Harnessing technology to support on-line model building and peer collaboration [1]

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Summary

A large scale design study in which 3000 middle and high school students from California and Massachusetts collaborated on-line about plate tectonic activity in their respective location. The students, demographically diverse, participated in this curriculum using WISE, Web-based Inquiry Science Environment (Linn, 1998), an integrated set of software resources designed to engage students in rich inquiry activities.

The curriculum engaged students in many inquiry-oriented, model-based activities. For example, students were scaffolded by WISE as they: a) drew initial models of plate tectonic phenomena in their respective area using WISE; b) wrote explanations of their models and shared their models and explanations with students on the opposite coast (east vs. west); c) were scaffolded to critique their peers' models; d) revised their models based on this feedback; and e) discussed the differences between E and W coast geology in an on-line forum.

Data analysis focussed on measuring content gainsand characterizing the nature of students' models and model revisions, as well as their discourse. Results suggest that this curriculum was successful in fostering deep content learning. The task of evaluating and critiquing their peers' models provides some insight into students' learning.

Grounded in research in Science Education and Cognitive Science

The "What's on your plate?" curriculum is based on students' misconceptions of plate tectonics of both the inside structure of the earth and of the causal mechanisms underlying plate tectonic-related phenomena (Gobert & Clement, 1999; Gobert, 2000), as well as students' knowledge integration difficulties (Gobert & Clement, 1994). It emphasizes students' active model-building and scaffolded interpretation of rich visualizations (Kindfield, 1993; Gobert & Clement, 1999; Gobert, 2000; Gobert & Buckley, in prep.) as strategies to promote deep learning. The curriculum is implemented in WISE (Web-based Inquiry Science Environment) developed by Marcia Linn & Jim Slotta at UC-Berkeley, which is based on 15 years of research in science education (Linn & Hsi, 2000).

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Previous cognitive research on Earth Science

There has been some previous cognitively-oriented work on earth science in general , including:

- the earth as a cosmic body (Vosniadou & Brewer, 1992; Nussbaum, 1979, Nussbaum & Novak, 1976; Sneider & Pulos, 1983);
- knowledge of rock-cycle processes (Stofflett, 1994);
- conceptions of earth and space as it relates to seasons and phases of the moon, (Schoon, 1992; Bisard et al, 1994);
- sea floor dynamics (Bencloski and Heyl, 1985);
- earth's gravitational field (Arnold, Sarge, and Worrall, 1995);
- misconceptions about mountain formation (Muthukrishna, et al., 1993); and
- modeling the geosphere, hydrosphere, atmosphere, and biosphere (Tallon & Audet, 1999);

As well, there has been previous research on misconceptions in Plate tectonics in particular, including:

- Ross & Shuell (1993) investigated children from K - 6th grade regarding their beliefs about the causes of earthquakes. Responses included: "the core gets too hot and hits the surface of the earth"; "the earth is letting out air like a sneeze"; and "earthquakes are caused by the wind, thunder and rain, or by mountains".
- Asked about what happens below the surface when there is an earthquake, again, a large proportion of the children answered that they did not know. Responses included: "roots underground pop"; "the plants might get "screwed up" because the seeds would jiggle around"; and "the earth has too much energy just like children who need to get rid of it".
- 1450 adults interviewed from southern California, many held the misconception that earthquakes could be predicted by "earthquake weather" (Turner, Nigg, & Daz, 1986).
- Research with graduate students in geology showed that many students at this level in their education still do not understand geologic time (Jacobi et al, 1996).

This research, where relevant, was used to inform pilot studies as background to design of the "What's on your plate?" curriculum. A study of students' learning difficulties in this domain (Gobert, 2000 & Gobert & Clement, 1994, 1999) yielded three main difficulties in students' model construction processes:
(1) problems with setting up a correct <u>static model</u> of the layers,
(2) difficulty understanding <u>causal and dynamic information</u>
(e.g., heat as causal in forming convection currents, or currents causing plate movement), and
(3) difficulties with the <u>integration</u> of several different types of knowledge including causal and dynamic knowledge into a causal chain in order to build an integrated mental model of the system.

Each of the three difficulties outlined above has different ramifications on model construction and revision processes, as well as the transfer and inference-making afforded on the basis of the model (for more detail, see Gobert, 2000).

See figure 1 for students' typical models of structure of earth (Gobert, 2000). See figure 2 for students' typical models of volcanic eruption (Gobert, 2000).

In addition, other research literature informed the design of the curriculum, namely, we drew on current findings from:

- causal models (White, 1993; Schauble et al, 1991; Raghavan & Glaser, 1995),
- model-based teaching and learning (Gilbert, S., 1991; Gilbert, J. 1993);
- model revising (Clement, 1993; Stewart & Hafner, 1991);
- diagram generation and comprehension (Gobert, 1994; Gobert & Frederiksen, 1988; Kindfield, 1993; Larkin & Simon, 1987; Lowe, 1989),
- the integration of text and diagrams (Hegarty & Just, 1993), and
- text comprehension (van Dijk & Kintsch, 1983; Kintsch, 1998).

Student Difficulty in Learning from Models

Previously it was thought that diagrams and models would facilitate students' understanding of difficult science concepts simply by "adding" a diagram or a model to the textbook's textual materials. However, research has shown that simply adding diagrams and models did not facilitate learning because it increased cognitive load on learners (Sweller, et al, 1990). Also, students lack the necessary domain knowledge in order to guide their search processes through diagrams/models in order to understand the relevant spatial, causal, dynamic, and temporal information (Lowe, 1989; Head, 1984; Gobert, 1994; Gobert & Clement, 1999). In particular, learning from models requires scaffolding of:

- search processes for acquiring rich spatial, dynamic, causal, and temporal information from models (especially with models in which all information is presented simultaneously).
- perceptual cues afforded by models in order to promote deep understanding.
- inference-making with models, again, to promote deep understanding (adapted from Larkin & Simon, 1987). For a fuller description of model-based teaching & learning (Gobert & Buckley, 2000).

Scaffolding Framework for Learning with Models in "What's on your plate?"

In the Making Thinking Visible project, we supported East and West coast students' collaborative on-line learning of plate tectonics using WISE (Web-based Inquiry Science Environment; Linn & Hsi, 2000).

The goal of the curriculum is that student learn:

- Content knowledge of the spatial, causal, dynamic, and temporal features underlying plate tectonics (data presented here).
- Inquiry skills for model-building and visualization (not presented here).

Epistemological understanding of the nature of scientific models (Gobert & Pallant, in press; (not presented here). Papers available at mtv.concord.org.

Overview of Model-based activities and scaffolding for unit: "What's on your plate?" (To see the unit, go to wise.berkeley.edu, click on Member entrance, and for login enter "TryA1" and “wise” as your password. Click on “Plate Tectonics: What’s on Your Plate?”).

- Draw, in WISE, their own models of plate tectonics phenomena.
- Participate in an on-line “field trip” to explore differences between the East and West coast in terms of earthquakes, volcanoes, mountains (beginning with the most salient differences).
- Pose a question about their current understanding (to support knowledge integration and model-building)
- Learn about location of earth’s plates (to scaffold relationship between plate boundaries anf plate tectonic phenomena).
- Reify important spatial and dynamic knowledge (integration of pieces of model) about transform, divergent, collisional, and convergent boundaries.
- Learn about causal mechanisms involved in plate tectonics, i.e., convection & subduction (scaffolded by reflection activities to integrate spatial, causal, dynamic, and temporal aspects of the domain).
- Learn to critically evaluate their peers’ models which in turn serves to help them think critically about their own models.
- Engage in model revision based on their peers’ critique of their model and what they have learned in the unit.
- Scaffolded reflection task to reify model revision which prompt them to reflect on how their model was changed and what it now helps explain. Prompts are:
  - “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….”
- Reflect and reify what they have learned by reviewing and summarizing responses to the questions they posed in Activity 3.
- Transfer what they have learned in the unit to answer intriguing points:
  - Why are there mountains on the East coast when there is no plate boundary there?
  - How will the coast of California look in the future?

METHOD

Participants. Approximately 1110 students participated in the Spring 2001 implementation of “What’s on your Plate?” These were drawn from 34 middle and high school classrooms across California and Massachusetts. From this large data set, data from 15 middle school classrooms was chosen for this paper; this represents data from three different teachers (1 in California and 2 in Massachusetts) each with five Science classes. The total number of students upon which this subset is based is approximately 360.

Procedure. Students were given a pencil and paper survey to assess both their content knowledge of the plate tectonics and their understanding of the nature of models both (this data is not described here); the same test was given before and after.

RESULTS & DISCUSSION

Pairs of students from one class on the West coast were partnered with pairs from two classes on the East coast because of the differences in class sizes. Five such sets or “virtual classrooms” (referred to as WISE periods) were created in WISE.

Data analysis. The data analysis is described in three parts. The first part describes the increases made in students’ understanding of the content as measured by pre-post gains. The second part provides some examples of students’ original models, their opposite coast partners’ critique, and the subsequent model revision.

Part. 1: Analysis of Variance of WISE periods 1-5 for content learning.

Analysis of variance was used on the total pre- and post-score on the content survey and computed for each WISE period (1-5). Again, since this is a design study, we are not comparing these groups to a control group, rather the goal is to iteratively revise the curriculum in response to data yielded. Thus, the purpose of the analyis of variance for content understanding is to get a general measure of whether the students’ understanding of the domain (as measured by the post-test) changed as a result the unit. It is also important to note that the teachers used the pre- and post-test scores for students’ grade on the unit; in this way, the implementation is also authentic.

In all of the WISE periods, the students made a significant gain on the post-test collapsing over teacher, meaning that all WISE periods acquired knowledge during the implementation of the “What’s on your plate?” unit. See Table 1 below for a summary of these findings.

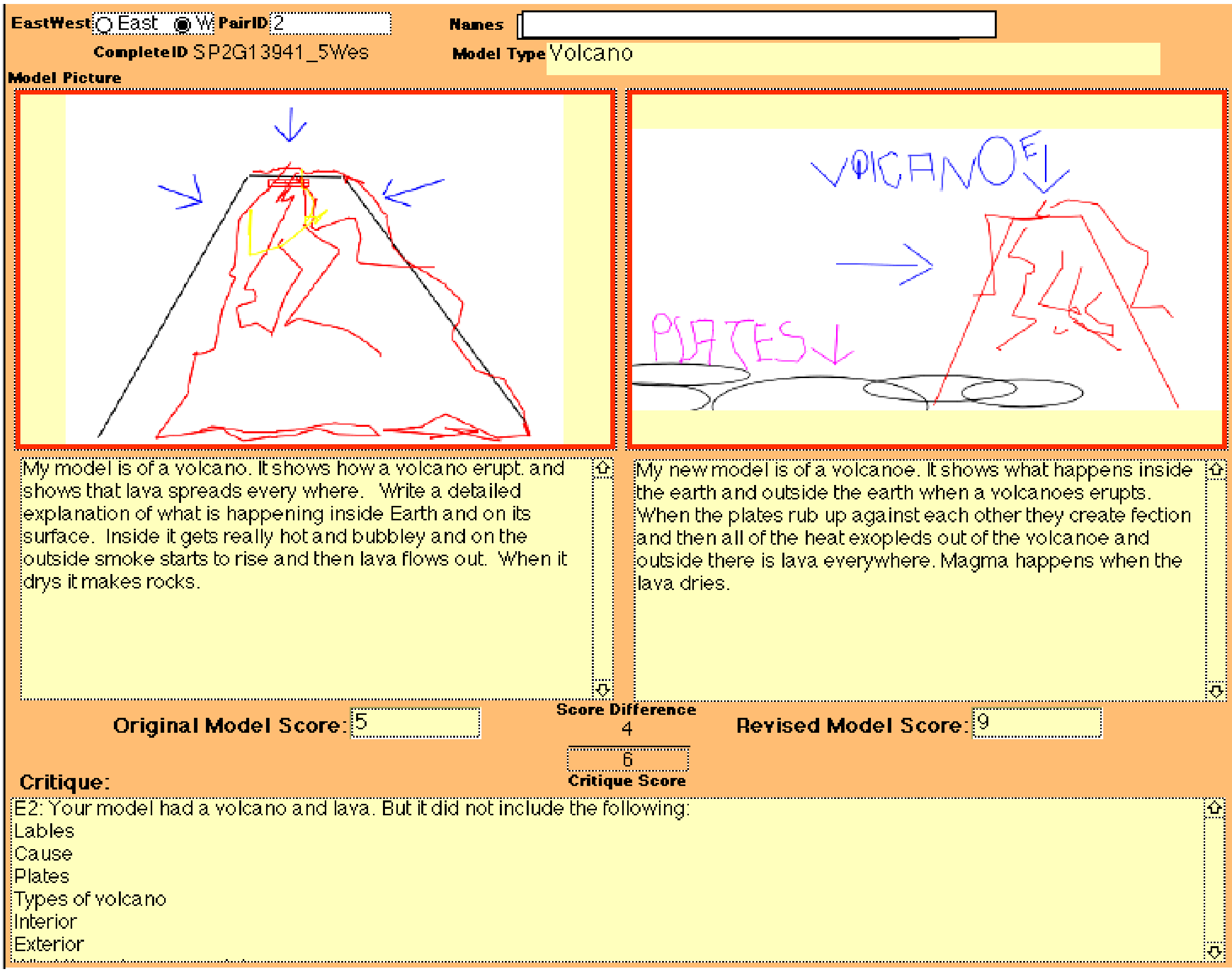
Table 1. Summary of Content Gains for each WISE Period

	F value	**p value**
WISE Period 1	44.982	<.0001
WISE Period 2	39.473	<.0001
WISE Period 3	26.654	<.0001
WISE Period 4	25.019	<.0001
WISE Period 5	18.220	<.0001

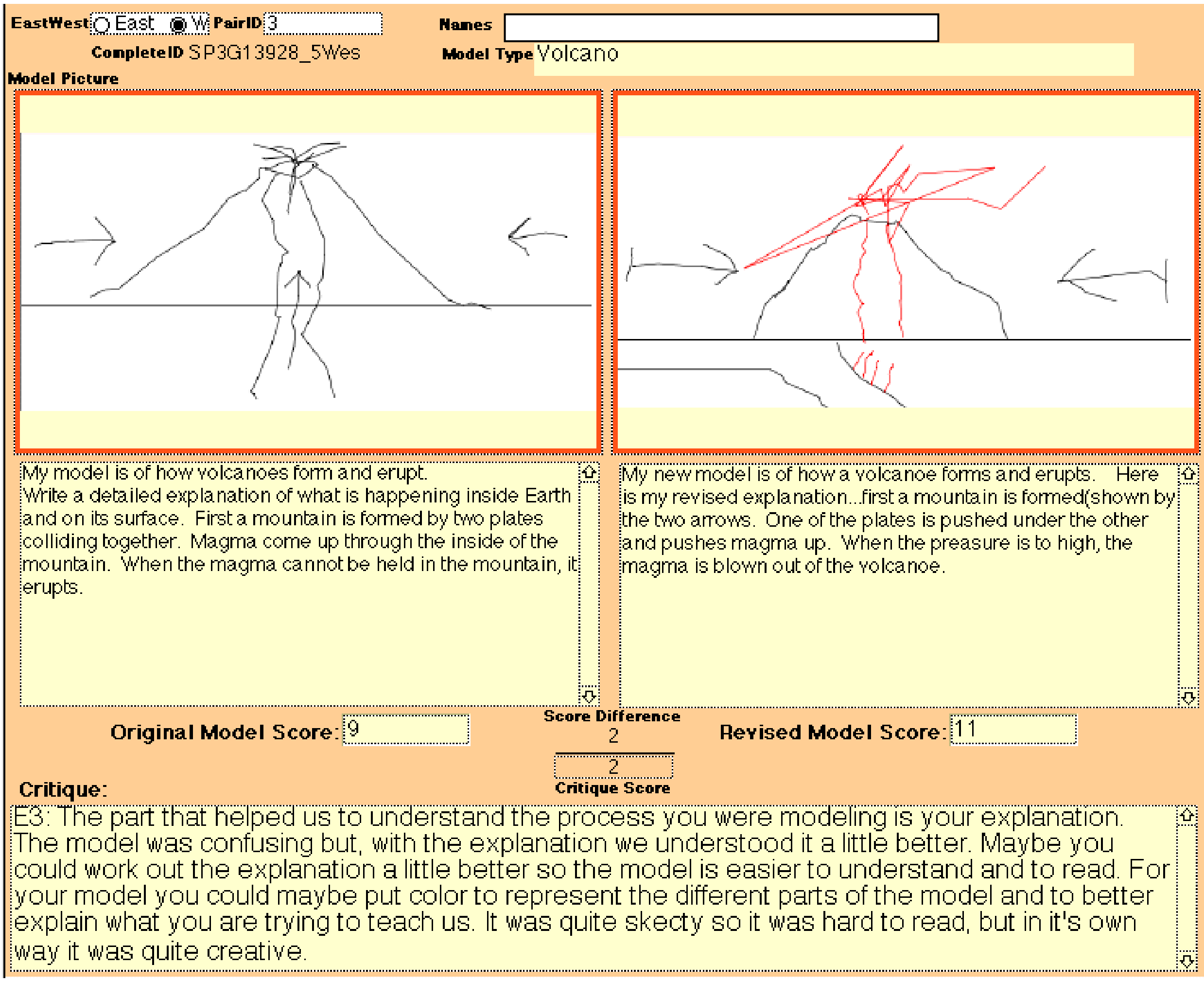
Figures showing the pre-post differences, etc. can be found in the Appendix.

Part. 2: **Examples of Students’ Original Models, Peer Critique, and Model Revision.**

From this large data set, we selected some examples to get a sense of the types of critiques students were writing for their peers and how these critiques influenced students’ model revision. In the following examples, the model on the left is the students’ original model and explanation. On the bottom under “Critique” is their opposite coast learning partners’ critique of the model. On the right are students’ revised models and revised explanations.



In this example, the students drew a model of volcanic eruption which includes only the crustal layer of the earth; that is, the inside layers of the earth are not depicted, nor are there any internal causal mechanisms responsible for volcanic eruption included in either the model or explanation. This type a model is called a "local" model and is consistent with previous research in this domain which showed that many students of this age group have models of plate tectonic phenomena which only include processes on the surface of the earth, i.e., they do not include the processes and mechanisms inside the earth (Gobert, 2000). The correct conceptions that are represented in the model and/or explanation are: hot magma, movement of magma beyond the volcanic cone, and magma forming new rock. The learning partners' critique is very detailed in that it suggests that the students' model needs "labels, cause, plates, types of volcano, interior, exterior, and what the volcano was doing". The students' revised model includes some the learning partners' suggestions. The revised model includes plates and labels and the students have elaborated on one type of volcano as requested by their learning partners. More specifically, in their explanation it appears the students were trying to depict/describe volcanism due to plate convergence. The students have also included plate movement and plate friction as causal mechanisms responsible for volcanic eruption. The inclusion of more causal mechanisms is a significant advance over their original model.

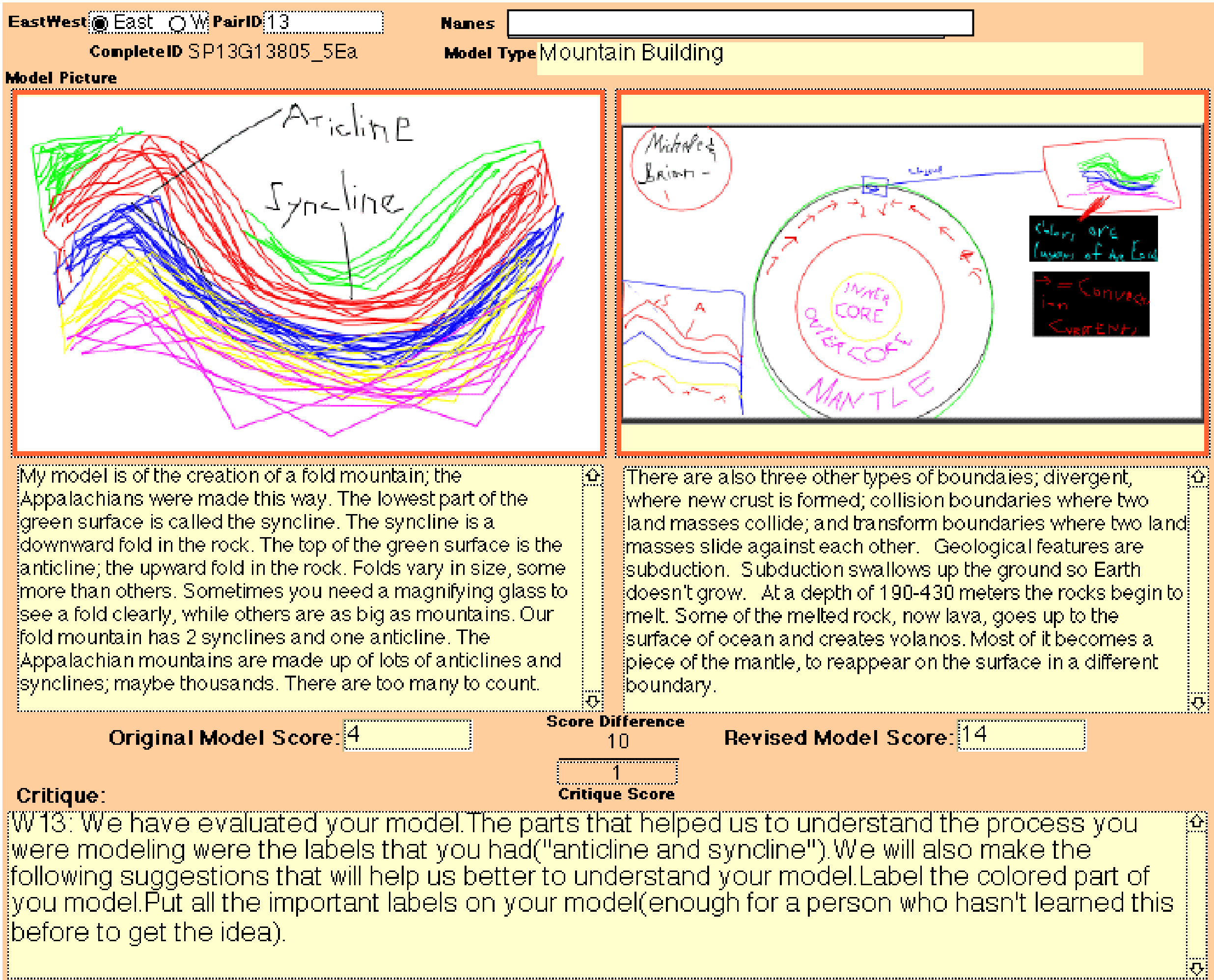

EastWest ○ East ◉ W PairID 3
CompleteID SP3G13928_5Wes
Names
Model Type Volcano
Model Picture

My model is of how volcanoes form and erupt.
Write a detailed explanation of what is happening inside Earth and on its surface. First a mountain is formed by two plates colliding together. Magma come up through the inside of the mountain. When the magma cannot be held in the mountain, it erupts.

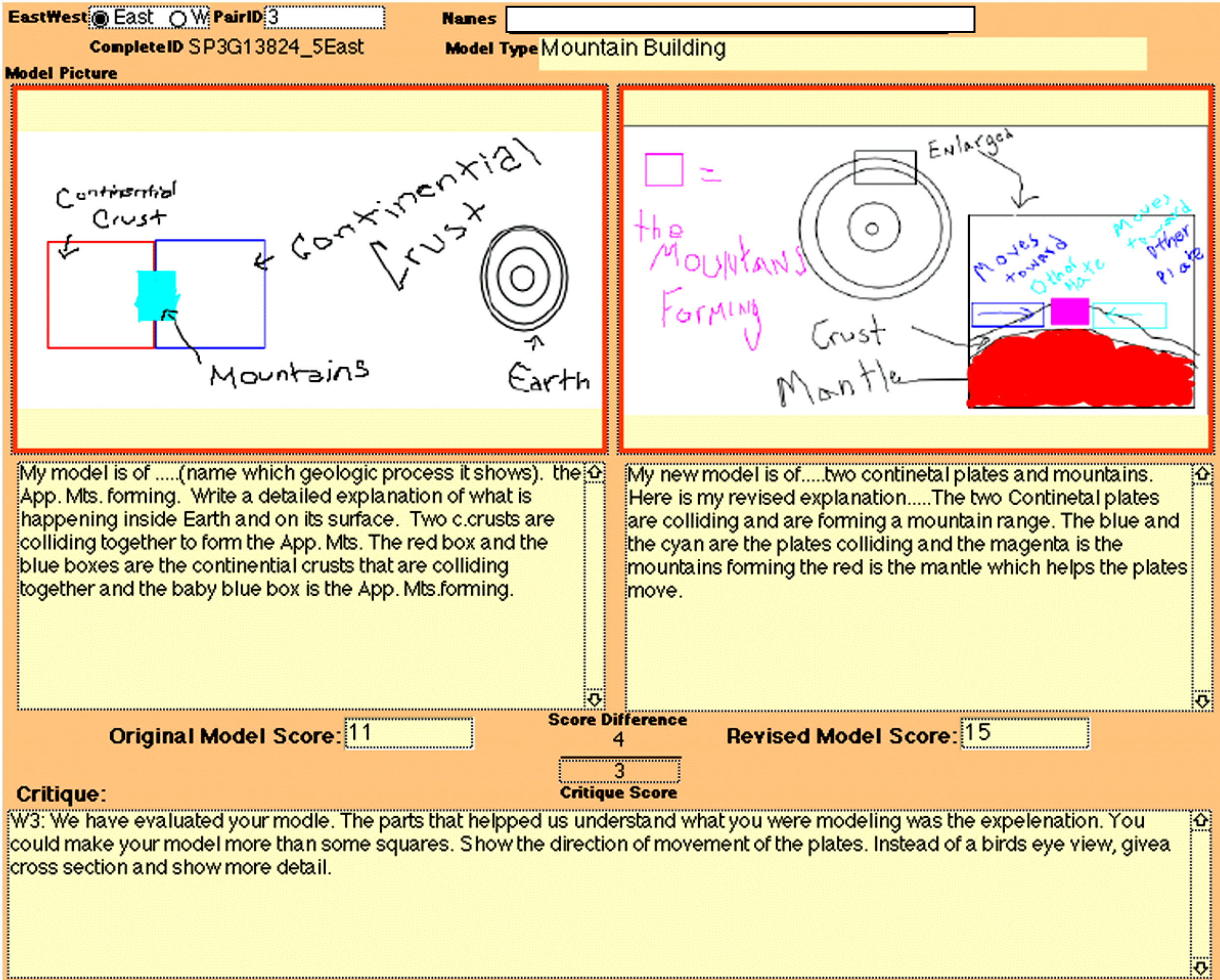
My new model is of how a volcanoe forms and erupts. Here is my revised explanation...first a mountain is formed(shown by the two arrows. One of the plates is pushed under the other and pushes magma up. When the preasure is to high, the magma is blown out of the volcanoe.

Original Model Score: 9
Score Difference 2
Revised Model Score: 11
2
Critique Score
Critique:
E3: The part that helped us to understand the process you were modeling is your explanation. The model was confusing but, with the explanation we understood it a little better. Maybe you could work out the explanation a little better so the model is easier to understand and to read. For your model you could maybe put color to represent the different parts of the model and to better explain what you are trying to teach us. It was quite skecty so it was hard to read, but in it's own way it was quite creative.

In this example the students' model represents a misconception, i.e., that a mountain is formed and fills up with lava and when it fills up, it erupts. Unfortunately, the learning partners' critique did not include much information upon which a revision could be based; this is possibly due to them not knowing what to do in the case of an "incorrect" model. In the revised model and explanation (which we assume is based on the content of the unit rather than the learning partners' critique), the students have added plate subduction and magma movement as a causal mechanism in how volcanoes are formed and have also included the concept of pressure as building up within the volcano. It is important to note that although their reasoning here is not entirely correct, intuitive conceptions such as pressure are rich, effective pieces of knowledge that can be effectively built upon (Clement, Brown, & Zietsman, 1989) and are usable anchors for developing understanding of convection (Gobert & Clement, 1994). As such the revised model represents gain in understanding.



In this original model above (left), the students had focused on the crustal layer of the earth and had not included what happens inside the earth when mountains are formed; that is, there is no structural information or causal information about the inside of the earth. Again, this is a "local" model of plate tectonic phenomena (Gobert, 2000) because it does not include any processes or mechanisms inside the earth. In the critique that was done by their West coast partners, the learning partners requested that they label their model. The revised model includes labels (as suggested); it is also a much more detailed model, suggesting that the students learned a great deal from the content in the "What's on your plate?" curriculum. Their new model includes the crustal layer as a "cut away" from the cross section view; it also includes convection as a causal mechanism in mountain building (in the original model there were no causal mechanisms included). The inclusion of convection as a causal mechanism, the relationship of the convection to the crustal movement and the location of the convection in the correct layers of the earth (the mantle), in their revised model represents a significant advance from their earlier model (Gobert, 2000).


EastWest ◉ East ○ W PairID 3 Names

CompleteID SP3G13824_5East Model Type Mountain Building

Model Picture

My model is of .....(name which geologic process it shows). the App. Mts. forming. Write a detailed explanation of what is happening inside Earth and on its surface. Two c.crusts are colliding together to form the App. Mts. The red box and the blue boxes are the continential crusts that are colliding together and the baby blue box is the App. Mts.forming.

My new model is of.....two continetal plates and mountains. Here is my revised explanation.....The two Continetal plates are colliding and are forming a mountain range. The blue and the cyan are the plates colliding and the magenta is the mountains forming the red is the mantle which helps the plates move.

Original Model Score: 11 Score Difference 4 Revised Model Score: 15

Critique: 3 Critique Score

W3: We have evaluated your modle. The parts that helpped us understand what you were modeling was the expelenation. You could make your model more than some squares. Show the direction of movement of the plates. Instead of a birds eye view, givea cross section and show more detail.

In this example, the students' original model has two views: a cross section view, and a crustal layer view. Their model and explanation include no causal mechanisms in terms of what happens inside the earth when mountains are formed; thus, it is a local model (Gobert, 2000). In the critique from their learning partners', it was suggested that the students include the direction of movement of the plates. This is a high level comment in that it reflects that the reviewers knew that this information was important to the causality of the system being depicted. The critique also includes comments related to the model as a communication tool, i.e., they suggested that the students include a cross section view rather than a bird's eye view which is good comment regarding the model as a communication tool. The revised model includes the earth in cross section form with a cut away that includes information about the plates moving toward each other. In addition the students have added the mantle as a causal mechanism. Although not a significant advance from the point of view of including more detailed causal information, the revised model is a better model from a communication standpoint, as was requested by their learning partners.

SUMMARY & CONCLUSIONS

The purpose of the study was to effectively implement the "What's on our plate?" curriculum into multiple middle school classrooms and investigate whether the curriculum, a rich, model-based inquiry unit could promote students' content knowledge. We also sought to investigate whether students would be able to use what they learned about models in order to critique others' models.

Results from the study thus suggest that students were able to achieve a deeper understanding of the domain, as evidenced by higher scores on the post-test for each of the five WISE periods. Thus, the unit appeared to foster students' understanding of the content of the domain. Since the unit contained content knowledge as well tasks involving peer critiques, we can not state on the bases of these data what the relative contribution of the two possible causal factors, nor was the study designed for this purpose.

More analysis of the existing data is needed in order to tease out the relative contributions of the content in the unit and the learning partners' critiques on model revision. Further data analysis is also necessary in order to characterize students' reasoning with models as a possible index of how their understanding of models is used in situ. Additional analysis of this data (which is stored on the WISE server) will provide insight into this, in particular if those who have a very sophisticated understanding of models are also able to use this knowledge to drive their content understanding further (Gobert & Pallant, in press).

This research utilized a state-of the art science learning environment, WISE, in order to engage students from each coast of the United States in authentic and engaging tasks in which they learned why the coasts are different in terms of their geology. This unit served as an example to its student participants how science is a collaborative activity. This research on modeling fits within a current vein of science education which seeks to promote integrated understanding by use of model-based tasks. In some of these programs students are either presented with models to learn from (Raghavan & Glaser, 1995; White & Frederiksen, 1990); alternatively, they are given tasks which require them to construct their own models (Gobert, & Clement 1994, 1999; Gobert, 1999; Penner et al., 1997; Jackson, et al., 1994). In the "What's on your plate?" curriculum, students are engaged in many authentic, model-based tasks, all of which were designed and scaffolded specifically to promote model construction and knowledge integration. Students were also scaffolded to critique their peers' models from the opposite coast. This activity represents a novel approach to both deepening students 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 as learning tools. All told, the "What's on your plate?" curriculum fostered deep content learning, as evidenced by large pre-post gain scores on both types of assessment tools. 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 on a broad scale (Linn & Muilenberg, 1996).

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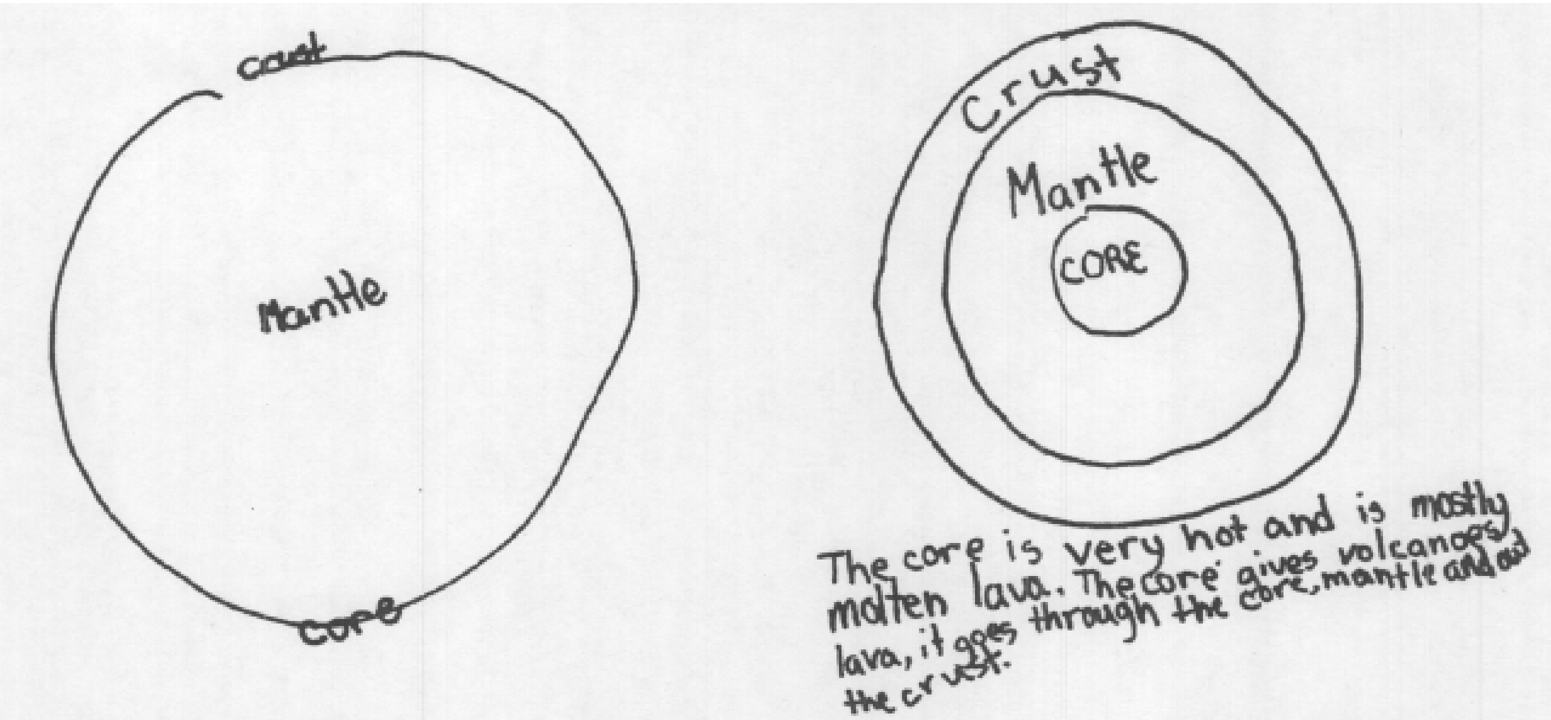
APPENDICES

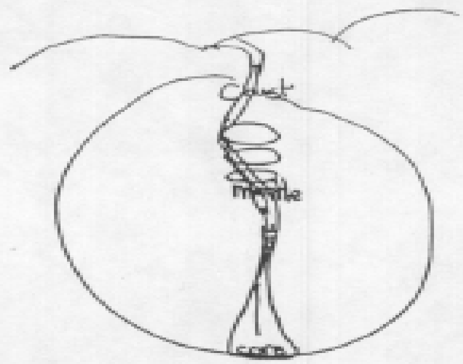
Table 1: Typical models of structure of earth by middle school students (Gobert, 2000), Type 0= 10.6%, Type 1=89.4%



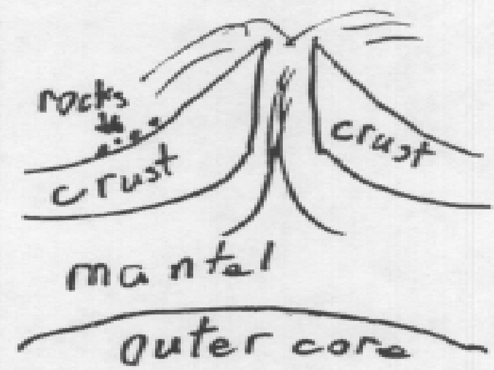
Type 0: Spatially Incorrect Model

Type 1: Spatially Correct Model

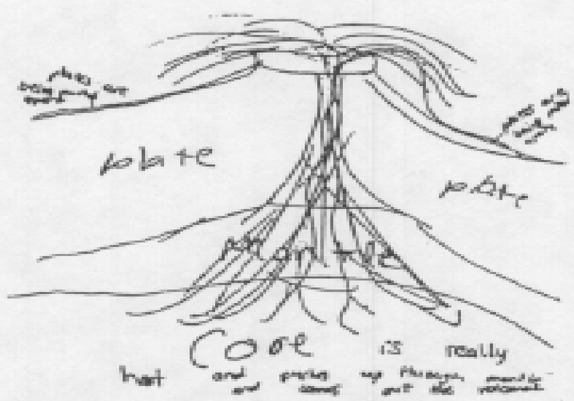
Table 2a: Typical models of volcanic eruption by middle school students (Gobert, 2000)



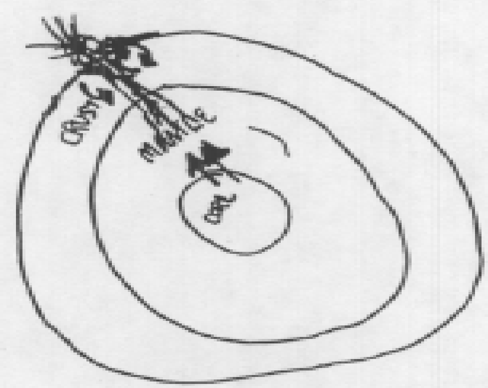
Type 1a: local 'Heat' model



Type 1b: Local 'Movement' model



Type 2: Mixed model



Type 3: Integrated model

Table 2b: Types of models of the causal and dynamic mechanisms in volcanic eruption by middle school students.

	Type of Model	*Characteristics*	*Frequency*	*Percentage*
TYPE 1a	Local 'Heat' Models	Heat-related mechanism(s) only; No movement-related mechanisms as causal	2	4.25%
TYPE 1b	Local 'Movement' Models	Movement-related mechanism(s) only; No heat as causal	29	61.7%
TYPE 2	Mixed Models	Few movement- and heat-related mechanisms; Notion(s) of heat and pressure	14	29.8%
TYPE 3	Integrated Models	Movement- and heat-related mechanisms;Includes heat as a causal agent	2	4.25%

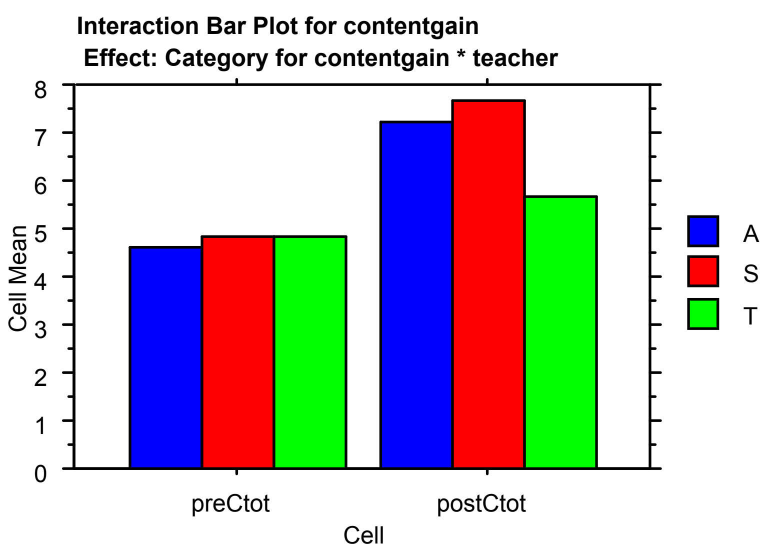
Appendix B1: Statistics and Figure for Period 1 Content Gains

ANOVA Table for contentgain

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
teacher	2	17.231	8.615	.998	.3745	1.996	.208
Subject(Group)	61	526.577	8.632				
Category for contentgain	1	130.331	130.331	44.982	<.0001	44.982	1.000
Category for contentgain * teacher	2	22.548	11.274	3.891	.0257	7.782	.680
Category for contentgain * Subject(Group)	61	176.740	2.897				

Means Table for contentgain
Effect: Category for contentgain * teacher

	Count	Mean	Std. Dev.	Std. Err.
A, preCtot	29	4.621	2.665	.495
A, postCtot	29	7.207	2.808	.521
S, preCtot	17	4.824	2.243	.544
S, postCtot	17	7.647	1.801	.437
T, preCtot	18	4.861	1.885	.444
T, postCtot	18	5.681	2.313	.545



A= Teacher A, West Coast
S= Teacher S, East Coast
T= Teacher T, East Coast

Fisher's PLSD for contentgain
Effect: teacher
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value
A, S	-.322	1.130	.5745
A, T	.643	1.110	.2540
S, T	.964	1.252	.1298

Appendix B2: Statistics and Figure for Period 2 Content Gains

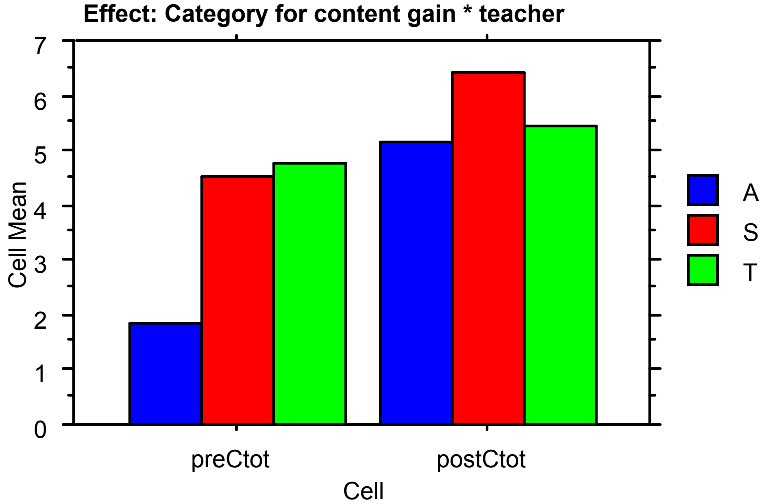
ANOVA Table for content gain

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
teacher	2	102.229	51.114	3.946	.0246	7.891	.687
Subject(Group)	60	777.298	12.955				
Category for content gain	1	115.695	115.695	39.473	<.0001	39.473	1.000
Category for content gain * teacher	2	38.791	19.396	6.617	.0025	13.235	.911
Category for content gain * Subject(Group)	60	175.860	2.931				

Means Table for content gain
Effect: Category for content gain * teacher

	Count	Mean	Std. Dev.	Std. Err.
A, preCtot	29	1.828	1.649	.306
A, postCtot	29	5.172	2.550	.474
S, preCtot	17	4.529	3.243	.786
S, postCtot	17	6.412	3.641	.883
T, preCtot	17	4.750	3.077	.746
T, postCtot	17	5.456	3.192	.774

Interaction Bar Plot for content gain
Effect: Category for content gain * teacher



A= Teacher A, West Coast
S= Teacher S, East Coast
T= Teacher T, East Coast

Fisher's PLSD for content gain
Effect: teacher
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
A, S	-1.971	1.307	.0034	S
A, T	-1.603	1.307	.0167	S
S, T	.368	1.468	.6209	

Appendix B3: Statistics and Figure for Period 3 Content Gains

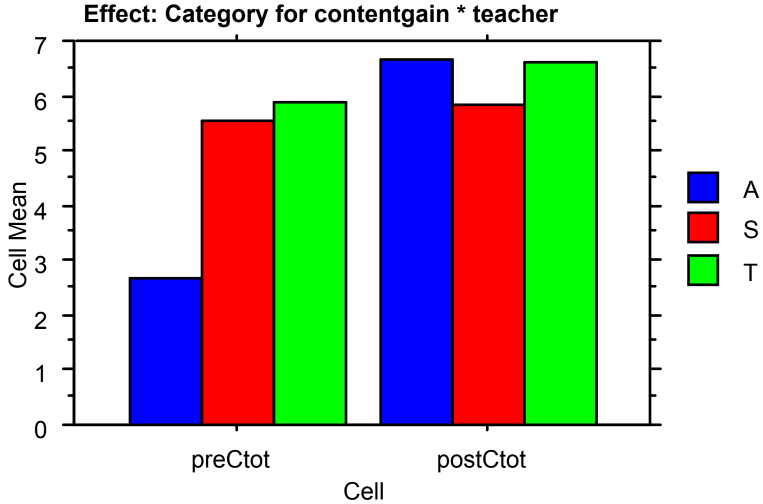
ANOVA Table for contentgain

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
teacher	2	60.752	30.376	2.525	.0883	5.050	.476
Subject(Group)	62	745.837	12.030				
Category for contentgain	1	85.178	85.178	26.654	<.0001	26.654	1.000
Category for contentgain * teacher	2	98.937	49.469	15.480	<.0001	30.960	1.000
Category for contentgain * Subject(Group)	62	198.133	3.196				

Means Table for contentgain
Effect: Category for contentgain * teacher

	Count	Mean	Std. Dev.	Std. Err.
A, preCtot	30	2.667	2.264	.413
A, postCtot	30	6.667	3.066	.560
S, preCtot	17	5.529	3.085	.748
S, postCtot	17	5.824	2.811	.682
T, preCtot	18	5.889	2.530	.596
T, postCtot	18	6.611	2.820	.665

Interaction Bar Plot for contentgain
Effect: Category for contentgain * teacher



A= Teacher A, West Coast
S= Teacher S, East Coast
T= Teacher T, East Coast

Fisher's PLSD for contentgain
Effect: teacher
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
A, S	-1.010	1.300	.1267	
A, T	-1.583	1.277	.0155	S
S, T	-.574	1.448	.4347	

Appendix B4: Statistics and Figure for Period 4 Content Gains

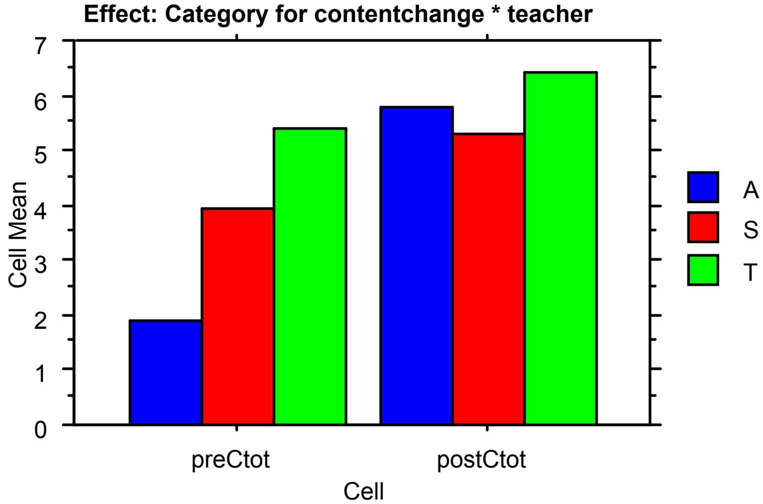
ANOVA Table for contentchange

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
teacher	2	97.656	48.828	3.898	.0254	7.796	.682
Subject(Group)	62	776.675	12.527				
Category for contentchange	1	130.942	130.942	25.019	<.0001	25.019	1.000
Category for contentchange * teacher	2	59.218	29.609	5.657	.0055	11.315	.855
Category for contentchange * Subject(Group)	62	324.487	5.234				

Means Table for contentchange
Effect: Category for contentchange * teacher

	Count	Mean	Std. Dev.	Std. Err.
A, preCtot	30	1.900	2.383	.435
A, postCtot	30	5.767	3.626	.662
S, preCtot	17	3.941	2.461	.597
S, postCtot	17	5.294	3.788	.919
T, preCtot	18	5.417	2.680	.632
T, postCtot	18	6.417	2.503	.590

Interaction Bar Plot for contentchange
Effect: Category for contentchange * teacher



A= Teacher A, West Coast
S= Teacher S, East Coast
T= Teacher T, East Coast

Fisher's PLSD for contentchange
Effect: teacher
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
A, S	-.784	1.385	.2645	
A, T	-2.083	1.360	.0030	S
S, T	-1.299	1.543	.0982	

Appendix B5: Statistics and Figure for Period 5 Content Gains

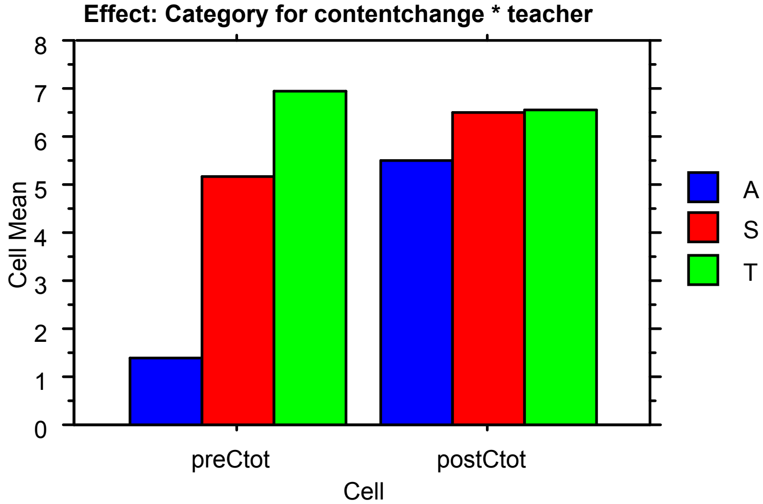
ANOVA Table for contentchange

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
teacher	2	256.450	128.225	13.509	<.0001	27.018	.999
Subject(Group)	60	569.514	9.492				
Category for contentchange	1	82.505	82.505	18.220	<.0001	18.220	.994
Category for contentchange * teacher	2	107.916	53.958	11.916	<.0001	23.832	.997
Category for contentchange * Subject(Group)	60	271.692	4.528				

Means Table for contentchange
Effect: Category for contentchange * teacher

	Count	Mean	Std. Dev.	Std. Err.
A, preCtot	29	1.414	1.376	.256
A, postCtot	29	5.483	3.043	.565
S, preCtot	19	5.158	2.873	.659
S, postCtot	19	6.526	2.796	.641
T, preCtot	15	6.933	3.644	.941
T, postCtot	15	6.533	1.959	.506

Interaction Bar Plot for contentchange
Effect: Category for contentchange * teacher



A= Teacher A, West Coast
S= Teacher S, East Coast
T= Teacher T, East Coast

Fisher's PLSD for contentchange
Effect: teacher
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
A, S	-2.394	1.236	.0002	S
A, T	-3.285	1.331	<.0001	S
S, T	-.891	1.446	.2248	