Misconceptions

Student's prior experience can be a dangerous guide, however, as students who take introductory courses harbor a number of misconceptions about the weather, general science phenomena, and what it means to "do science." Research has shown that unless these misconceptions are explicitly identified and addressed, new knowledge is made to fit existing misconceptions rather than being used to revise them.

We will report on the first stage of our investigations, in which we examine the preconceptions that students have about the phenomenon of El Niño. We will investigate student conceptions of El Niño for three reasons: its popularity in the media ensures that most students are not entirely unfamiliar with it, it naturally falls under the umbrella of an earth systems approach, and it includes complex relationships among many processes.

3. CONCLUSION

The development of the VE takes advantage of the significant advances in computing power to adapt scientific tools in an inquiry-based learning environment that will foster deeper understanding. Our goal is to use the emerging technology to provide a new kind of experience that is significantly more than multimedia information. We seek to engage the learner in conceptual exploration - enabling the learner to think constructively and to "act like a scientist." Thus, our pyramid focuses on student exploration using authentic scientific tools and developing reasoned relationships between phenomena, processes, building blocks, and fundamental principles.

4. REFERENCES AND ACKNOWLEDGEMENTS

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