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CILT2000: Visualization and Modeling

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CILT2000 helped VisMod evolve from a collection of local and distinct research and development efforts into a solid field of education. Previous intellectual efforts focused around (a) modeling and simulation tools, (b) visual explanation tools, (c) visual data analysis tools, (d) exploring student needs in the context of VisMod, and (e) exploring instructional frameworks for VisMod. These focus areas have evolved in two main trajectories, representing the evolution of the field, the generalization trend, which seeks to identify general principles and guidelines for designing learning environments, and the equitable application trend, seeking to use knowledge gained in the field to leverage education in general.

KEY WORDS: visualization; modeling; simulation; design principles.

The phrase "one picture is worth a thousand words" is a core idea of the Visualization and Modeling (VisMod) theme. Numerous studies indicate that appropriate visualizations can improve learners' perception of the objects they represent (e.g., Kali and Orion, 1997), as well as learners' conceptual understanding (e.g., Linn and Hsi, 2000). However, this finding raises many questions concerning the nature of this "picture," the goals for using it, the process of its design, and the contribution of technology for introducing innovative methods for presenting visual information. At CILT2000, about 60 participants, who are actively involved in diverse aspects of this area, gathered to share their ideas and create new partnerships for further elaboration of the VisMod theme.

The discussions that took place at our workshop and the projects that were proposed indicate a shift in participants' interests, reflecting the current dynamics in the VisMod field. In previous years, participants' intellectual efforts were focused around five areas representing research and development concerning different types of usage of VisMod tools. This year, however, these foci have evolved into two new trajectories (Fig. 1). The first trajectory is the synthesis and generalization of the existing knowledge in the field, forging it into general design principles and guidelines. The second can be described as "beyond VisMod" and is characterized by utilizing this knowledge for actual application in the field of education, taking into account issues of equity between diverse learners (described below). The discussions at the workshop were more cohesive than in previous years and directed toward a common goal. There was less unbounded optimism about the tremendous capabilities of technology for creating VisMod tools. Rather, participants were more critical and cautious in pinpointing the specific potential of such tools for education.

The focus areas of participants' interests in previous years, which were represented at CILT2000 by seed grant reports, were the following

EXPLORING DIFFERENT TYPES OF VISMOD TOOLS

- Modeling and simulation tools – An area focusing on the underlying models that drive scientific phenomena. Participants were interested in exploring learning processes in situations in which students *use* simulations of such phenomena, designed by researchers, as well as in situations in which students *build* their own simulations and models. An example exploring student *use* of simulations and models

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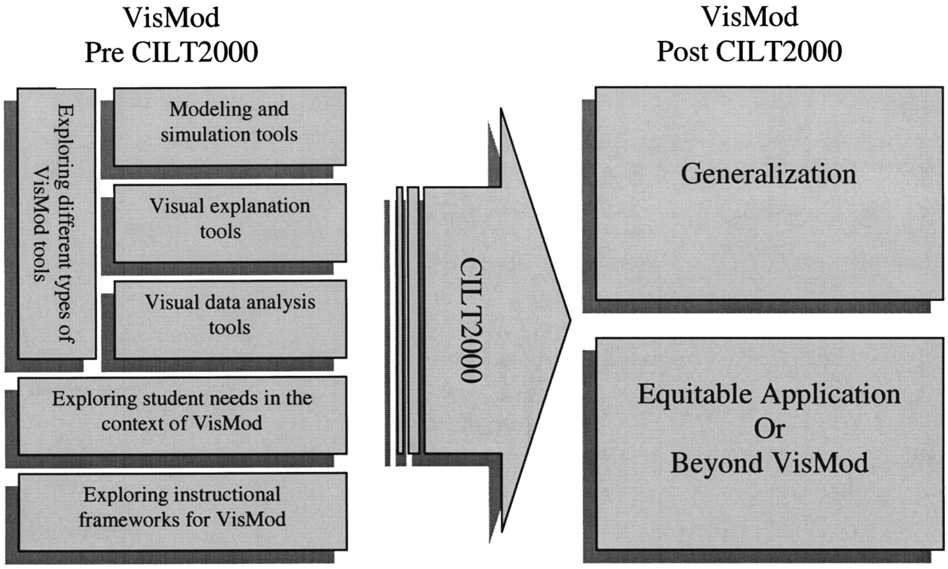

Fig. 1. Dynamics in the VisMod field.

was presented by Margaret Corbit from the Cornell University. Corbit led the "Modeling Malaria" project (http://www.scicentr.org/malaria/index.html) in which students can use a computer simulation to explore how the tropical disease malaria spreads through the countryside in the mythical land of Cardoon under various hypothetical circumstances (Fig. 2). An example exploring the potential of simulations and models *built* by students was presented by Alexander Repenning from the University of Colorado, who presented *AgentSheets* (http://www.agentsheets.com). This tool supports student authoring of simulations for all kinds of subject areas, and turns the resulting simulations into Java applets, which enable manipulation and communication of the simulations on the Web. Repenning claims that learners benefit most from designing all or at least some aspects of their own simulations, and that the challenge is to enable this design as a learning activity without turning students into programmers (Repenning *et al.*, 1999).

- Visual explanation tools – In contrast to the modeling and simulation area, which focuses on more general-purpose tools, the focus here is on the use of representations designed to communicate specific ideas. The research and development in this area concentrates on the cognitive benefits of these tailored visual explanations, and explores the role of animation, video, and virtual reality in learning. An example is Geo3D (http://yaelkali.org), a tool designed by Yael Kali at the Weizmann Institute of Science, which assists students in perceiving geological structures and in envisioning cross-sections through these structures (Fig. 3). By conducting "spatial investigation"—manipulating animated visual illustrations of three-dimensional fold and fault structures—students improve spatial skills needed for structural geology (Kali and Orion, 1997).
- Visual data analysis tools – This area focuses on making sense of complex empirical data sets for use by learners, usually by adapting scientific visualization tools for the specific needs of students. Examples are WorldWatcher (http://www.worldwatcher.nwu.edu) (Fig. 4) and My World that were presented by Daniel Edelson from the Northwestern University. These tools provide visualization and analysis environments of geographic information systems (GIS) designed for nonexpert learners. Edelson claims that the same properties that have made visualization a powerful technology for scientific discovery by scientists—the ability to render complex data for visual interpretation—make it a potentially powerful tool for science learning by students (Edelson *et al.*, 1999).

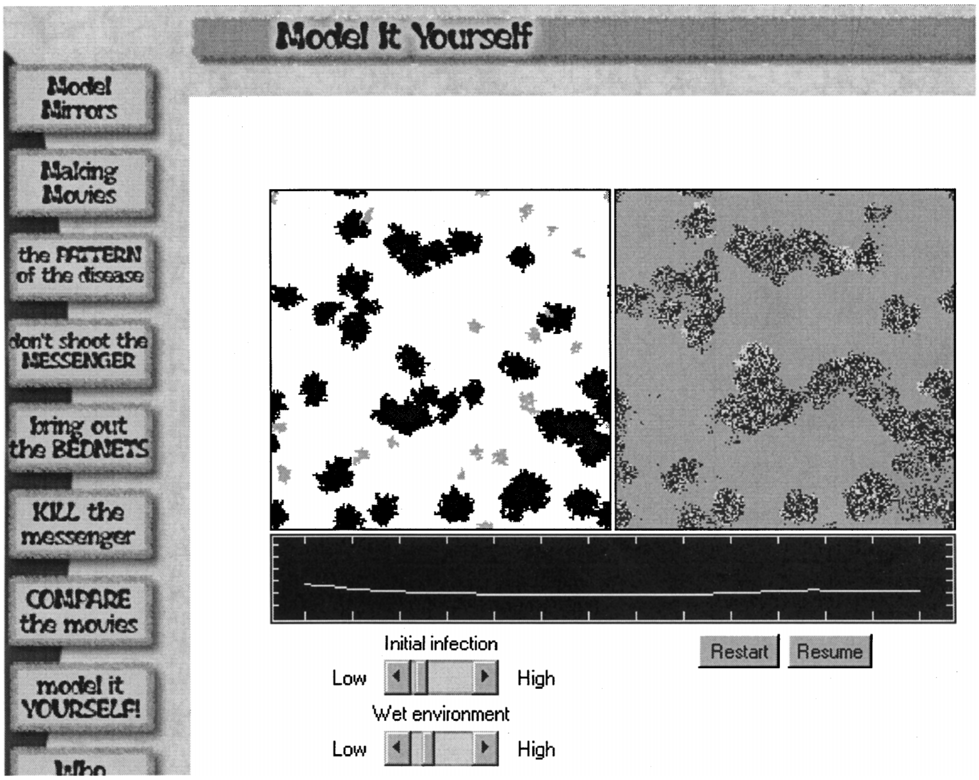

Fig. 2. Modeling malaria.

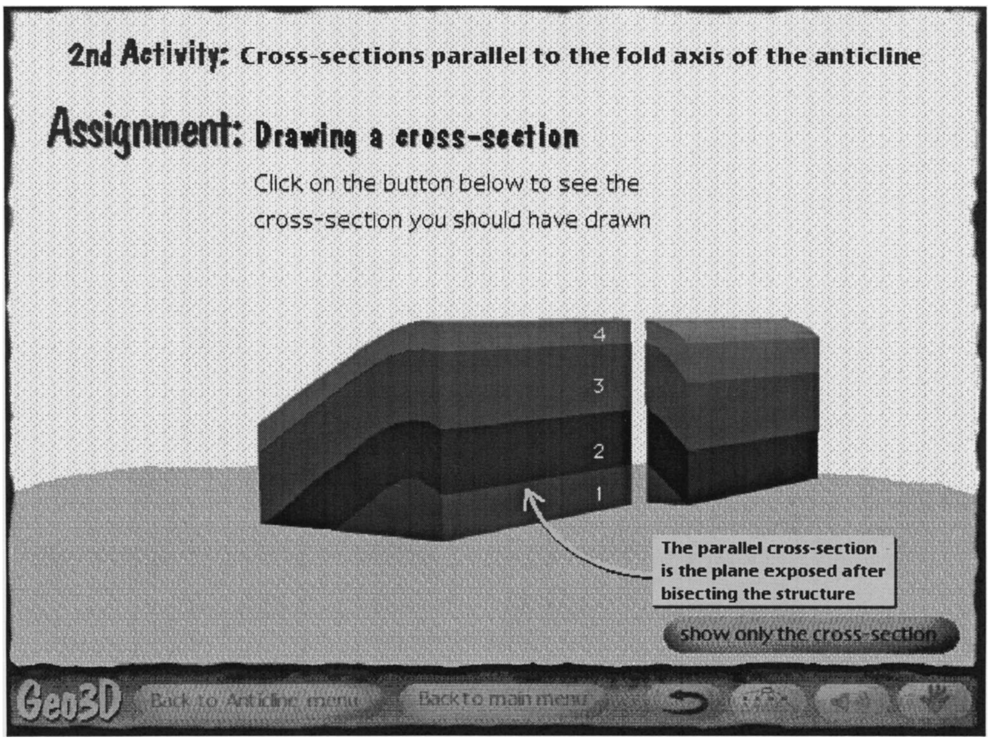

Fig. 3. Spatial investigation in Geo3D.

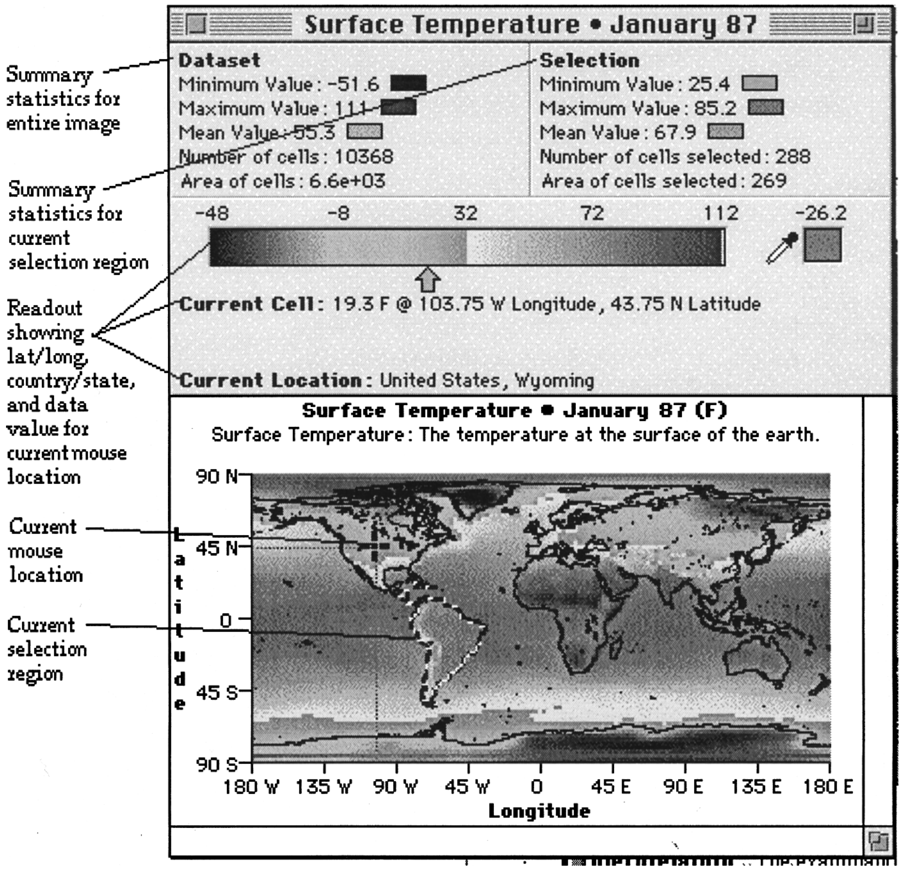

Fig. 4. A WorldWatcher visualization window.

EXPLORING STUDENT NEEDS IN THE CONTEXT OF VISMOD

This area focuses on the learner, rather than the tools, and explores diverse needs that different uses of VisMod tools can address. An example is the focus of some VisMod participants on representational approaches for young children (grades K-6). Students at this age face particular developmental challenges in understanding and manipulating abstract representations. The research in this area addresses questions such as: What kinds of tools exist that support student use of manipulation of representations in diverse subject matters? What do we know about students' abilities to use such representations? A presentation by Tom Moher from the University of Illinois described a tool designed for science inquiry learning by elementary students. "Virtual Ambients" (http://www.evl.uic.edu/correlations) are configurable, simulated phenomena within which learners may navigate, make observations, raise questions, and develop support for hypotheses (Fig. 5).

EXPLORING INSTRUCTIONAL FRAMEWORKS FOR VISMOD

Visualizations are not used in a void, but in a curricular context. This area focuses on the pedagogical implications of different instructional approaches, and deals with questions such as: What do we know about the kinds of instructional frameworks that support the use of VisMod tools? How do these frameworks work together in different environments? How can the best features of existing learning environments be converged into a single, coherent context for supporting VisMod activities?

Activities for leveraging this trend include a project called "Deformed Frogs at the Exploratorium" which explored the integration of web-based curriculum materials (http://scope.educ.washington. edu/amphib) with an informal

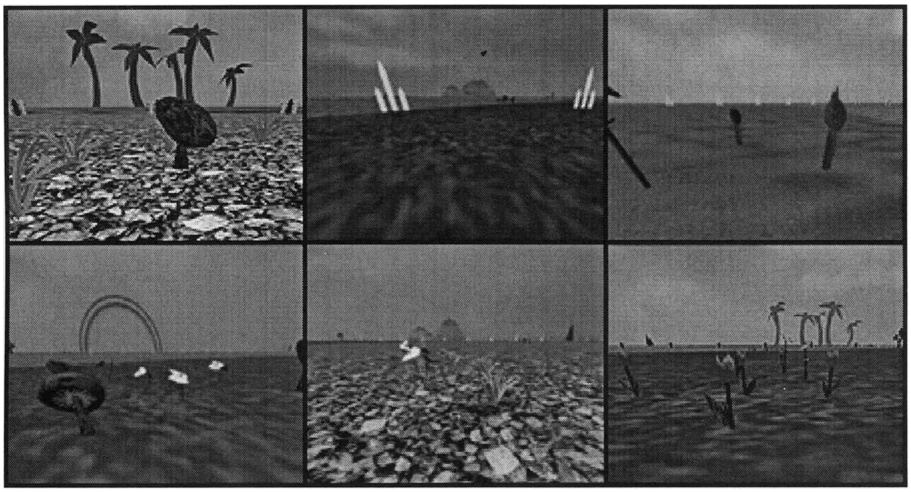

Fig. 5. Virtual Ambients.

science-learning environment at the Exploratorium museum.

FUTURE TRENDS IN VISMOD

The above focus areas have evolved in two main directions: *generalization* and *application*. The generalization trajectory was represented at CILT2000 in participants' interest in identifying general principles and guidelines for designing *learning environments*. The interest in exploring learning environments, frameworks that serve as containers for a diversity of contents, exemplifies one area of this trajectory. Another is the area of *design principles*, which deals with the tacit knowledge gained by designers in the iterative process of designing educational software. For instance, a design principle might include information about educational contexts in which interconnected multiple representations of a phenomena are useful, and those contexts in which they are not, and can even cause confusion among learners. The thrust to abstract and synthesize this design-knowledge, which is currently distributed among a large and heterogeneous group of people is another example of the generalization trajectory, seeking to fuse the knowledge already gained in the field to provide useful guidelines for future designs.

One of the new VisMod projects that exemplified the generalization trend, "Principles and Guidelines for Design of Technology-Based Learning Environments: Construction of an On-line Guide," is a collaborative group of leading designers in the field. The group is forging their ideas into an online searchable database of design principles, which would provide a framework for the community of designers in the development of new learning environments (http://cilt.org/seedgrant/seedvm00.html).

The application trajectory, or the beyond VisMod approach, was particularly apparent in a list of about 30 questions that were brainstormed at our workshop, which eventually served as ideas for seed grant proposals. These questions can be classified into several topics that deal with issues of using the knowledge gained in the field of VisMod to leverage education in general. Such issues are professional development for the usage of VisMod tools in education, assessment of the effect of such tools on learning, scaling the usage of these tools in the educational system, and designing VisMod tools in an equitable manner to suit a diversity of learners. For instance, one of the new seed grants is investigating the effect of student epistemologies on their ability to use models as effective tools (http://cilt.org/seedgrant/seedvm00.html). One of the focus areas of this project is to explore the ways in which students with less sophisticated understanding of scientific models, who are typically considered "less skilled at science learning," can benefit by instructional strategies designed to promote epistemological thinking.

In summary, CILT2000 helped VisMod evolve from a collection of local and distinct research and development efforts into a solid field of education. This evolution was expressed both in the more cohesive discussions of participants at our workshop, and by the new trajectories that emerged from these discussions. We anticipate that the outcomes of the new seed grants, which represent the current trends toward both generalization and application of existing knowledge in VisMod, will provide the VisMod field with tools and syntheses that would further leverage its development in the near future.

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