Do argumentation tasks promote conceptual change about volcanoes?

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Abstract

In the present studies, we assessed college undergraduate research participants' models of the earth's composition and dynamics, both without and with access to a web site on plate tectonics. In previous studies, it has been found that argument writing tasks promote better understanding from web pages, with the best comprehension of texts observed when students write arguments using a two-window browser. In the present investigation, we are interested in whether or not students in this condition acquire more advanced conceptual models of the subject matter than naïve students, or students in other reading/ writing conditions.

In previous studies (Wiley & Voss, 1999; Wiley 2001) the task of writing an argument and the presentation of web pages in two side-by-side windows were found to lead to the most comparison, integration and explanation in student essays. This resulted in better understanding of the subject matter, as measured by inference and analogy tasks. Theoretically, presenting information in multiple sources as well as asking students to construct their own arguments both seem like conditions which may especially prompt active processing, and demand that readers try to develop their own models of the text. (Wiley & Voss, 1999, Perfetti, 1997; Kintsch, 1998). The present studies first investigated what Earth Science concepts students held, specifically pertaining to the causal nature of volcanic eruptions, without receiving any instruction at all. Second, we advanced a taxonomy of student concepts about volcanoes and plate tectonics, and we investigated whether manipulating the writing instruction (essay or argument), as well as the type of web interface (one window or two windows) the materials were presented in, had any effect on the quality of students' causal models of a phenomenon in Earth Science, the eruption of Mt. St. Helens

Earth Science Concepts

Students' understanding of Earth Science concepts is a historically neglected topic that has only begun to receive the necessary attention. Consequently, mental representations of the complexity of our planet and the causes of its natural phenomena is an appropriate topic for conceptual change researchers to focus on as well as an important goal for educators. By the age of 13, most children have acquired a spherical earth concept. They have developed a model of the Earth that corresponds to a planet (a huge sphere surrounded by space). Vosniadou and Brewer (1992) delineated a series of models that many children hold as they approach a mature understanding of the earth's shape. Most children will acquire a round earth concept by fifth grade. This knowledge alone is an important building block for understanding of many Earth Science concepts, however, there are still important conceptual developments in Earth models that need to occur in order for students to understand many other topics in Earth Science.

For many Earth Science topics, following the adoption of a spherical Earth model, the students need to refine their understanding of the compositional properties and surface features of that model. Specifically, students need to develop models that can account for rock cycles, mountain formation, sea floor dynamics, and geological disasters such as earthquakes and volcanoes. They need to develop models that explain geological data relating to changes in the Earth's surface. This seems to be problematic for many students as they are presented with new Earth Science information.

Generally around fifth or sixth grade, the composition and dynamics of the Earth are included in an Earth Science curriculum. Ross and Shuell (1993) found that students in grades K through 6 had many misconceptions about the causes of earthquakes. Some examples of young children's misconceptions are: that earthquakes are caused by wind or weather; that volcanoes are caused by the heat of the sun or by mountains; and that volcanoes and earthquakes can have animistic/humanistic explanations, like the earth is "upset", and that these events somehow reflect the earth's mood or temperament.

The American Geological Institute (1991) has prescribed the understanding of how the Earth's crust is moving and the Theory of Plate Tectonics as essential questions to be answered by students in grades 9-12. However, even after their first instruction on these topics, students have many misconceptions about the causes of earthquakes and volcanoes. Marques and Thompson (1997) found that sixteen and seventeen year-old Portuguese students held numerous misconceptions about the Earth's continents, magnetic field, and tectonic plate movements. For instance, some students believed that tectonic plates rotate around a

plate axis, while others believed that there is a progressive cooling of the Earth, which causes the crust to crack. Barrow and Haskins (1996) have shown that Earth Science misconceptions extend beyond grade 12 and are exhibited by college students in an introductory geology course, of which less than 7% believed their earthquake knowledge to be good or excellent. Many adults think that earthquakes can be predicted by the weather or the tides. Some still have a model of the earth's surface with continents floating on top of oceans, while others see volcanoes and earthquakes as the result of the earth building up too much pressure, heat or other internal stuff, making the Earth like a balloon or pimple. Clearly, Earth Science is a domain where mastery among children and young adults is rare and misconceptions are widespread.

In one of the few investigations that have been done on people's understanding of advanced Earth Science concepts, Gobert (2000) has found that when younger students attempt to produce causal explanations about Earth Science phenomena, they tend to demonstrate incomplete or distorted knowledge. Gobert (2000) classified student models using typologies of the interior of the Earth and the causal mechanisms of volcanic eruptions. Gobert's typology of explanations for volcanic eruption consists of type 1a models in which mechanisms are heat-related only (like the earth core gets too hot), type 1b models, which involved movement-related causal mechanisms and are void of heat-related causal concepts (like the magma rises or pushes up through the crust and causes a volcano), type 2 mixed models, which contain some elements of heat and movement causal mechanisms but are not elaborate or integrated (the inside of the earth is hot, magma pushes up), and type 3 models, which consist of multiple, well integrated, heat-related and movement-related mechanisms. At level 3 the idea that heat causes movement, and more specifically that convection currents in the earth's core cause tectonic plate movements, is important.

Gobert's typology is a useful one in analyzing and categorizing the models of Earth Science students. With some minor additions and fine-tuning it is utilized in the data analysis in the present studies.

Argumentation Tasks

It is possible that part of the problem with students understanding of Earth Science is that they don't integrate the information that they are presented with into a coherent and complete model. The achievement of this goal could be aided by encouraging students to engage in tasks that facilitate the integration of relevant concepts that are presented to them.

Past work has indicated that argument writing is a task that requires students to integrate information, particularly when it is necessary to coordinate information from different sources to make a cohesive representation of a phenomenon. Wiley and Voss (1999) found that when students were asked to write arguments about the causes of the Irish Potato Famine from multiple sources it resulted in essays with more transformation, integration, and explanation of the presented information, than when students were asked to write narratives from the same set of sources. Furthermore, students who wrote arguments were better able to identify correct inferences and underlying principles about the causes of the Potato Famine after the writing task. In comparison to students who wrote narratives from textbook chapters, students who wrote arguments from the multiple sources in a web site demonstrated a better understanding of the subject matter. Based on this evidence, Wiley and Voss (1999) concluded that tasks which require students to construct their own representation of a situation yield the most conceptual learning in web-like environments; and the argument writing task promoted understanding because it required students to integrate information from across multiple sources as they created support for a thesis. This result is consistent with other studies demonstrating that tasks that require learners to engage in active, constructive and integrative tasks lead to the best understanding of text (e.g., Chi, de Leeuw, Chiu & LaVancher, 1994; Goldman, 1997; McNamara, Kintsch, Songer, & Kintsch, 1996, Scardemelia & Bereiter, 1987) as well as studies on collaborative discourse which have found that students who engage in more argumentation-related behaviors develop a better understanding from peer discussion (Anderson, et al. 2001; Chinn, Anderson & Waggoner, 2000).

There has been little work studying how students use multiple windows, or looking at optimal conditions for multiple window use (Foss, 1989; van Oostendorp, 1996). Recently, Wiley (2001) found that when readers were given explicit instruction on how to use the browser there were some learning benefits for a two-window interface, while there was an even more resilient facilitation for argumentation task. There appears to be growing evidence that engaging in argumentation, and similar tasks, facilitates conceptual learning and integration of new material.

Present Studies

In the present studies, we assessed undergraduates' models of the Earth's composition and dynamics. In the first study we asked undergraduates for their understanding of what causes volcanic eruptions without providing them with any reading material. In a second study, we tested whether undergraduates would display more mature models after engaging in argumentation tasks. Undergraduates were asked to read documents from a web site about earthquakes and volcanoes either with the general instruction to learn the information so that they could write an essay about what caused the eruption of Mt St Helens, or the specific instruction that they should read the site in order to write an argument of what caused the eruption of Mt St Helens. In addition, students either read the information presented in a single-window or two-window browser. In general, past

work has found that both the two-window design of the browser as well as the argument writing task are responsible for promoting understanding, with the best comprehension of the text observed when students write arguments using a two-window browser. In the present investigation, we are interested in whether or not students in this condition acquire more advanced conceptual models of the subject matter.

An accurate understanding of the nature of the eruption of Mt. St. Helens would entail the following information: Mt. St. Helens is a subduction zone volcano, which means that it is located on a tectonic plate boundary and not on a hotspot. The Earth's tectonic plates are known to move, due to convection currents in the Earth's liquid layers. The plates that lie underneath Mt. St. Helens pushed together, or converge, leading to subduction. Consequently, this subduction (one tectonic plate sliding underneath the other) causes solid mantle from the bottom plate to be pushed down to areas of higher temperature. This solid mantle melts in the high temperature and became viscous liquid magma. Viscous magma builds up and causes an increase in pressure, which is not released until the magma shifts and an eruption occurs.

Study 1
Method
Participants. 28 undergraduates at the University of Illinois at Chicago participated in this experiment.

Procedure. The participants were asked to answer the question "What caused the eruption of Mt. St. Helens on May 18, 1980?". Students were asked to write at least a paragraph.

Measures. Student concepts were assessed by coding answers for the kind of models that students had of how volcanic eruptions happen. The coding scheme was originally based on Gobert's (2000) typology, but several categories needed to be added or amended to account for the models we observed in our protocols. The different levels of our typology are described below.

Student Models of Volcanic Eruptions

It should be noted that some models are not necessarily incorrect explanations of volcanic eruptions per se, because they could account for certain types of volcanoes. But many are not sufficient explanations of why Mt. St. Helens, a stratovolcano, erupted as it did.

Type 0 Incorrect, Superficial Models
Students were assigned a 0 if their explanation of the cause of volcanoes was related to an irrelevant surface feature of the earth. Examples of explanations at Level 0 are that volcanoes are caused by surface conditions, such as wind, avalanches, landslides, mountains, weather, sun, the orbit of planets, tides, faults, time, dormancy or too much lava, as well as non-explanations. Essays that did not include any of the major causal agents identified below received a 0.

Type 1 Local Models
Models that mentioned single, local causes of movement or heat, as in Gobert's (2000) typology, or the concept *pressure* were assigned a '1'. Models were given this rating if they expressed the idea of one of these three as being the causal agent in the eruption of the volcano. The addition of the concept *pressure* as a type 1 causal agent was made because this concept is a separate notion from heat or movement and is relevant to the eruption of a stratovolcano, such as Mt. St. Helens, in which no gas escapes from the volcano before a violent eruption. A second amendment from Gobert's typology was splitting the movement category into two separate categories, one specifically related to magma or lava movement, and the second related to plate movement. After proposing this coding analysis, none of the students had an explanation related to magma movement alone, so a single movement category was retained.

Explanations of Type 1A tended to mention hot, melting or molten magma, the temperature of the magma, and the heat of the earth's core. Explanations of Type 1B mentioned the movement, shifting, colliding, rubbing or interacting of plates. Explanations of Type 1C tended to mention that the volcano or Earth was full of gas, the magma had too much gas, that there was pressure or that the magma was being kept under force.

Type 2 Mixed Models
Models that included plate movement with either heat, pressure, force or chemical processes were assigned a '2'. In these models, multiple factors were mentioned but not causally related.

Type 3 Integrated Models
Only models that causally related heat or pressure and movement in either direction (i.e. convection currents cause plate movement; or plate movement causes plates to subduct and melt, forming magma that rises under volcanoes) were coded as level 3 models.

Examples of explanations included in the naïve student models along with frequency of occurrence are included in Table 1.

Table 1: Frequency of Naïve Models with Examples

Model	Examples	Frequency (%)
Type 0	I assume that the eruption was due to a geological disturbance such as a sudden misalignment of orbits.	7 (25%)
Type 1A	The eruption of Mt. St. Helens was caused by the heat build up	3 (10.71%)

	in the earth's core…	
Type 1B	The eruption of the volcano was caused by a sudden shifting in the earth's tectonic plates. This shifting caused a disruption of the mountain…	8 (28.57%)
Type 1C	The eruption of Mt. St. Helens occurred because there was an enormous amount of pressure on the volcano… It couldn't keep the lava in, and erupted.	7 (25%)
Type 2	The eruption of Mt. St. Helens was caused by movement in the plates.... The lava is heated to the point where it has to escape.	2 (7.14%)
Type 3	Volcanic eruptions are the result of the earth's tectonic plates shifting below the surface. As the plates move past each other, friction builds up and hot magma forms. Once the plates are pushed to a certain point, the magma is forced up through volcanoes.	1 (3.57%)

Implications

A surprising number of undergraduates have incomplete or incorrect models of why Mt. St. Helens erupted. Consistent with anecdotal reports, there are a number of persistent misconceptions about why volcanic eruptions and earthquakes occur. In study 2, we address the extent to which students may undergo conceptual development as they construct arguments from evidence presented in a web site.

Study 2

Method

Participants. 40 undergraduates at the University of Illinois at Chicago participated in this experiment.

Design. There were two manipulations in this experiment. The first manipulation was in the instructions that students were given. Twenty of the students were asked to read the web site in order to "write an essay of what caused the explosion of Mt St Helens in 1980", while the other twenty were given the exact same instructions except the word *essay* was replaced by the word *argument*.

The second manipulation was in the format of the browser in which the web site was presented. In this experiment, students either read the documents from a single-window browser, meaning they chose documents from a document list that was presented at the start of the experiment, and viewed the documents one at a time. The other half of the students were given a two-window browser, but they also got specific instructions about why they were being given two windows "in order to compare across documents". Further in this condition the list of documents was split in half, so that in order to read all of the information readers had to use both windows. All students received explicit instruction on how to use the browser environment.

In each of the two presentation conditions, half the students received an essay writing instruction while half received the argument writing instruction. This yielded a 2x2 (writing task x browser format) design with 10 students in each of the four conditions.

Materials. The contents of the page were taken from the USGS web page**.** Pictures and diagrams were presented with captions, but in their own windows (as documents). There were no hyperlinks between documents other than navigational links back to the overview lists, and between the overview list and the documents.

Procedure. The participants were asked to read documents from a web page about Geological Hazards in order to write either an essay or an argument. All participants were given 30 minutes to read the documents and write their essays.

Measures. Students' concepts were assessed by evaluating the quality of the essays. We coded essays using the coding scheme developed in Study 1. Two raters independently coded each essay, blind to condition. Inter-rater reliability was above .90. Discrepancies were resolved through conversation.

Additionally a demographics questionnaire was administered at the end of the experimental session that included the question, "How much did you know about Mt. St. Helens and its relation to plate tectonics before reading this site?" Participants answered this question on a scale of 1-10, with 1 meaning "not much" and 10 meaning "a lot".

Examples of Student Explanations

The following examples are excerpts of the participants' written essays. Two examples of each category are provided. Only the portions of the essays containing relevant ideas are included.

Type 0 Incorrect, Superficial Model

… the climate has a dramatic effect on volcanoes.

Type 1A Local Heat Model

… in certain locations around the world volcanism has been active for a long time which means there are a hot spots under the plates which are exceptionally hot regions that provide localized high heat energy to use.

…Below some plates there are hot regions which give off high heat energy, thus sustaining volcanism.

Type 1B Local Movement Model

…The earth is built around a dozen plates...As the plates move, it causes the plates to rub against each other, causing

the explosion of the volcano.
…In the case of Mt St Helens, an oceanic-continental boundary formed. A dense plate from the ocean floor meets a less dense plate of continental land, creating the mountainous area around Mt St Helens....The material of the dense plate goes deep into the earth and eventually transforms into magma, a product of a volcano…

Type 1C Local Pressure Model
…The fierce explosion of Mt. St. Helens was due to the fact that gas was trapped inside the magma. This gas can't escape until magma enters the throat of the volcano...
…Mount St Helens violent explosion was due to great amount of silica (in the magma).... These are what stop gases from escaping at the proper time…

Type 2 Mixed Models
…There could be several reasons why Mt. St. Helens erupted. However, I believe a collision of oceanic and continental plates caused the earthquake that caused Mt. St. Helens to erupt...Eventually the Juan de Fuca plate and the North American plate, smashed into each other, causing a great disturbance underneath Mt. St. Helens volcano. The gas inside the volcano could not escape... the pressure built up inside the volcano and grew too strong and came out as one big burst.
…Three plates come into play underneath Mt. St. Helens...The movement of these plates and the added build up of pressure cause a seismic zone to form under Mt. St. Helens...

Type 3 Integrated Models
What produced the explosion of Mt. St. Helens? The explosion could have been caused by the collision of oceanic and continental plates... As the subducting oceanic crust melts within the asthenosphere the new magma rises to the top of the surface and forms volcanoes. Shallow earthquakes are associated with high mountain ranges when intense compression is occurring. Most volcanic eruptions occur near plate boundaries.
The eruption of Mt. St. Helens was caused by the unsettled magma and gas pressure. As plates meet, the denser heavier plate will be forced to sink below the lighter plate. As it moves below, magma is formed as extremely high temperatures below the mantle melt the plate. Gas and magma flow to the surface, pushing until mountains and volcanoes, which will eventually erupt, are formed. They erupt due to this pressure...

Distribution of Models across conditions
The distribution of models by reading, writing and window condition are presented in Table 2. A 2x2 (writing condition x window) ANOVA was conducted on the groups' numerical self-ratings of previous Mt. St. Helens knowledge and there were no significant differences across the experimental groups, ($F<1$).

Table 2: Frequency of Models by Writing and Window Condition

Model level	0	1	2	3
Narrative				
1 window	3	6	1	0
2 window	1	5	2	2
Argument				
1 window	1	3	5	1
2 window	1	3	4	2
Total	6	17	12	5
Reading	15%	42.5%	30%	12.5%
No Reading	25%	65%	7%	4%

Chi square analysis on the frequency of models by writing condition indicated that models were not evenly distributed. Narrative writers had more models at levels 0 and 1 versus 2 and 3, while argument writers had more models at levels 2 and 3 if anything ($X^2(1)=4.44$, $p<.03$). (An overall chi square analysis on the eight cells was not possible due to low cell size). No effects of number of windows were seen in a chi square on the frequency of models by the windows condition, ($X^2<1$).

Implications:
The results of this study indicate that young adults have incomplete models of the Earth's composition and dynamics as indicated by their observed models of the eruption of Mt. St. Helens. Although several students were able to exhibit some understanding of volcanic eruptions in general, many of their models did not show any understanding of the importance of the Theory of Plate Tectonics or that there are different kinds of volcanoes. Generally, students could not accurately describe Mt. St. Helens as a subduction zone volcano, even after reading several documents about the topic that contained all of the necessary information.

Consistent with Wiley (2001) it was found that argument writing did facilitate better understanding and model building from scientific electronic text, while providing a two-window browser only showed a beneficial trend. These results, based on a small number of participants, further suggest that conceptual development, in a domain such as Earth Science, is aided by tasks that encourage integration. But the degree of learning (and the fact that not all students achieved an understanding of plate tectonics and volcanic eruption in this condition) suggests that there may be other pieces of the puzzle needed to advance students beyond their misconceptions in this domain.

It may be that in areas such as Earth Science, where students lack concrete experience with observing and dissecting planets, some concepts are particularly difficult to learn about from text. Additionally Gobert (2000) asserts that plate tectonics concepts are difficult for children to learn due to the large size scales of the agents involved, and the

extremely long temporal scales that extend far beyond a human lifetime. Students may also find it difficult to integrate and visualize these concepts in order to understand the structure and behavior of the planet. Based on the presented studies this holds true for young adults as well. Mastery of this domain essentially requires understanding dynamic spatial information, which may make images, animations and simulations quite important. Although in general, evidence for the beneficial effects of visual adjuncts on learning is mixed (Wiley, in press; Wiley & Hemmerich, in press), for the mastery of these concepts such adjuncts may be critical. We are interested in pursuing this hypothesis, and its effects on long-term learning, in future studies.

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