Inquiry Learning Through Students' East-West Coast On Line Collaboration about Plate Tectonics [1]

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Introduction

This paper will briefly describe a framework, curriculum, and large scale design study involving a total of 1100 middle and high school students from California and Massachusetts who collaborated on-line about plate tectonic activity in their respective location. The students, drawn from demographically diverse schools, collaborated on-line using WISE (Web-based Science Environment, Linn & Hsi, 2000). WISE is an integrated set of software resources to engage students in many types of scientific inquiry, including prompted reflection, electronic discussions, evidence sorting and argument mapping, collaborative search for evidence, collaborative design, and analysis (Linn, 1998; Linn & Hsi, 2000).

The theoretical framework employed in this research draws principally from Model-based Teaching & Learning, put forth in a special issue of the International Journal of Science Education (Gobert & Buckley, 2000). Modelling fits within a current vein of science education which seeks to promote integrated understanding by use of model-based tasks such as, presenting students with models to learn with (Raghavan & Glaser, 1995; White & Frederiksen, 1990), or engaging them in model-building tasks (Gobert, & Clement 1994, 1999; Gobert, 1998; 1999; Penner et al., 1997; Jackson, et al., 1994). Having students critique each others' models, as in the work described here, is a novel approach to both deepening their understanding of the content (so that they may critique others' work) as well as fostering an understanding of what models are and how they are used in science (Gobert et al, 2002). It is believed that having students construct, reason with, and critique each others' models engages them in authentic scientific inquiry, and can significantly impact lifelong learning and scientific literacy (Linn & Muilenberg, 1996) by developing generative knowledge that can be intergrated across science topics and applied to real world problems, such as understanding scientific findings described by the media (Linn, 1999). Since being scientifically literate includes understanding the nature of science, as well as understanding science content and having inquiry skills (Perkins, 1986), the model-based approach here can promote all three types of science knowledge.

Domain Studied

The domain Plate Tectonics was chosen for two reasons. First, it is an excellent domain in which to investigate students' modeling skills because of the important role that model building and causal reasoning play in understanding the hidden mechanisms, e.g., convection underlying

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continental drift, earthquakes, volcanoes, mountain formation, and sea floor spreading[2]. Secondly, it is an excellent context in which to foster students' understanding of science and of models both because there are many excellent models in the domain with which to engage learners in model-based tasks, and theory of plate tectonics is a good example of the dynamic nature of science, how scientific inquiry proceeds, and how a hypothesis can be proposed, discarded, modified, and then redefined.

Plate tectonics, which is typically covered in fifth or sixth grade and then again in eighth or ninth grade is representative of a difficult school science topic. It is difficult to learn for many reasons: 1) the earth's internal layers are outside our direct experience, 2) the size scale and the unobserved processes, e.g., convection, are difficult to understand (Ault, 1984; Gobert & Clement, 1994; 1999), 3) the time scale of geological processes is difficult for people to conceptualize since it surpasses our reference of a human lifetime (Jacobi et al., 1996), and 4) it involves the comprehension and integration of several different types of information, such as, spatial, causal, and dynamic (Gobert & Clement, 1994; 1999).

We designed a curriculum unit called "What's on your plate?" around two WISE pedagogical principles, namely, Make Thinking Visible and Help Students Learn from Each Other.

Make Thinking Visible. Here, we: 1) engage students in drawing tasks to make their models explicit and use these as knowledge artifacts for both model revision as well as peer critique, and 2) provide students with a set of **dynamic, runnable models** of plate tectonic phenomena. Here, students use the runnable prototypes to visualize dynamic, causal, and temporal processes in order to test, critique, and revise their own models. WISE prompts students to justify and explain their changes in order to reify learning. Prompts to be designed include: "What does your new model include that it didn't before?", and "What does your new model describe or explain that it didn't before?"

Help Students Learn From One Another. In terms of **helping students learn from one another,** we engaged students in tasks in which they critiqued their learning partners' models from the opposite coast. We did this to provide students with an opportunity to both think deeply about the domain in order to do the critiques, as well as think about how models are used as tools for communication in science.

The "What's on your plate?" unit the students are engaged in model-based inquiry activities and tasks to learn from one another in the following ways:

1. ***Students' Model Building & Explanation of their Models***. Students were asked to construct in WISE visual models of plate tectonic-related phenomena; that is, each pair of students drew a model of how mountains are formed (East coast only) while students on the West coasts drew models of earthquake or volcanic eruption. Students were then asked to write in WISE a short explanation for their models with the following prompt "Now that you have drawn your model, write an explanation of what happens to each of the layers of the earth when an earthquake erupts (or a mountain is formed, a volcano erupts)". Once students had done these two steps, they posted their models and explanations for their learning partners on the opposite coast.

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[2] The theory of plate tectonics states that the outer layer of the earth (the crust) is broken up into slabs (the plates) which move on the partially molten layer of the earth (the mantle) due to the convective movement of hot magma in the mantle (Feather, Snyder, & Hesser, 1995; Plummer & McGeary, 1996).

2.Students' Evaluation and Critique of the Learning Partners' Models. Students read two pieces of text in WISE called "What is a Scientific Model? And "How to evaluate a model?" in order to give them some basic knowledge with which to evaluate their leaning partners' models. Then students were prompted to critique learning partners' models using prompts that were presented in WISE. The prompts include:

- 1. Are the most important features in terms of what causes this geologic process depicted in this model?
- 2. Would this model be useful to teach someone who had never studied this geologic process before?
- 3. What important features are included in this model? Explain why you gave the model this rating.
- 4. What do you think should be added to this model in order to make it better for someone who had never studied this geologic process before?

These prompts were designed to focus students' thinking about models in two general ways: the causal mechanisms/processes depicted (items 1 and 3), and the model as a communication tool to learn or reason with (items 2,and 4). Prompts similar to the latter have been successful in getting students to generate rich explanations (Gobert, 1997b), and it was believed that they might be successful here as well in getting students to think about how useful a model is as a tool for communication purposes. Once students discussed the evaluation with their in class partner (computer partner), they then posted their evaluation for their opposite coast learning partners to evaluate.

*3**. Students'Model Revision&Justification***. Students read the evaluation that was written and posted by their learning partners on the opposite coast. They were the asked to revise their models based on the critique from their learning partners as well as the content knowledge they had learned from the unit (the model-based content activities will be discussed next). They were also asked to write a revised explanation for their new models. Lastly, here students were asked to justify their changes to their models in WISE in order to engage students in reflection about how their understanding had changed. Prompts here include:

- I changed my original model of.... because it did not explain or include...."
- "My model now includes or helps explain…"
- "My model is now more useful for someone to learn from because it now includes…."
- "I revised this on the basis of my learning partners' critique in the following ways….
- **"I revised this on the basis of the activities in these WISE units….. ".**

4. ***Geology Websites***. As part of the unit students do an on-line field trip and are guided to visit multiple USGS websites with current data in order to the differences between the coasts in terms of their mountains, volcanoes, and earthquakes. After each "site visit", students write a relfection note for their learning partners on the oppoiste coast about what they have learned about earthquakes, volcanoes, and mountains on their coast. This reflection note is posted for the learning partners to read and reflect on in terms of how the data observed differ from that of their own coast.

Students also visit a Plate boundaries website in order to speculate about how the location, frequency, and magnitude of geological events (mountains, earthquakes, and volcanoes) "observed in Activity 2 are related to plate boundaries in the earth's crust. After visiting the plate boundaries website, students are asked to write a Reflection Note with the following prompt: Write one (or two) question(s) you have about plate boundaries or plate movement that will help you better understand why the geologic processes on the West and East coasts are different. Students revisit these questions in a Discussion Forum later in the unit.

*5. **Dynamic-runnable models***. These models were designed in line with previous research which has shown that visualization facilitates the understanding of dynamic phenomena (Monaghan & Clement, 1995) and that middle and high school students can understand rich dynamic concepts if provided with the appropriate scaffolds and tools (Jackson, et al., 1994; Ploger & DellaVedova, 1999; Frederiksen, White, & Gutwill, 1999).

Students view and read about the different types of plate boundaries, namely, collisional, divergent, convergent, and transform boundaries in order to begin to think about how the location of and type of plate boundary are related to geological occurences on the earth's crust. Students reify their learning by writing reflection notes about what types of geological events are typical of specific types of plate boundaries.

Students also visit a model of mantle convection which is accompanied by a text which scaffolds their understanding of the dynamic and causal features of the model by directing their processing of the causal and dynamic information in the model as it "runs". Students write a reflection note to explain how processes inside the earth relate to plate movement.

Lastly, students visit a series of dynamic models which depict different types of plate convergence, namely, oceanic-oceanic convergence, oceanic-continental convergence, and continental-continental convergence. Again, students' understanding is scaffolded via a text which directs their processing of the causal and dynamic information in each model as it "runs.

To view "What's on your Plate?"—you can either start an account for yourself, or go to an account that has already been set up (but it may have others' work in it that cannot be changed) on the computer provided. To get your own account for this unit, go to the WISE new student registration page http://wise.berkeley.edu/pages/newStudent.php Fill in with your: First name, Last name, for PERIOD, put 10, enter a password of your choice, for your student registration code, type SZP87G. Click on "go to the student portal."Or to go to an account that is already set up, go to wise.berkeley.edu, click on Member entrance, and for login enter "AnonyM1" and "try" as your password.Click on "Plate Tectonics: What's on Your Plate?".

Summary

This research utilized a state-of the art science learning environment, WISE, to promote deep learning of subject-matter in plate tectonics and model-based inquiry skills involving model critiquing and revision. Data from this large scal research project has yielded significant learning gains both in terms of students' content knowledge of Plate Tectonics as well as their understanding of the nature of models in science. As such, from these data, it appears that model-based tasks, students' critquing each others models, and students' collaboration are useful approaches to promoting learning in this domain and scientific literacy in general.

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