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ABSTRACT

Models and modeling are frequently used as instructional tools in science education to convey important information concerning both the explanatory and structural features of topic areas in science. The efficacy of models as such rests almost entirely upon students' ability to conceptualize them as abstracted "representations" of scientific phenomena. This investigation considers the relationship between students' epistemology of scientific models and their success at learning about a complex system, namely plate tectonics. Ninth-grade students were asked to draw diagrams at three specific points in a short text: (1) a static model; (2) a causal/dynamic model of the movement in the layers; and (3) an outcome in the world, i.e., volcanic eruption due to two plates moving away from one another. Students received a posttest to assess different types of knowledge, namely spatial knowledge, causal/dynamic knowledge, and knowledge through inference. Students were also administered an epistemology questionnaire to assess understanding of what a model is. Those who held more sophisticated epistemologies of science were better able to transfer what they had learned in order to reason about other plate tectonics phenomena and more difficult conceptual knowledge involved in the causal mechanisms of plate tectonics. Contains 25 references. (PVD)

The Relationship between Students' Epistemologies and Model-Based Reasoning

by
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The relationship between students' epistemologies and model-based reasoning [1]

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Introduction

Models and modeling are frequently used as instructional tools in science education to convey important information concerning both the explanatory, i.e., causal, and structural features in topic areas in science. The efficacy of models as such rests, almost entirely, upon students' ability to conceptualize models as abstracted representations of scientific phenomena; that is, to understand models as a *representation* of a scientific phenomena. The utility of models in terms of developing students as scientifically literate individuals rests on students' ability to make predictions about a given target system in the real world on the basis of these scientific models; that is, the model's *predictive power*. It is the basic thesis of this paper that the degree to which models can serve as *representations with predictive power* depends on students' epistemology or epistemological commitment to a model as an explanatory framework of the scientific phenomena under inquiry.

In recent years, there has been a resurgence of interest in students' views of knowledge and learning, or "epistemologies". Studies have addressed students' views of the nature of learning in general (Schommer, 1990, 1993) and in specific domains including science (Linn, Songer, & Lewis, 1991; Hammer, 1994a, 1995). Several studies have shown that students' epistemologies predict learning outcomes (Schommer, 1990; Songer & Linn, 1991), supporting claims that these epistemologies influence students' learning (Perkins, Jay, & Tishman, 1993; Bereiter & Scardamalia, 1989). More relevant to the present research is the finding that one's epistemology of learning has an influence on students' knowledge integration, both in learning science (Songer & Linn, 1991; Rukavina, 1991; Rukavina & Daneman, 1996) and in learning in other domains (Schommer, 1990; Schommer et al, 1992).

The issue of knowledge integration is undoubtedly an important one, and has been approached from multiple perspectives with regard to why and how it is influenced by students' epistemologies. There are two such approaches pertinent to the research presented herein. The first is that pursued by researchers in the science education tradition who investigate how students' epistemologies of science facilitate knowledge integration in specific domains (Linn & Songer, 1993; Songer & Linn, 1991). Here, one's epistemology of science as either a static list of facts to be memorized versus a dynamic system of principles to be understood was found to accompany integrated understanding in thermodynamics.

The second perspective is that pursued by researchers in the text comprehension tradition who investigate how students' epistemologies of learning in general affect the comprehension of information acquired from textual information sources. Here, one's epistemology of learning as either quick or not-at-all, and their epistemology of the nature of knowledge as either simple or complex were found to positively affect comprehension tasks that tap memory for both discrete facts and integrated knowledge in some studies (Schommer, 1990; Schommer et al, 1992), and were found to affect comprehension for integrated knowledge only in other studies (Rukavina, 1991; Rukavina & Daneman, 1996).

Each perspective offers insight about learning and knowledge integration. The latter, the text comprehension approach, differs from the science education approach in that a text is used to convey information to students and learning and knowledge integration are defined and measured in terms of

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patterns of recall and conceptual post-test questions. In the science education approach, multiple instructional methods are used (e.g., curriculum units, computers as "lab partners", etc.; Songer & Linn, 1991), and integration is defined more broadly by conceptual post-instruction inventories.

In the present study, we argue that these two approaches are more complementary than one would first assume. The goal of the present research is to build on and integrate the research from the two perspectives by examining knowledge integration by invoking the construct of mental models (Johnson-Laird, 1980; Kintsch, 1986). That is, we are arguing that mental models can be seen as the unifying structures being referred to as "integrated knowledge" by other researchers (Songer & Linn, 1991; Rukavina & Daneman, 1996). In invoking mental models as explanatory constructs, we are arguing that the processes of integration are similar, at least in part, to the processes which are being used in text comprehension. Succinctly stated, knowledge integration *is* mental model construction.

Our research differs from many other studies of epistemology (Hammer, 1995; Songer & Linn, 1991; Rukavina & Daneman, 1996; Schommer, 1990; Schommer et al, 1992) in that we are defining this term in a slightly more narrow way. We are specifically interested in the nature of students' epistemologies of scientific models, as opposed to epistemologies of the nature of learning (cf., Schommer, 1990; Schommer, 1993) or the nature of science (Songer & Linn, 1991). In doing so, we have adapted Grosslight et al's (1991) questionnaire to assess students' conceptions of scientific models. This will be discussed in more detail later in the paper.

In the research to be presented, we investigated the relationship between students' epistemology of scientific models and their success at learning about a complex system, namely, plate tectonics. Plate tectonics was chosen as the domain of study because models are conventionally used in this domain in order to describe the explanatory mechanisms underlying plate tectonic phenomena (e.g., convection) which are beyond direct experience. Briefly, the theory of plate tectonics proposes 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 slow convective movement of hot magma in the mantle. This topic is usually covered in many grades, typically at Grade 5 and then again at Grade 8 or 9.

METHOD

Purpose of the Study

We sought to examine whether students with a sophisticated epistemology of scientific models as opposed to those with a more simplistic epistemology of scientific models would construct more detailed and integrated diagrammatic models of plate tectonic phenomena. That is, whether students' understanding of scientific models (sophisticated or naive) would affect the nature of the diagrammatic models they construct in the domain of plate tectonics. Additionally, we were interested in assessing whether holding a more sophisticated view of scientific models might allow students to make richer inferences on the basis of these models, once constructed. Our rationale for inference measures is based on the notion that "deep" or "rich" knowledge is transferable to other tasks, as compared to "inert" (Bereiter & Scardamalia, 1985) or "static" knowledge (Songer, 1989) which typically is not transferable.

Subjects

As an initial exploration of this hypothesis, one class of grade 9 students participated (23 students in total); the class was selected from a high school located in the mid-west.

The Learning Task

The students were given a short text (about 2 pages). The learning condition was the same for all students; that is, the students were asked to draw diagrams at three specific points in the text. In each case, the students were asked to include and label as much information that they could "so that a friend who had never heard of this could learn about it."

The diagrams which were requested were:

1) -- depict only static/spatial information (i.e., the different layers of the earth)
2)-- depict the dynamic movement/processes which are occurring in these layers
3) --depict/summarize what happens in the layers of the earth when volcanoes erupt due to two plates moving away from one another.

These diagram tasks which have been previously used as learning tasks (Gobert & Clement, 1994; Gobert, 1995, 1997) present a learnable progression of models: a static model first, followed by a causal/dynamic model of the movement/processes in the layers, and lastly an outcome in the world, i.e., volcanic eruption due to two plates moving away from one another. The focus here then is on scaffolding students' model-building processes (White, 1993; Raghavan & Glaser, 1993) on the basis of progressively more complex diagrams constructed by the learner in which first a static/spatial model is constructed, and then is annotated with causal and dynamic knowledge.

Post-test on Plate Tectonics

A written post-test was then administered with three types of activities:

1) multiple choice and short answer questions assessing both knowledge of static as well as causal/dynamic aspects of the domain. An example of a question assessing static knowledge is: "Where is the thinnest part of the crust?". An example of a question assessing causal and dynamic knowledge is: "The movement in the crust of the earth is caused by. . .?"

2) two diagram tasks (student-generated) assessing two aspects of the students' visual model of plate tectonics: 1) the static features of the domain, and 2) causal and dynamic features of the domain.

3) four written inference questions which required that students to transfer what they had learned to explain:
a) ..... why & how earthquakes are formed (another phenomena caused by plate tectonics);
b) ..... what convection zones are;
c) ..... what subduction zones are and where they occur;
d) ..... the difference between volcanic eruption caused by plates moving apart and that which is caused by an ocean plate and a continental plate colliding.

All of the post-test items were then categorized by the type of knowledge they assessed, namely, spatial knowledge, causal/dynamic knowledge, or knowledge gained through inference. All subsequent analyses were performed using these three types of knowledge as dependent variables.

Thus, from this post-test, there are two sets of quantitative data, namely,
i) the diagrams which were generated during the reading of the text (analyses on-going; not going to be presented herein), and
ii) their performance on the post-test, namely, their scores on spatial knowledge, causal and dynamic knowledge, and knowledge acquired through inference.

Epistemology Assessment

The epistemology questionnaire was adapted from a questionnaire by Grosslight et al (1991). The purpose of the questionnaire was to describe students' understanding of what a model is and what it is used for. The first three questions, following Grosslight et al were: "What comes to mind when you hear the word model?", "How would you describe a model to someone who didn't know what a model is?" and "What are models used for?" These questions were used to find out what students' understanding of a model is and how it is used. After eliciting students' knowledge of what a model is, they were presented with a model of the water cycle. The reason for presenting the water cycle was that many students in Grosslight et al focused on models as people or things and not as representations. This may have been because students do not associate the word model with the models that they use in the classroom. That is, the students may understand what a model is and what it is used for, but may not actually use the word "model" to describe these tools. Students were then given a model of the water cycle and asked "Can this be considered a model?" , and "Could you use this as a model? If so, how?". These questions sought to assess students' understanding of how the word model, in their understanding, might relate to the water cycle model presented. Finally, following Grosslight et al, the students were asked about how models are designed and created, whether a model could be changed, and if there could be multiple models of the same phenomena.

Scoring of the Epistemology Questionnaire

The scoring deviates from the coding scheme of Grosslight et al. (1991). The main goal of the Grosslight et al study was to describe students' epistemologies of scientific models. In this study, we sought to rate the answers according to the following scheme. All questions were scored on scale of 0 to 2, 0 to 3, or 0 to 4 (depending on the question). The students' responses were scored in terms of the degree of their understanding of a model as a representation of an idea or how something functions. A score of zero was given when students answered with a naive conception of models, e.g., that models are merely small replicas of objects. A high score reflected an advanced conception of models, e.g., that models are used to reflector explain how something functions.

The first five questions sought to assess students' understanding of what a model is and what it may be used for. A low score was given to students who viewed models as physical objects such as model airplanes or cars. A high score for these questions would be given when students explained models to be representations of an idea or how things work and are used to instruct, show, understand or explain how something works. In the case of the diagram of the water cycle, a high score was given to students explaining that the water cycle model could be used as a model to show how the water cycle works. The following is a representation of the scoring categories and representative data from that category.

Question 1: What comes to mind when you hear the word model?

Score & Description	ID	Example
0 : Models are people.	37	"Nikki Taylor"
	39	"I think of Pamela Anderson"
1: Examples of models like "model airplane, with no explanation of how this is model-like.	26	"It's a smaller scale figure of something"
	61	"a smaller version of the real thing"
2: Models are representations	1	"Something you can use to show an example of something"
	8	"A 3-D picture of the land"
	10	"I think of many things, a model car, a science fair model, or a super model like Cindy Crawford. But they are all visually representing something".
3: Models show how something works	2	"An object that visually describes a report, publication, or writing. It could be a 3-D model or computer animated, or anything visual that you can touch and you could show how something works"
	36	"a hands on plastic thing that shows you how something works - like a model of a heart or something. It could also be a picture or a diagram."

Question 2: How would you describe a model to someone who didn't know what a model is?

Score & Description	ID	Example
0 : Models are people.	39	"A good looking gal"
	63	"It is a person who shows off clothes for an advertisement bit"
1: Examples of models like "model airplane, with no explanation of how this is model-like.	26	"I would say its a building of something that is exact but smaller"
	61	It looks the same, but it is smaller"
2: Models are representations	1	"It is smaller than the real thing and is used to show an idea or an example"
	8	""It is a 3-D picture of mountains or something"
	10	"It is something that visually as well as physically represents something"
3: Models show how something works	2	"An object that describes visually a report or some writing, something you can touch and show how something works"
	38	"An object that shows you what something is supposed to look like or how something works"

Question 3: What are models used for?

Score & Description	ID	Example
0: Showing clothes, like a clothing model	39	"to give products more sex appeal"
	63	"to show off clothes""
1: Decoration, models as playthings or something to look at.	32	"To show something or demonstrate a project"
	61	"visual aids"
2: Replicas to show features that you might not see because of scale	8	"To show you a smaller scale size of something"
	10	"To physically as well as visually represent something"
3: Explain how something works, demonstrate an idea or assist in instruction.	35	"Models are used as a better explanation to people so they can understand a situation better"
	1	"to show an idea"

Question 4: Students are given a diagrammatic model of the water cycle and asked: Can this be considered a model?

Score & Description	ID	Example
0: No	35	"No, a model must be 3-D"
0.5: Yes, but gives no other information.		
1: Yes and claims that the model is a replica.	5	yes, its a model picture of the water cycle"
	66	"yes, its a picture or diagram of something"
2: Yes and give the reason that the model shows the water cycle.	52	"yes, it can be 3-D or on paper. It explains the water cycle"
	64	"yes because it's an example of the water cycle and how it works"

Question 5: In reference to the model of the water cycle students are asked: Could you use this as a model? If so, how?

Score & Description	ID	Example
0: No		
0.5: Yes, but gives no other information.		
1: Yes and claims that the model is a replica.	5	"yes, its a model picture of the water cycle"
2: Yes and give the reason that the model shows the water cycle.	63	"Yes. Follow the arrows and it shows the cycle it runs"
	2	"Yes. You could show how the water cycle works and how runoff works".

In the second half of the questionnaire, questions were used to rate students' understanding of how models are built and changed. The first two questions relate to model building and designing. Again, high scores are given to students whose answers reflect an understanding of models as representations. For example, students' understanding of how close a model should be to the real thing and what to include when making a model originates from the idea that the model should be identical to the real object (physical view) to the model should be close enough to be able to understand the idea (abstract view). Questions 7 and 8 ask the students to consider whether a single model is absolute; that is, can there be more than one model for a situation and can that model change? Students with the understanding that models are a representation tend to answer that there are multiple models and that models are changeable. If a model is a representation, then models are based on a person's understanding of the situation or idea. In this case, it is clear that there can be more than one idea of how something works and that the underlying idea can change. On the other end of the continuum, students who believed that models are exact replicas of the "real" thing focused on physical differences. For example, there can be multiple physical models if the person developing the model is looking at the object from a different point of view or that they are looking at different parts of the object. Also, these physical models can be changed if something about the situation changes. For example, if the student's model is a globe then it might be changed if something happens to the land. The following shows more specifically how the questions were scored along this continuum from physical to abstract models along with examples from the questionnaire.

Question 6: How close does a model have to be to the real thing?

Score & Description	ID	Example
1: Exact.	2	"Pretty close, if not exact. If you publish it, it must be <u>very</u> exact, so nobody can disprove you"
	61	every way except for size"
2: As close as possible.	1	"as close as it can be"
	36	"In order for you to get something out of a model, it has to be really close to the real thing. If it is not, you won't understand it and will be confused".
3: Just what is important to how the object works.	53	"Only to the point where it gives the correct information and also so it shows what the object, thing, idea or person looks like"
	6	"It has to be able to show the idea clearly"

Question 7: How do you know what to include in a model?

Score & Description	ID	Example
1: Everything	26	"A model should be an exact replica"
2: As close as possible.	8	"everything about your model so you can tell what you are making"
3: Just what is important to how the object works.	53	"Whatever information will tell the consumer, production managers or others what is does and what it looks like"
	1	"The things you need to show or explain to someone"

Question 8: Can scientists have more than one model for the same thing?

Score & Description	ID	Example
0: No		
1: Yes, no explanation		
2: Yes, there are different perspectives of the same system	61	"yes, different versions"
	25	yes, they can show different sides and shapes of the same thing only if it is a model"
3: Yes, there are different aspects of the same system.	36	"Yes, scientists can have more than one model for the same thing. You can include different parts, or just show it differently"
	10	"Yes, it could show different perspectives or different layers"
4: Yes, there are different ideas about what it looks like or how it works.	53	"Yes, cause different scientists are entitled to different ideas on what things looks like and how they work"
	1	"Yes because of different information"

Question 9: Are there instances that would require this model or any model to be changed? If yes, what are they?

Score & Description	ID	Example
0: No		
1: Yes, no explanation		
2: Yes, if something physically changes about the object modeled	61	"Yes, if the product is changed"
	8	"The thing that the model is could change"
	20	"Yes, such things as earthquakes, tornadoes, floods, etc.".
3: Yes, new information is found to change beliefs.	53	"Yes, changes in data or beliefs"
	10	"Yes, knew findings and other scientific things".
	2	"Yes, new theories or evidences being proved otherwise"

The scores on the epistemology questionnaire were totaled for each student. The students were divided into two groups based on a median split, one group reflecting a naive perspective on the nature of scientific models, and one group reflecting a sophisticated perspective on the nature of epistemological models (as described above). The naive group's scores on the epistemology questionnaire were between 2 and 13 points out of a total of 26 points. The sophisticated group's scores were between 15 and 26 points, again, out of a total of 26 points.

Analyses of variance were conducted on the two epistemology groups in order to ascertain: 1) whether those with a sophisticated (versus naive) epistemology of scientific models were better able to construct diagrammatic models of plate tectonics phenomena, as measured by the spatial, and causal and dynamic dependent measures assessed by the plate tectonics questionnaire, and

2) whether those with a sophisticated (versus naive) epistemology of scientific models were better able to make inferences from these models, once constructed, as measured by the inference questions assessed by the plate tectonics questionnaire.

RESULTS

Three analyses of variance were conducted; one for each of the three dependent measures: spatial knowledge, causal & dynamic knowledge, and knowledge acquired through inference. Each will be discussed in turn.

Analyses for understanding of the spatial aspects of the domain.

There were no significant differences found between the naive epistemology group and the sophisticated epistemology group on their understanding of the spatial/static aspects of the domain (F=.001, p= .98). Table 1 below summarizes the means and standard deviations.

Table 1. Group means for understanding of spatial/static aspects of the domain.

Group	Mean	St. dev.
Naive Epistemology (n=10)	6.30	3.2
Sophisticated Epistemology (n=9)	6.33	3.1

Analyses for understanding of the causal and dynamic aspects of the domain.

There were no significant differences found between the naive epistemology group and the sophisticated epistemology group on their understanding of the causal and dynamic aspects of the domain (F=.075, p= .79). Table 2 below summarizes the means and standard deviations.

Table 2. Group means for understanding of causal and dynamic aspects of the domain.

Group	Mean	St. dev.
Naive Epistemology (n=10)	11.90	5.2
Sophisticated Epistemology (n=9)	12.67	6.9

Analyses for knowledge transfer or inference.

There was a significant difference found between the naive epistemology group and the sophisticated epistemology group on their knowledge acquired through inference on the basis of their models (F=4.7, p= .045) in which it was found that those with a sophisticated epistemology of science and scientific models outperformed those with a naive epistemology of science and scientific models in terms of their ability to transfer what they had learned in order to make rich inferences about: why & how earthquakes happen, what convection currents are, what subduction zones are and where they occur, and the difference between volcanic eruption caused by plates moving apart versus volcanic eruption caused by the movement of an ocean plate and a continental plate. Table 3 below summarizes the means and standard deviations.

Table 3. Group means for inference or knowledge transfer.

Group	Mean	St. dev.
Naive Epistemology (n=10)	2.40	2.6
Sophisticated Epistemology (n=9)	5.67	3.9

Protocol Data from Epistemologically-Naive versus Epistemologically-Sophisticated Students on the Inference or Knowledge Transfer Questions.

Question 10: Can you use what you have learned today to explain why and how earthquakes happen?

ID	**Epistemologically-Naive Students** (epist. score </= 13)	ID	**Epistemologically-Sophisticated Students** (epist. score >/= 15)
61	"earthquakes happen when two plates collide"-- score = 1	50	"Yes, the earthquakes happen when the plates collide and the magma comes up. When the plates collide they push rock up with great force"-- score = 3
56	"if you want to know how the earthquakes started you can find out from the ocean noise" score = 1	2	"Yes, they occur when the Earth's plates collide or rub against each other, creating friction and heat. Since friction creates energy, the energy must be released, and some times very quickly. Like when a plate buckles and snaps from the energy, other plates fight to fill its space. The energy was released and caused other plates around it to move, causing the shaking of the Earth."-- score = 4

Question 11 - Can you explain what convection currents in the earth are?

ID	**Epistemologically-Naive Students** (epist. score </= 13)	ID	**Epistemologically-Sophisticated Students** (epist. score >/= 15)
32	"the moving hot magma in the mantle is what convection currents"-- score = 1	55	"Convection currents are when magma pulls the plates down and makes them sink down. Then the plates turn to magma." -- score = 4
24	"The cycle is involving, heating, rising, cooling and sinking. Circular pattern; magma currents." -- score = 2	38	"Convection currents in the earth are the movement of plates in the earth's crust due to the movement of lava. The lava is the convection cause as the heat from the core makes hot lava rise and cool magma fall. The cool magma is then heated and moves up while the now colder magma goes down. This circular motion is called convection." --score = 6

Question 12 - Can you explain what subduction zones are and where they occur?

ID	Epistemologically-Naive Students (epist. score </= 13)	ID	Epistemologically-Sophisticated Students (epist. score >/= 15)
58	"In the ocean"-- score = 1	55	"Subduction zones are when ocean plates and land plates collide. The ocean plate is a lot denser so it sinks." -- score = 2
54	"Subduction zones are when a continental plate collides with an ocean plate. They occur on the coast." -- score = 1	2	"Subduction zones are places where the ocean has dropped its sea floor due to the collision of another plate, and molten rock takes the place of the abolished floor." --score = 3

Question 13 - Can you explain the difference between volcanic eruption which is caused by two plates moving apart and volcanic eruption which is caused by an ocean plate and a continental plate colliding?

ID	Epistemologically-Naive Students (epist. score </= 13)	ID	Epistemologically-Sophisticated Students (epist. score >/= 15)
9	"moving a part cases a plate to relese preser and comeing together causes pressure."-- score = 0.5	55	"Two plates moving together are pushed up and two plates moving apart the magma just goes between them. When an ocean plate and a continental plate collide, the ocean plate sinks down and becomes magma because of the heat and pressure." -- score = 6
37	"one is going one way and the other is going the other way." -- score = 1	50	"An eruption with two plates moving apart is just the lava coming between the plates. An eruption with an ocean plate and continental plate is when two plates collide. The ocean one gets pushed under the continental. The ocean one gets melted into magma causing there to be too much, making it find a fault in the crust to get the extra released." --score = 6

DISCUSSION

The purpose of this study was twofold: 1) to ascertain whether those with a more sophisticated epistemology of scientific models were better able to construct diagrammatic models of plate tectonic phenomena than their peers who held naive views of scientific models, and 2) to assess whether those with more sophisticated views of scientific models could make richer inferences on the basis of their models once constructed than their peers who held naive views of scientific models.

With regard to model-building, two dependent measure were used: students' spatial understanding of the layers of the earth, and their causal and dynamic understanding of the processes causing plate tectonic phenomena. No significant differences were found between those holding with a more sophisticated epistemology of scientific models and those holding naive views of scientific models. However, since all students were given the same learning task, i.e., the construction of diagrammatic models at specific points in the text, and previous research has found that these particular diagramming tasks promote rich model-building in students (Gobert & Clement, 1995; Gobert, 1997), it is possible that potential differences in model-building due to differences in epistemology were washed out. That is, the task of generating diagrammatic models served as a compensatory function for those with naive epistemologies of scientific models, i.e., these students may not naturally seek to integrate their knowledge and construct rich models, but the task directed them to do so. Previous research has shown that presenting an organizing structure or learning task can facilitate knowledge integration by promoting a strategy for learning that they may not have otherwise used (Alexander & Judy, 1988; Ostero & Kintsch, 1992). In one study in particular, presenting students who held naive epistemologies of learning with an integrated text lead these students to answer high-level questions similar to their epistemologically-sophisticated counterparts (Rukavina & Daneman). Follow-up research will be needed in order to assess whether the task of generating diagrammatic models served as compensatory function for those with naive epistemologies of scientific models.

With regard to inference-making with their models, these data suggest that those who held more sophisticated epistemologies of science were better able to transfer what they had learned in order to reason about other plate tectonics phenomena and more difficult conceptual knowledge involved in the causal mechanisms of plate tectonics (i.e., convection). Questions used to assess this were: a) explain why & how earthquakes are formed (another phenomena caused by plate tectonics); b) explain what convection zones are; c) explain what subduction zones are and where they occur; and d) explain the difference between volcanic eruption caused by plates moving apart and that which is caused by an ocean plate and a continental plate colliding. These data are consistent with studies of the effects of epistemology on integration of textual material (Rukavina, 1991; Rukavina & Daneman, 1996) and those assessing the effects of epistemology on integration of scientific principles (Songer & Linn, 1991).

Additional analyses of existing data is on-going to assess potential differences between the high and low-epistemology groups in terms of the processes used in constructing the diagrams during the reading of the text. As previously said, whether or not differences here on the basis of epistemology are borne out, additional research is needed using a variety of learning tasks in order to assess whether certain tasks serve a compensatory function for those lacking integration skills or a sophisticated epistemology of scientific models. If certain tasks appear to compensate for one's naive epistemology of science, these tasks could be used successfully in instruction. Instruction with regard to the nature of science and scientific models as well may facilitate such knowledge integration in this domain (Linn & Songer, 1993).

The approach presented in this research seeks to integrate text comprehension and science education approaches to the issue of students' epistemology and its effect on knowledge integration as both which offer insight into the complex problem of learning. This approach draws on both the process and product of science learning (Gilbert, 1991) while incorporating the important issue of one's view of science models and what they stand for.

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