JP1.5 THE VISUAL GEOPHYSICAL EXPLORATION ENVIRONMENT: A SCIENTIFIC TOOL-KIT FOR LEARNERS

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1. INTRODUCTION

The Visual Geophysical Exploration Environment (VGEE) is an inquiry-based learning environment that allows learners to construct visualizations of real geoscience data as starting points and anchors for their investigation of natural phenomena. In addition to a visualization interface and specially prepared data sets, it includes an online curriculum and supporting materials, web-based interfaces that archive student work, and simple interactive concept-based models that can be used both within and outside of the visualization environment.

The VGEE provides a vehicle to evaluate some of the functionalities afforded by emerging Digital Libraries. A key part of the vision of Digital Libraries is to allow new interactive resources that encourage students to participate in science using authentic scientific tools. The VGEE allows us to examine these strategies for student engagement and make recommendations for the library.

Because the VGEE includes specific data sets and learning tools, its being catalogued in the library will help to contribute to the development of procedures and protocols for cataloguing these new resources. In particular, its curriculum can be catalogued in its entirety and as topical elements, the concept models can be catalogued as their own elements, and the visualization environment can itself be catalogued. Finally, VGEE datasets will cooperate with efforts to create a data web and develop protocols for making data useful to learners and educators.

2. THE PROMISE OF VISUALIZATION

One of the key functionalities envisioned in the Digital Library for Earth Science Education (DLESE) is the ability to find data sets and meaningfully render the information they contain (DLESE Strategic Plan). Visualization offers a number of advantages to the science classroom. It removes mathematical skill as a barrier to understanding, exploits a natural human ability to identify visual patterns, can be more engaging for learners, and if offers opportunities to use the tools of scientists (Edelson, *et al.* 1999). Most current uses of visualization, however, are limited to two dimensions, leaving the learner with the formidable task of fusing together multiple spatial and temporal perspectives as well as multiple variables into an integrated conception of the phenomena. (Tufte, 1990). A multi-variable three-dimensional visualization environment offers students a fundamentally different perspective; rather than fusing different conceptions to arrive at an understanding, learners being with a holistic view and look for relationships among variables and perspectives (Hay, 1999).

3. CHALLENGES FOR USING INQUIRY AND VISUALIZATION

In spite of these potential benefits, there is significant work still to be done in understanding how inquiry-based visualization environments can become valuable tools for learners. One particular challenge is that learners require some scaffolding to successfully use multi-dimensional visualization environments to construct physically meaningful representations of geophysics phenomena. Misconceptions about the nature of three-dimensional visualization need to be addressed (Hay, 1999) and novices need clues about the appropriate use of visual tools (Edelson, *et al.* 1999). As both authors point our, simply borrowing the visualization tools of practicing scientist is not appropriate for learners. We have used the principles of learner-centered design to design an interface in the VGEE's visualization environment that communicates with learners. This interface is built with functionality from a research-oriented visualization environment, the Integrated Data Viewer (IDV), developed at Unidata. The visualization environment is shown in Fig. 1.

4. AN EMBEDDED VISUALIZATION TUTORIAL

Early classroom applications of the visualization environment demonstrated the usability of the interface, but pointed to the need for additional support for learners in two key areas, scientific context and constructing and interpreting visualizations (Pandya, *et al.* 2002).

We have exploited the ready customizability of the IDV interface to develop a scaffolded set of interfaces that embed visualization concepts within the science investigation. As an example, the current curriculum in the VGEE is centered on the phenomena of El Nino and La Nina. The curriculum begins with students using simple contour maps to explore their conceptions of temperature on a global scale. These maps are two-dimensional and deal with temperature primarily; earlier research with the VGEE suggests that this combination is somewhat intuitive to students (Hay, 1999). The visualization environment launched at this point in the curriculum has a limited set of functionality. Later instances of the visualization environment will provide expanded functionality, but this functionality will be tied to specific targets of scientific investigation. This scaffolding will introduce visualization techniques as they become useful in the context of the investigation; this avoids intimidating learners with unnecessary complexity early on and allows us to gradually expand the repertoire of tools. In addition, each of the

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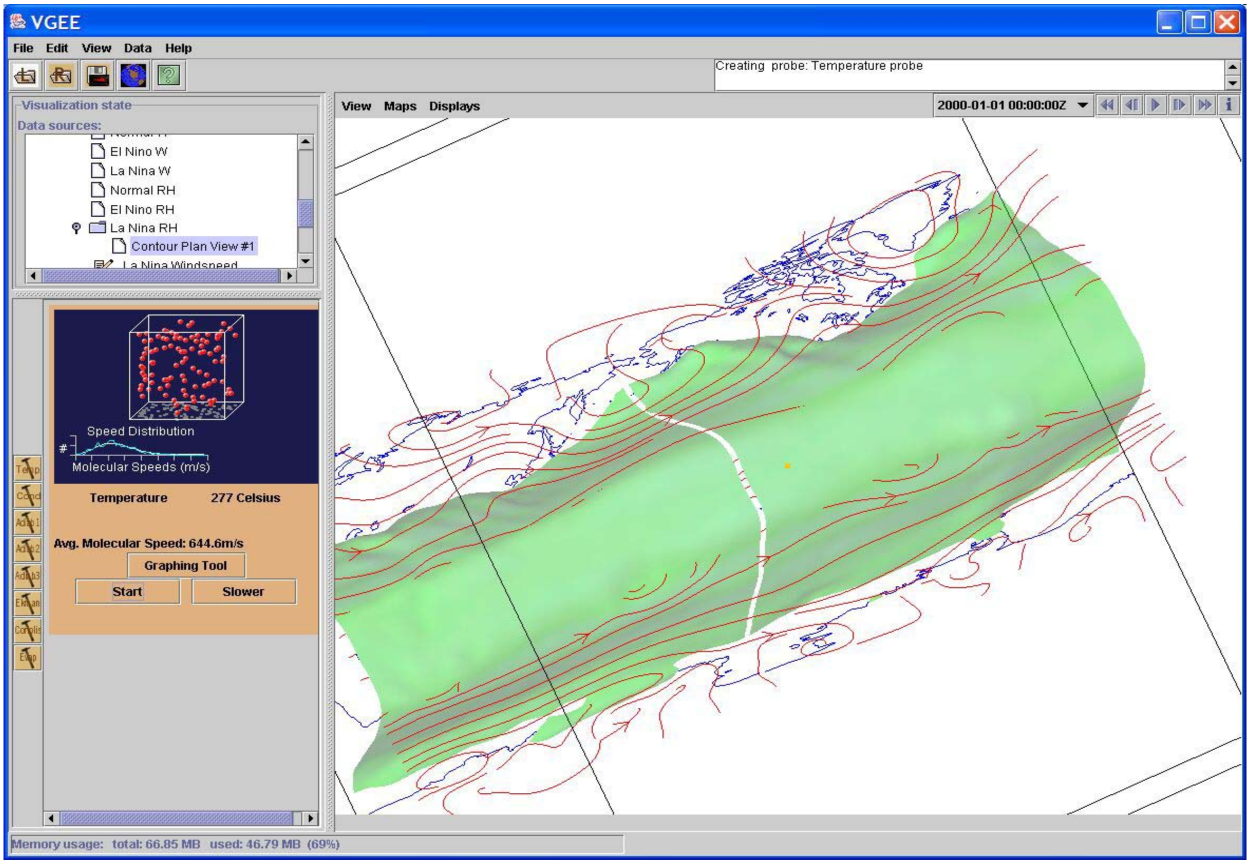


Figure 1: A screenshot showing the VGEE's visualization environment and a learner-constructed visualization.

visualization tutorials will be catalogued members of DLESE, allowing another pathway for discovery.

5. PROBES AND CONCEPT MODELS

The VGEE includes a number of Concept Models to help students organize their inquiry. Concept Models are idealized computer simulations that give students the ability to explore and discover key concepts of science without the distractions of the real world. An example of a concept model is shown in Fig. 2.

The number of these idealized models on the web, (e.g. Partnershjp to Advance Learning in Science and the Suomi Virtual Museum) attests to their potential usefulness. They make up a visible and attractive part of the evolving National Science Digital Library (NSDL) and DLESE. Since these idealized models comprise a key part of the libraries and capitalize on the unique technology available in a digital library, studying their effectiveness is a key part of investigating the overall effectiveness of digital libraries.

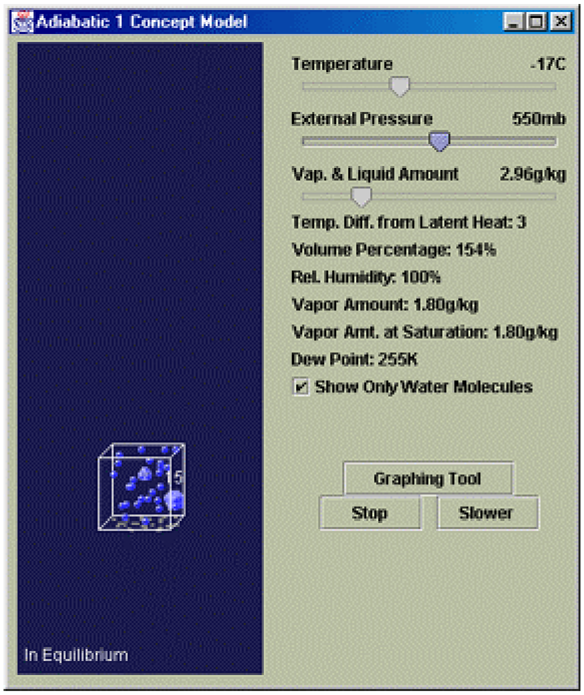
One particular weakness of these models is the problem of transfer: students might not use information learned in one context in another context, although they should. In the VGEE, concept models can also be used as probes; learners can have the models respond realistically to conditions in their own visualizations. This innovation allows students to directly relate the theoretical information in the concept models to the complexity of their visualization; this jump in the complexity may provide a model for transferring knowledge to real world experiences of geophysical phenomenon.

For example, in the VGEE a student might construct a number of visualizations of a hurricane. The learner would notice that the clouds in the eyewall correspond to the same regions where upward motion occurs To help explore this relationship, students use idealized concept models alone. This allows them to filter out other variables and zero in on the relationship in question by varying only one or two variables. After using a series of concept models, learners would understand that rising motion and adiabatic expansion lead to cooling which in turn produces condensation. After this, student could use these same idealized models within their hurricane visualization. Instead of lifting air in a known, idealized environment, they could lift air from the hurricanes base.

This functionality allows us to address a fundamental question of how students can generalize information from idealized concept models. This question has broader implications about the utility of integrated concept models throughout the library and by extension, contributes to an evaluation of the library.

6. Discovering and Using Data

One of the goals of DLESE and the NSDL is to facilitate access to distributed data: a way to search, discover, browse, and use distributed data in the same seamless way we now interact with distributed documents via the web. The Thematic Real-time Earth



Data Distributed Servers (THREDDS) project, which seeks to develop a catalogue of data descriptions that mediates between data-providers and users, contributes to this effort. THREDDS includes the capability to annotate individual data sets based on the character and attributes of the data. These annotations would allow users to search data created and catalogued by and for researchers in ways that make sense in educational contexts. These annotations can be generated automatically as part of the THREDDS services, and be included in the DLESE catalogue of the data. For example, THREDDS services might scour data provider's catalogues and generate a second catalogue of distributed data sets appropriate for educational use that includes hurricanes. This process could be automated so that the catalogue is continuously updated in real time to include the latest hurricanes.

The VGEE includes configuration files that could respond to the annotations attached to the data sets. Initially these annotations would be used to allow users to find data sets similar to the one they are already using. For example, a learner using the VGEE in a hurricane educational module might be provided with an evolving list of distributed hurricane data sets that they could investigate. Further development of the VGEE might allow the visualization interface itself to adapt to the dataset. For example, the VGEE interface would pull in probes that are particularly relevant to hurricane investigation when a hurricane dataset was loaded. If the learner switched to an El Nino data set, then, the visualization interface might adapt to include probes for upwelling.

The final step is to connect the data sets, curriculum, and customizable visualization environment VGEE by cataloguing these components within the DLESE and NSDL. DLESE and NSDL currently allow the cataloging of educational materials, but are still developing protocols for software tools and data sets. Developing a means to catalogue the datasets and tools could be considered a case study, and provide a means to understand how users access and use these tools and datasets. By providing multiple pathways to distributed data we can compare the discovery mechanisms and develop an understanding of what factors influence data discovery in diverse contexts. Existing logging software within DLESE could be extended to give an idea of the discovery of data in that context, for example. Focus groups and usability studies could provide additional data. This data could be used to identify trends in data use, perhaps providing the baseline data for future studies.

7. CONCLUSION

The VGEE is an inquiry-based, visualization-anchored tool kit. In addition to a multi-dimensional learning environment, it includes data sets, idealized concept models and probes. These components offer an opportunity to test the effectiveness of the technologies that set digital libraries apart from other learning systems. In particular, the visualization environment allowed us to assess the utility of visualization and pointed to the need to include instructional guidance in constructing visualization. The embedding of the concept models within the visualization environment model as probes allows us the chance to explore how students transfer information from concept models to less idealized contexts. This is especially relevant to the library as a whole, since its resources include many of these concept models. The VGEE also includes applications that will to contribute to and benefit from the architecture to support the data web.

8. WEBSITE

http://www.dlese.org/vgee

9. REFERENCES AND ACKNOWLEDGEMENTS

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