INTERACTIVE MODELING AND VISUALIZATION
                IN UNDERGRADUATE SURVEY COURSES

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1.   INTRODUCTION

Over the past decade, the paradigm for undergraduate education has shifted in focus from teacher-centered to student-centered learning, which encourages the student to become more involved in facilitating the learning process and creating a positive learning environment.

An attendant challenge to this paradigm shift is to develop these constructivist environments so that the student not only comprehends the what and where and when of a topic, but is compelled to ask how and why.

One possible solution is to integrate an interactive modeling and visualization environment into the undergraduate learning structure. Such an element engages not only comprehensive thought as before, but also the analytical thought all scientists use every day.

2.   INTERACTIVITY

There exist methods to develop such modeling and visualization environments through the Internet. For instance, the Java programming language from Sun Microsystems provides one method of including the non-trivial, interactive

Figure 1: Boundary Layer Winds Interactive Model

content necessary to engage the student. It can be used in powerful ways in an endless variety of educational materials. Java's power does not only come from the exercises and interfaces, it comes also from the ability for the applets to solve equations on a local machine -- reducing server demand and providing a quicker response to changes and manipulations.

The virtual-machine concept in Java (write once and run anywhere on any operating system) along with its object-oriented nature (and the implicit reliance on the notion of reusable class libraries) makes it a highly efficient environment for developing interactive modeling tools. These tools may have similar objects, designs, and/or

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algorithms between them which can streamline Java development because the content can be shared (Plutchak, 1998). Whole applets can also be reused within different contexts -- where its purpose lends itself to multiple concept understanding. When the sophistication afforded by Java is not needed, Macromedia's Shockwave tool will be able to enhance interactivity.

3. LEARNING

It is important to remember that the tools themselves do not improve learning. Interactive tools are only a complement to the authentic activity structures that drive the inquiry.

3.1 An Example

The first interactive example developed illustrated boundary layer winds. Students can manipulate variables such as altitude, surface friction, and hemisphere and explore how the both the wind and all the forces which affect it react to these changes. Future additions will develop more interactivity and allow students to manipulate the pressure gradient and latitude. Directed questions about the interactive example can be given by the laboratory instructor to give focus to what can be learned. However, it is still the student's responsibility to explore and learn. They can try to infer what factors contribute to the wind changing directions, and even be reinforced on concepts learned earlier about subjects like Coriolis force and geostrophic wind.

Why did we choose a topic like boundary layer winds? We did so for a couple of reasons. The first is that this is a fundamental principle that is difficult to explain in a textbook -- it is often misunderstood or simply passed-off as too difficult a concept to grasp. This concept (and others like it) can benefit remarkably from the implementation of interactive elements because understanding this topic serves as a building block for more advanced processes and phenomena.

The second reason to develop this particular example is because we want to create interactive simulations on fundamental principles because the concepts learned from these simple applets are the same for multiple phenomena. Once you have an interactive illustration, it can be reused in different contexts and explanations. For example, the concept of boundary layer friction and the attendant balance of forces can be applied to other phenomena like land/sea breezes, midlatitude cyclones, and to further extent, ocean currents.

3.2 Other Efforts

Similar interactive modeling tools are already available from other geoscience education partners like Iowa State University (Yarger, 1999 -- http://www.pals.iastate.edu/), the University of Wisconsin (http://ProfHorn.meteor.wisc.edu/wxwise/), and others. However, more interactive models illustrations must be developed -- especially on fundamental topics, where their uses are more wide-ranging.

3.3 The Framework

It is recognized that it is not sufficient to simply develop all these tools and make them available online. They must be integrated into a framework that complements the interactive media with curricula and activities that support them. This provides an environment where the student discovers relationships. Relationships in the example of boundary layer winds can be how the boundary layer winds are affected by surface friction, or which forces change more dramatically with a change in altitude.

3.4 Comparison to a Textbook

An important question is just how does this compare to a picture in a textbook? For example, let's look at the sea-breeze problem. It is a highly involved three-dimensional phenomenon that in a textbook can only be described with a series of two dimensional illustrations and text. However, in a laboratory setting where the sea-breeze is being discussed, students would have the opportunity to interact with a sea-breeze model. With this model, they can explore the full sea-breeze circulation -- with the ability to adjust the model settings (e.g., different land-sea heating rates, Coriolis parameter, strength of the background on/off-shore flow) and observe the responses -- enabling the student to understand how the resulting sea-breeze structure evolves and why such responses occurred. So if done right, the interactive elements added to the curricula provide a stronger student-centered environment than one taught from a textbook.

4. IMPLEMENTATION

4.1 Initial Work

Initial implementation of these interactive models will be integrated within the existing Weather World 2010 framework (http://ww2010.atmos.uiuc.edu/) and used in a laboratory course setting. The boundary layer wind example mentioned above has been implemented and is located within the Weather World 2010 educational module on forces and winds (http://ww2010.atmos.uiuc.edu/guides/mtr/fw/home.rxml)

4.2 Future Work

Future implementation will take place inside a new learning environment called the Virtual Exploratorium (Pandya et al., 2000). This environment which focuses on "doing science" provides a consistent framework for interactive examples. The structure of this framework is like that of a pyramid, of which the foundation of the pyramid contains the fundamental principles -- the most basic laws applicable to all nature. It is on this foundation that all the other concepts and phenomena are built upon. Therefore, the benefits of developing interactive elements at this level are magnified, because their reusability can be fully exploited.

One goal of the Virtual Exploratorium is to develop a three-way integration between the interactive Java modeling environments, the educational curricula, and the real time data. By adding the real time data, a more direct link to current weather and more applicable examples are established. When the student can relate what they learn to what they've seen or read in the news, it enhances their understanding by making it more fun and real.

5. CONCLUSION

The shift from teacher-centered to student-centered learning has brought the idea encouraging scientific thought and the how's of a subject matter to the fore. Establishing interactive models for exploration can provide the student with a means to further investigate a topic and discover relationships in a manner not available in an ordinary textbook. Even though more interactive models are needed, developing a consistent framework of content and inquiries is just as important for understanding. Using both Weather World 2010 and the new Virtual Exploratorium, we plan to develop both the interactive models as well as the student-centered environment.

7. REFERENCES

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