THE EFFECTS OF SPATIAL ORGANIZATION AND STUDENT GENERATION DURING SELF-REGULATED, ONLINE LEARNING WITH DOMAIN OVERVIEWS

by

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STATEMENT OF THESIS APPROVAL

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ABSTRACT

Concept maps have been shown to have positive effects for students on recall. This is because, among other things, they are designed to show learners the relationships between concepts in a visuospatial way. However, it remains to be seen how concept maps affect deeper forms of learning, or whether it is the attention to the relationship between the concepts in the map or the concepts themselves that support the learning. This research examined the impact of the spatial organization of graphical search interfaces on deep learning as well as the impact of focusing student attention on the conceptual relationships between map nodes in this graphical search interface by asking them to generate information about those relationships. Results showed a nonsignificant trend suggesting that participants who were asked to generate information about the relationship between concepts showed greater recall when not learning from a concept map.

I dedicate this to Paula, my mother, for teaching me to always question and to Cori who stood by me through the entire process.

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CHAPTER 1

LITERATURE REVIEW

1.1 Online Information Search and Retrieval with Digital Libraries

The Internet has changed the way that individuals access information. This creates challenges for learners and educators as they adopt new methods for finding and using information during educational tasks. The Internet provides learners with access to vast quantities of information in a large variety of formats. For example, a learner might access an online text, a diagram, an animation, a video, or a simulation in which they can explore the application of various concepts. Digital resources available online range from generalized information that novices may utilize to highly specialized documents and services that are useful only to experts in a particular domain.

Despite claiming to know much about the Internet and how to use it to find information, Internet users tend to understand very little about how Internet searches work and consistently find information that is incorrect and poorly sourced (Graham & Metaxas, 2003). While the amount of information on the World Wide Web makes it *possible* for learners to gather the information that they need, the open nature, quantity and variety of the information available online makes it difficult to efficiently access relevant and accurate information.

1.2 Using the Internet for Learning: Challenges for Users

It can be interesting to compare the Internet to a traditional library because both types of repositories provide users with ready access to many documents such as primary texts, academic journals, datasets, etc. Researchers in information search and retrieval sometimes have made that comparison (Marchionini & Maurer, 1995). However, if one considers the Internet itself to be a type of online library repository, there are many impediments to its use, including that the "collection" of resources is only loosely organized and that the majority of the information is not vetted for quality. While the variety and number of online resources available to users are a general benefit of the Internet, they also are qualities that create difficulties and challenges for educators and learners who want to make use of Internet resources. Learners often need more knowledge than they possess to be able to search effectively for needed information (e.g., generate relevant keywords) and to be able to recognize this information as useful once they find it (Butcher & Sumner, 2011). Due to the quantity of diverse information present on the web, many times, a learner will find it difficult to form a clear understanding of information found (as discussed in Lynch, 2008). Search engines such as Google are very good for accessing petabytes of text and multimedia content, but rarely provide contextualized information that is specific to an individual learner’s needs or tasks. Simple queries using these engines are not robust enough for the demands of most people who are seeking information. Although an expert using these search engines and entering precise terms may be provided with a good selection of resources for their needs, most novices who are using search engines retrieve information that is too decontextualized for easy analysis or investigation (Marchionini, 2006).

From a practical perspective, there are some useful aspects of simple, decontextualized search queries. Many users are interested in accessing factual knowledge or gathering disparate information for leisurely use. Most search engines facilitate this need nicely. However, it is important to understand the difference between informational access and education (for a discussion, see Lynch, 2008). Lynch (2008) noted that gaining access to information is not the same thing as becoming educated by such information; while the Internet offers a great opportunity for disciplined students to *find* information, students typically need more support and guidance in working with digital resources in order to *learn* from them in meaningful ways (e.g., to synthesize across resources and integrate with prior knowledge).

Despite the aforementioned challenges, use of the Internet by students for both information search and completion of school assignments is increasingly rapidly and steadily; indeed, many students see online search as nearly a ubiquitous part of all aspects of learning (Browne, Freeman, & Williamson, 2000; Pew Research Center, 2002). Not only do students seek information online, but 94% of educators with Internet access use it for instruction or for administrative purposes (Gray, Thomas, & Lewis, 2010). Internet access by people across the world continues to increase as well and, with every year that passes, more people gain access to all of this information (Internet World Stats, 2012; National Telecommunications and Information Administration, 1999). Clearly, there is a strong need for an organized approach to finding relevant and accurate information during online learning.

1.3 Digital Libraries: Supporting Learning Online?

One potential solution to supporting online learning has been the development of educational digital libraries. Much like traditional libraries, a digital library provides its users with access to an organized set of resources that preserves information and artifacts. Its purpose is not only to make high-quality information and data available to specialized groups of learners, but to use technology to make information accessible to people in informal learning environments (Marchionini & Maurer, 1995). One main difference between a digital library and a traditional library is that a digital library does not own the content that it contains. Rather, the digital library catalogs and vets resources (in multiple forms) that appear in many places across the Internet. The digital library provides tools to facilitate identification of useful, relevant materials and then provides learners with a link that will direct them (elsewhere) to the online cataloged content. In this way, the digital library serves more as a conduit to relevant materials online rather than a repository for those materials.

The National Science Digital Library (NSDL) is one example of a large-scale, educational digital library. The NSDL focuses on providing relevant, accurate, and vetted pedagogical resources for STEM (science, technology, engineering, and mathematics) topics. It is intended to serve the needs of students and teachers in grades K-12 as well as undergraduate and graduate students and lifelong learners (Zia, 2000, 2001). The NSDL provides access to digital materials on the Internet that have been recommended for cataloging by the educational community or the resource developer. It also identifies relevant material by using a type of software called web crawlers to do targeted searches to find educational resources online (Bergmark, Lagoze, & Sbityakov, 2002). Because everything must be catalogued and categorized, the amount of material on the NSDL compared to the amount of material that can be found across the web by other search engines is relatively small (McCown, Bollen, & Nelson, 2005). However, with this increased constraint comes greater relevance: all of the materials within the digital library are relevant to its educational focus.

In cataloging material as part of an educational digital library, experts typically vet the material as educationally relevant and scientifically accurate; for example, NSDL provides a "Resource Quality Checklist" (http://nsdl.org/content/files/ pdfs/resource_quality_chklst.pdf) to help collections developers ensure that resources are appropriate for cataloging. Accordingly, searches in an educational digital library will return only educationally relevant resources that have been determined to be of high quality. To effectively use online material found on the web, learners usually must determine whether information is trustworthy or not (Iding, Crosby, Auernheimer, & Klemm, 2009). Thus, searching within a vetted educational collection may be particularly helpful for novice learners who often have a difficult time analyzing the veracity of online information and determining the trustworthiness of Internet resources (Graham & Metaxas, 2003). One study (McCown et al., 2005) compared pedagogical results returned from the NSDL (using its keyword search) to those returned from Google (also using keyword search). In this study, 11 subject matter expert teachers judged results returned by Google and NSDL as either relevant, semirelevant, or nonrelevant based on Virginia state standards. Researchers found that neither Google nor NSDL were rated as relevant or helpful for students to learn state standards, though Google ranked slightly higher than the NSDL. Thus, even within an educational digital library, educators (and students) may need significant support in finding resources that are well-suited to learning tasks. This may be especially important when considering that for most educational tasks, users need to engage in learning with digital resources as they search for and select these resources online (Marchionini, 2006).

There are two main parts that constitute a digital library like the NSDL. There is some sort of body of information that is organized or collected and there are tools of varying power to analyze and work with the corpus of information (Marchionini & Maurer, 1995). In the NSDL, for example, there are bodies of information collected, search tools to help a student or an educator look for information, and metadata fields that tag and organize catalogued resources (e.g., grade level, subject keywords, common core standards). NSDL provides users with two main search tools to access its catalogued resources: General Search and Science Literacy Maps. The General Search uses keywords to retrieve relevant resources catalogued in the NSDL – this search and retrieval process is functionally equivalent to the keyword search provided by commercial search engines, although it relies on different underlying algorithms. The Science Literacy Maps are node-link diagrams that are similar in appearance to concept maps. These maps are based on the AAAS strand maps (Compare http://www.project2061.org/publications/atlas/sample/1_1_ER.pdf from American Association for the Advancement of Science, 2013 and http://strandmaps.nsdl.org/?id=SMS-MAP-1446 from National Science Digital Libraries, 2013) and show how learning goals for a scientific topic build on each other over time (see Figures 1 and 2). In the NSDL Science Literacy Maps, clicking on a learning goal (depicted in a map node) takes the user to the NSDL resources that have been catalogued as relevant to that learning goal.

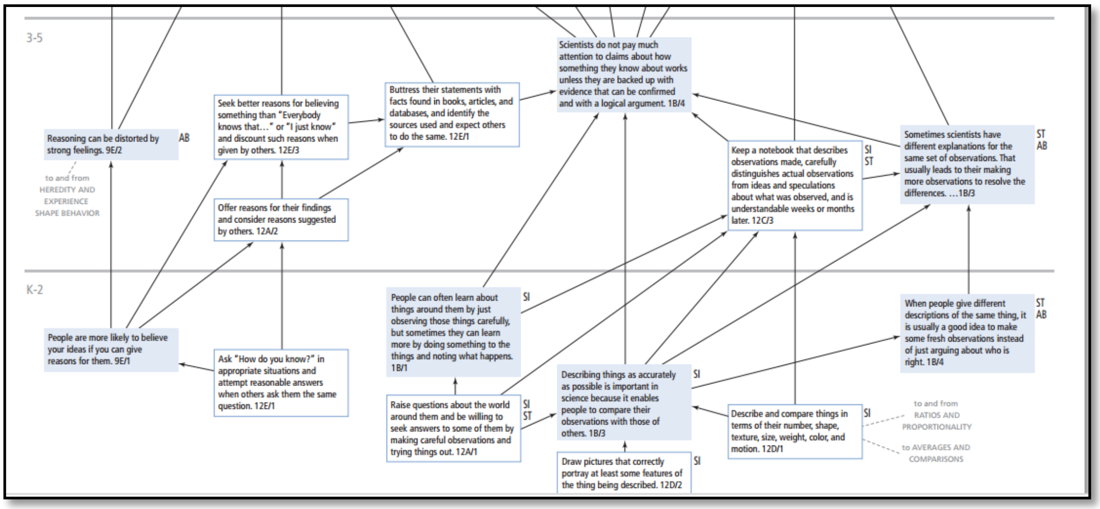


Figure 1. An example of an AAAS strand map.

Thus, these interfaces provide two different methods for online discovery in the NSDL educational digital library: keyword search and graphical search.

1.4 Learning through Online Search

Marchionini (2006) provides a theoretical model of information search that highlights the difference between lookup, learn, and investigate. Lookup is the term he uses to describe fact retrieval or navigation, both of which encompass the primary focus of most students using search engines. Learn is the term used for how people acquire knowledge or compare things found on the Internet. And investigate is the term for what information seekers do when they analyze, evaluate, and discover new information. The model also highlights exploratory search as especially pertinent to activities that involve learn and investigate. It also makes note that all three investigative activities many times act in parallel because learners may engage in all of them simultaneously.

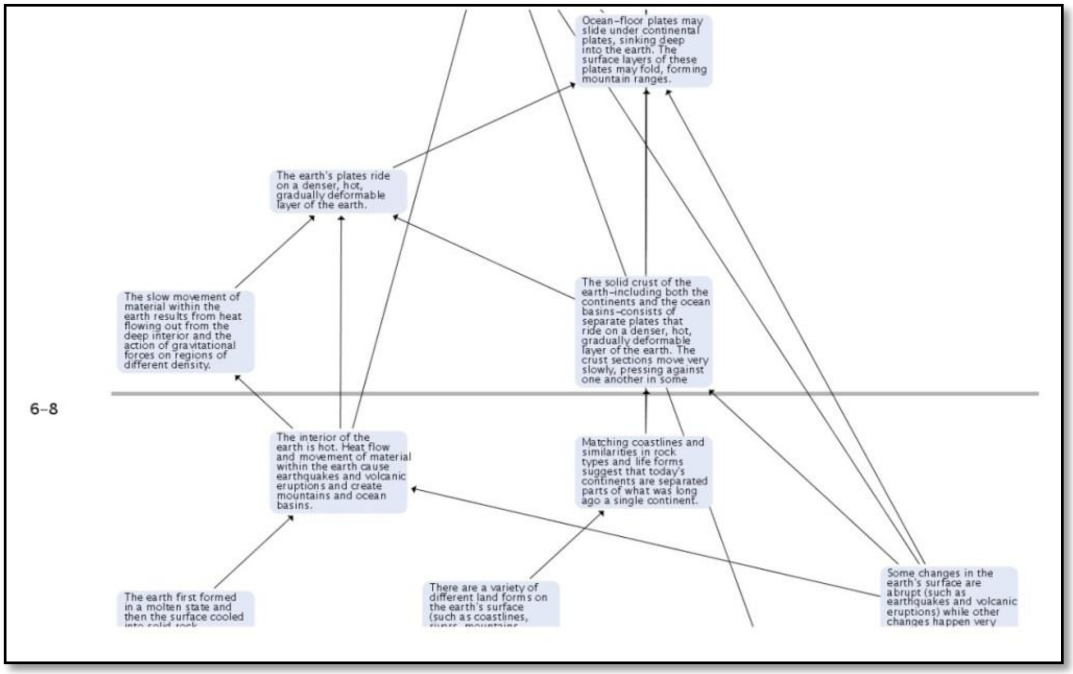


Figure 2. An excerpt from the NSDL map view.

Learning and investigation take time and tax the cognitive processes of the information seeker. Search tasks that involve simultaneous learning (or using the Internet for education as Lynch, 2008, defines it) are most successful when combined with browsing and analytical strategies; in these cases, searches are used to guide the learner to digital resources at which point analytical and investigative skills can be applied most effectively.

Web searches that provide support for deeper acquisition of knowledge are essential for effective learning. For these searches to be successful for meaningful learning, they must not only provide context about the domain but also must detail the relationships between various concepts (Marchionini, 2006) as well as show how these concepts relate to the whole body of relevant information (Lynch, 2008). This is especially true for a novice who might not make connections and identify relationships between various concepts spontaneously during study.

Searches that support deeper learning involve multiple iterations and return sets of objects that require meaningful cognitive processing and interpretation (Marchionini, 2006); however, novice users have been found to spend more time formulating and revising online queries than they spend analyzing the data or domain content (Marchionini & Maurer, 1995). Butcher, Bhushan, and Sumner (2006) found that graphical search interfaces – that is, interfaces that provided an organized representation of knowledge within a domain – changed this pattern of novice performance. The research of Butcher et al. (2006) utilized graphical interfaces in the form of node-link diagrams (much like concept maps); these diagrams provided information about domain concepts in the nodes and represented relationships between domain concepts via links between the nodes. This research found that novices who utilized the graphical search interfaces spent more time focused on domain content during search than novices who were engaged in keyword searches.

More recent research (Butcher, Davies, Crockett, Dewald, & Zheng, 2011) has demonstrated the impact of graphical search interfaces within an educational digital library. Butcher et al. (2011) found that, compared to a commercial search engine or a keyword search interface within NSDL, learners who worked with a graphical search interface (the Science Literacy Maps in NSDL) engaged in deeper thinking about and more efficient searches for domain-relevant digital resources. However, it is important to recognize that learners using the commercial search engine as well as the keyword search from the digital library both had to *generate* their own search queries whereas learners using the graphical interface had to analyze and select from provided queries (in the form of learning goals). Since formulating queries has been identified as an effortful process within information search and retrieval (Marchionini & White, 2007), a key question is whether the learners of Butcher et al. (2011) benefitted more from the content of the graphical interface (i.e., the text in the nodes) or the structure of the graphical interface (i.e., the visual organization of the nodes). It is important to understand when and how different aspects of the graphical search interface help students. In order to consider this question, we first consider the established learning benefits of a similar graphical representation: concept maps.

1.5 Concept Maps

Nesbit and Adescope (2006) defined concept maps as graphic organizers that use labeled nodes to denote concepts and uses links to show relationships between these various concepts. Concept maps are spatial distributions of verbal information (Rewey, Dansereau, Skaggs, Hall, & Pitre, 1989). There are various terms to describe concept maps. Generally, concept maps are node-link diagrams where concepts and key words are represented by nodes and links show the relationship between those concepts and key words. Knowledge maps are a type of concept map and include knowledge propositions, such as phrases or sentences, in the nodes instead of keywords. In this paper, the term concept map will be used for the sake of simplicity to refer to all these forms of node-link diagrams. Mainly, concept maps are designed to show learners the relationships between concepts in a visuospatial way. Researchers have posited that concept maps are important and useful because they have the ability to represent a variety of relationships and structures in a single, easy to understand display (Alverman, 1981; Chimelewski & Dansereau, 1998; Moore & Readance, 1984; Patterson, Dansereau, & Wiegmann, 1993).

One important use of a concept map is based on the subsumption theory described by Ausubel (1963). The theory focuses on the prior knowledge of students as being one of the most important factors in what a student can learn or is ready to learn (Ausubel, Novak, & Hanesian, 1978). Concept maps may overcome some of the difficulty that some learners have with gaps in their prior knowledge by presenting a visual representation of knowledge components and their organization within a domain. Since learners with low domain knowledge tend to generate incorrect inferences during comprehension (Moravcsik & Kintsch, 1993), a graphical representation of domain knowledge might be helpful to students in identifying and analyzing core domain content. Nesbit and Adescope (2006) determined that, compared to other forms of learning like lectures, using concept maps in education results in stronger learning gains. Concept maps have been found to have positive effects on recall of main and intermediate ideas (Rewey et al., 1989), likely by making the macrostructure of text information easily available to the learner (Chimelewski & Dansereau, 1998). Findings also suggest that concept maps may be especially beneficial for lower performing or novice learners. Concept maps work better with students who have a low verbal ability or low domain knowledge (Nesbit & Adescope, 2006). O'Donnell, Dansereau, and Hall (2002) postulated that low-performing students with low verbal ability who use concept maps will be faced with less cognitive load, since concept maps provide students with key terms and concepts as well as a representation of how these concepts are linked up with other key terms and concepts.

Essentially, concept maps can help novice users learn more effectively when they do not understand completely the breadth and organization of knowledge in a particular field. However, it is important to note that the results reported above have mainly been observed for memory-based outcomes rather than deeper understanding. As discussed later in this paper, this may have important implications for the use of graphic interfaces for online learning.

1.6 Extending Concept Map Benefits to Graphical Search Interfaces

Because concept maps provide a structural organization to domain information, they may also facilitate more complex processes during information search. When graphical search interfaces provide a concept map-like organization of domain content, they allow students to access information without previously knowing how concepts relate to one another or what keywords are important to their task within the domain. Indeed, research has found that learning from a source that provides a visual representation of domain knowledge improves a student's understanding (McCrudden, Schraw, & Lehman, 2009) and graphical search interfaces may help facilitate searches that are focused on learning. Findings have indicated that graphical search interfaces may promote deep level thinking as well as surface level thinking (Salmerón, Baccino, Cañas, Madrid, & Fajardo, 2009) and may facilitate deeper engagement with scientific concepts (Butcher et al., 2006). In fact, Salmerón et al. (2009) showed that graphical overviews (i.e., concept maps) increased comprehension, especially when the overviews were presented at the beginning of the exercise, as is the case with concept maps, and especially with difficult material, as is the case with the scientific material they used.

1.7 Deep vs. Shallow Learning

There is a long history of cognitive research demonstrating that recall and understanding are not equivalent learning outcomes (Hilgard, Irvine & Whipple, 1953; Jenkins, 1974; Olander, 1941). Kintsch (1988, 1994, 1998) has distinguished between learning and understanding within a well-known model of comprehension: the Construction-Integration (CI) model. In the CI model, knowledge can be formed at three levels: the surface level, textbase, and situation model. Most relevant to this work are the textbase and situation model. The textbase relates to text memory; it does not represent exact words or sentences from a set of learning materials but it does represent the text's main ideas in the form of knowledge propositions. A good example of a textbase would be when students intensively engage in learning a large amount of information in a short amount of time. This "cramming" focuses on recall and memorization. Although students may be able to recall information for a short period of time, the textbase representation fades quickly. The textbase should be considered a relatively shallow form of knowledge. It typically is assessed by techniques like multiple choice or fill in the blank questions that test students' memories for text information (Butcher & Kintsch, 2012).

As Kintsch (1998) points out, learners can memorize a text without understanding it. That is, they may encode the text without activating relevant background knowledge or making inferences based on what they read. When students exhibit deeper understanding, they have formed a different level of knowledge called the situation model (Kintsch, 1988). The situation model is formed by the integration of information from a text with the prior knowledge of the learner. Integration of new and prior knowledge facilitates a deeper understanding of the to-be-learned content and creates a flexible and powerful representation of the new information. It allows the learner to transfer their knowledge and apply it in new ways and in new situations. The situation model, when it is formed, endures for much longer than the textbase (Kintsch et al., 1990). The situation model is assessed by techniques that require learners to apply their knowledge to new contexts, such as short answer questions, inference items, and application tasks (Kintsch, 1994).

As Butcher and Kintsch (2012) noted, many students equate learning from a text with memorizing its basic ideas and subsequently recalling the material. This may stem from the fact that traditional educational tasks often test for recall rather than deeper understanding. In the current study, both textbase recall and situation model understanding are assessed (as described in the Methods section of this paper).

1.8 Student Generation of Relationships Between Concepts Within a Domain

Theoretical work suggests that students will learn more when presented with a situation in which they must construct something as part of the learning process (Chi, 2009). Students who generate or construct content while learning develop a deeper understanding of the concepts they are learning. In fact, research has found that as instruction provides more consistent opportunities for constructive learning, students tended to have higher problem-solving abilities and more easily notice and correct errors but those who engage in more passive learning do not (Kastens & Liben, 2007). However, it can be difficult to determine when educational technologies should require students to generate their own content versus providing content with which the student can learn. In many cases, students may not possess the necessary prior knowledge or skills to develop correct or meaningful content. This essential tension between generating and providing content has been called "the assistance dilemma" (Koedinger & Aleven, 2007).

The difficulty of knowing what students should generate versus what should be provided to them has been explored in learning with concept-map style representations. Gurlitt and Renkl (2008) found that novice learners learned more when they were asked to generate only the label between linked relationships rather than the lines indicating relationships as well as the labels. Thus, novice learners benefitted by being provided with relationships but generating information about the relationships. In contrast, learners with high prior knowledge benefitted by increased generation: these leaners learned best when generating relationships *and* labels rather than the labels alone. Gurlitt and Renkl (2008) argued that novice learners needed a highly coherent map to organize their generative efforts. In follow-up research, Gurlitt and Renkl (2010) found that novice students engaged in more elaborative processing when labeling lines that were provided on concept maps as compared to creating the lines in addition to labeling them. This research also demonstrated advantages of having students labeling provided lines (rather than creating *and* labeling the lines) in terms of learning outcomes and perceived self-efficacy. Thus, when using concept-map style representations to support learning, novices appear to need support in identifying relationships (via provided lines) but may be able to learn more when asked to generate information about those relationships.

1.9 The Current Study

The current study examined the impact of the spatial organization of graphical search interfaces (i.e., concept maps of learning goals that provide access to online educational resources) compared to the domain content in the maps nodes in supporting student learning during online educational tasks. Spatial organization was tested using either a map view or a list view to preview domain concepts and to provide access to digital library content. In addition, the current study examined the impact of focusing student processing on conceptual relationships between map nodes. Relational processing was tested either by asking students to write a short description of node relationships (write) or simply to view the maps (no write). Thus, the current study used a 2 (spatial organization: map vs. list) X 2 (generation of relationships: write vs. no write) factorial design. The hypotheses were as follows:

H1: The map view will result in deeper understanding of domain content, but only when students attend to conceptual relationships by writing descriptions of node connections.

H2: Participants who study the map view as well as generate relationships (the map/write condition) will show greater understanding of the relationships between concepts.

H3: The list view will result in better factual learning, but only in the case where students view the map passively instead of writing descriptions of node connections.

CHAPTER 2

METHOD

2.1 Participants

Participants were recruited through the Educational Psychology Subject Pool of a major public university in the western United States. A total of 56 students took part in the study. 14 participants were male and 42 participants were female. Average participant age was 23 (range 18 – 41, *SD* = 15). Sixteen participants were seniors at the university, 24 were juniors, 8 were sophomores, and 3 were freshmen. There were also 2 graduate students and 1 participant who was working on a second bachelor's degree. Participants self-reported an average 9.8 hours of Internet use per week. They received credit in an educational psychology course for participation.

Participants were randomly assigned to one of four conditions (see Table 1).

2.2 Materials

The experiment used a personal computer with two monitors. This allowed the participants to see the overview of the concept information on one screen while they studied the details of that information on the other screen.

Table 1. Description of Experimental Conditions

	Map	**List**
Write	Students viewed a map interface and provided self-generated descriptions of the relationships between nodes	Students viewed a list interface and provided self-generated descriptions of the relationships between nodes
No Write	Students viewed a map passively; they did not generate descriptions explicitly	Students viewed a list interface passively; they did not generate descriptions explicitly

The learning materials used in this study were from the National Science Digital Library. Students engaging with these materials learned about plate tectonics; this included the causes and effects of plate tectonics as well as the history behind the discovery of plate tectonics.

2.2.1 Map view

The map view reproduced the content and structure of the Plate Tectonics Science Literacy Map from NSDL.org (see Figure 2). This map contained learning goals written in blue boxes (i.e., nodes). Nodes were organized by grade level (horizontally) and by topic (vertically). Lines between the nodes indicated relationships between those topics and showed how learning goals built on each other over time. Clicking a node in the map interface opened a list of relevant digital resources from the NSDL related to the learning goal contained in the node (see Figure 3). The map view had 12 nodes that participants could click and 18 links depicted between the nodes.

2.2.2 List view

The list view reproduced the content of the same NSDL Science Literacy Map as the map view, but organized the learning goals serially as a list rather than spatially as a graphical network (see Figure 4). Thus, the map and list views contained the exact same text. They also contained the same amount of nodes (both contained 12 nodes). However, it had only 11 relationships depicted between the nodes. Clicking a learning goal in the list view returned the same list of resources as clicking the learning goal in the map view (see Figure 5).

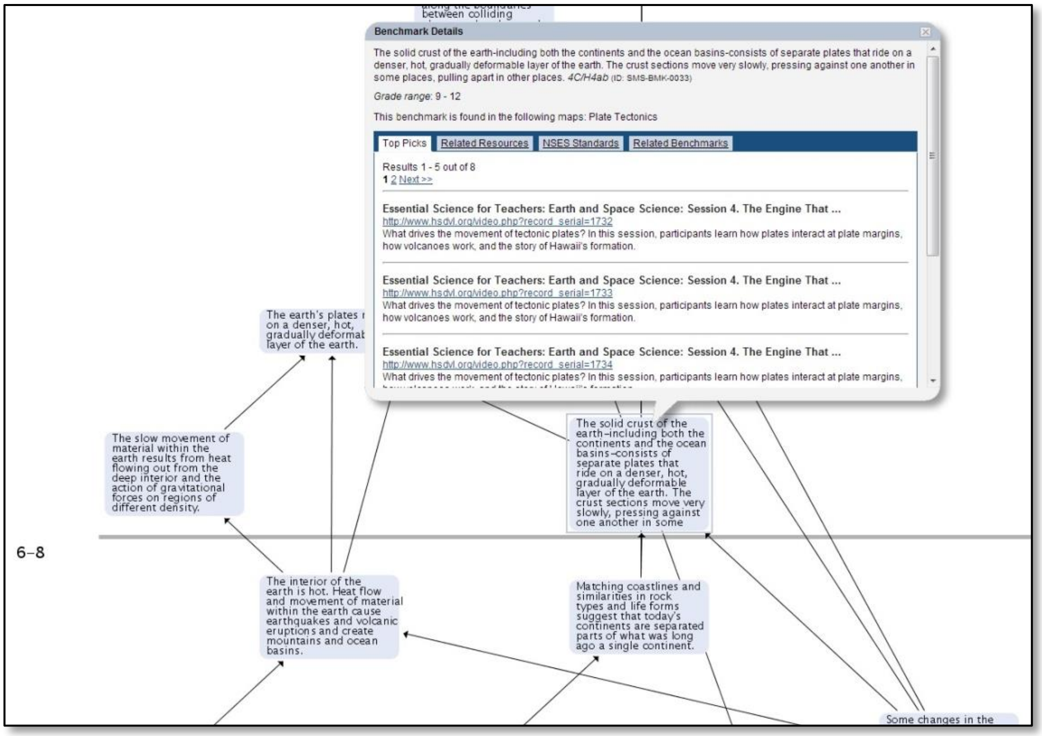
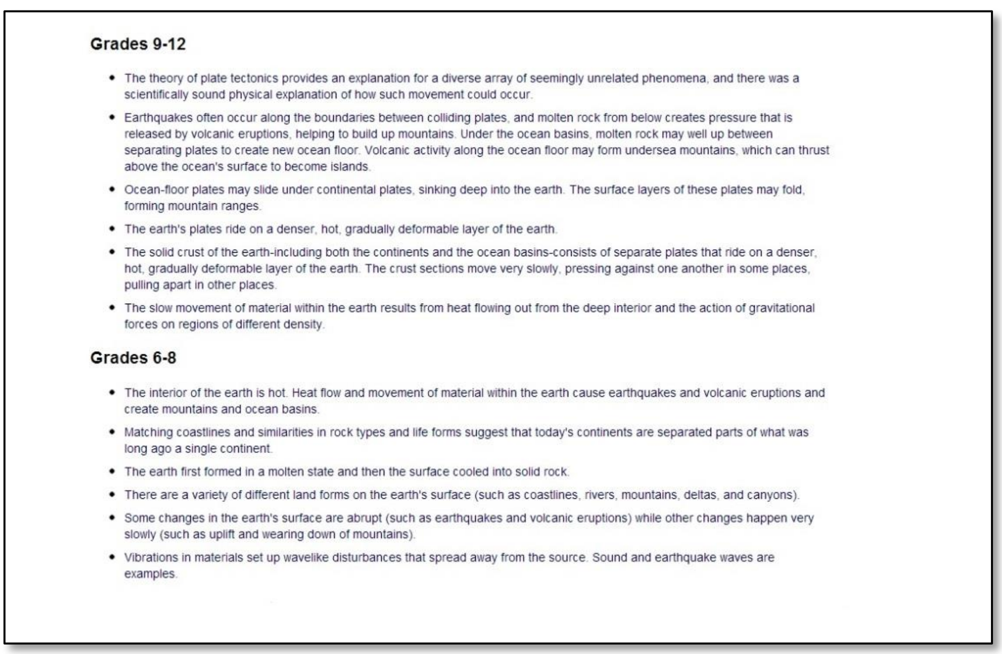


Figure 3. An example of digital resources in the NSDL map view.



Grades 9-12

- The theory of plate tectonics provides an explanation for a diverse array of seemingly unrelated phenomena, and there was a scientifically sound physical explanation of how such movement could occur.
- Earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands.
- Ocean-floor plates may slide under continental plates, sinking deep into the earth. The surface layers of these plates may fold, forming mountain ranges.
- The earth's plates ride on a denser, hot, gradually deformable layer of the earth.
- The solid crust of the earth-including both the continents and the ocean basins-consists of separate plates that ride on a denser, hot, gradually deformable layer of the earth. The crust sections move very slowly, pressing against one another in some places, pulling apart in other places.
- The slow movement of material within the earth results from heat flowing out from the deep interior and the action of gravitational forces on regions of different density.

Grades 6-8

- The interior of the earth is hot. Heat flow and movement of material within the earth cause earthquakes and volcanic eruptions and create mountains and ocean basins.
- Matching coastlines and similarities in rock types and life forms suggest that today's continents are separated parts of what was long ago a single continent.
- The earth first formed in a molten state and then the surface cooled into solid rock.
- There are a variety of different land forms on the earth's surface (such as coastlines, rivers, mountains, deltas, and canyons).
- Some changes in the earth's surface are abrupt (such as earthquakes and volcanic eruptions) while other changes happen very slowly (such as uplift and wearing down of mountains).
- Vibrations in materials set up wavelike disturbances that spread away from the source. Sound and earthquake waves are examples.

Figure 4. Screen shot of the NSDL list view.

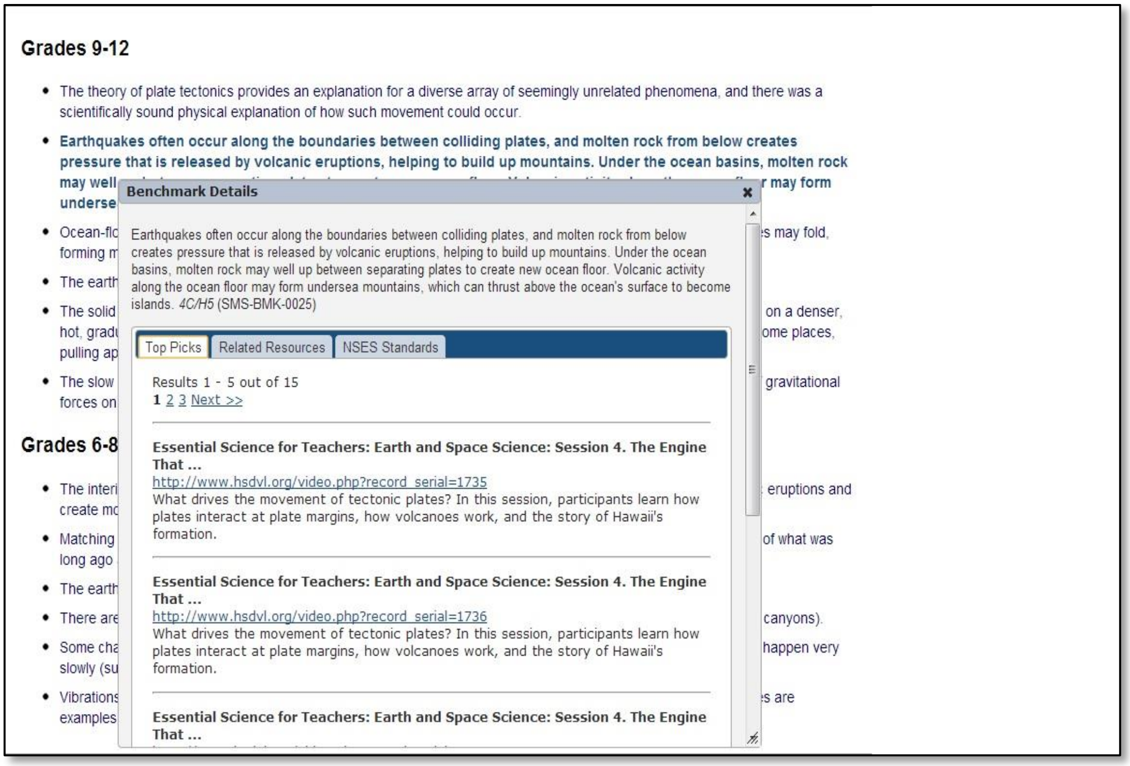


Figure 5. An example of digital resources in the NSDL list view.

2.2.3 No write view

The no write views were the same as the map and list views described above. They did not facilitate typing within the representation.

2.2.4 Write view

A version of the NSDL map and list view (Figure 2 and Figure 3) was developed so that participants could generate typed descriptions of the relationships that existed between concepts. They were made to look as similar to the original map and list interfaces as possible but with text-entry boxes that were inserted into the graphical display. The participants used these boxes to input their self-generated descriptions of relationships between linked nodes in both map view (see Figure 6) and list view (see Figure 7). The map view offered 17 areas where participants could generate information about the relationship between nodes while the list view offered 11 areas.

2.3 Assessments

2.3.1 Demographics survey

The demographics survey asked basic questions about age and gender, as well as collecting information about participants' educational experiences and Internet habits (see Figure 8).

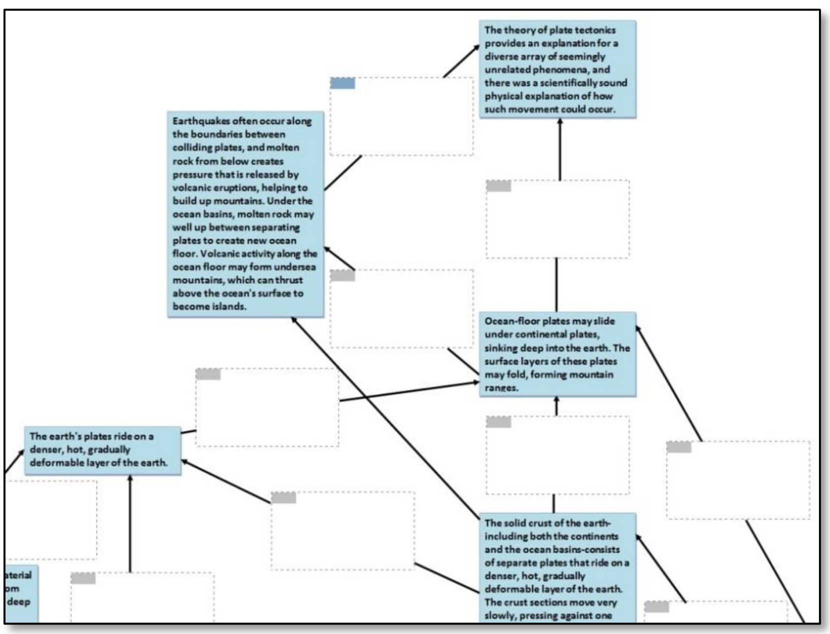


Figure 6. Excerpt of the NSDL map/write view.

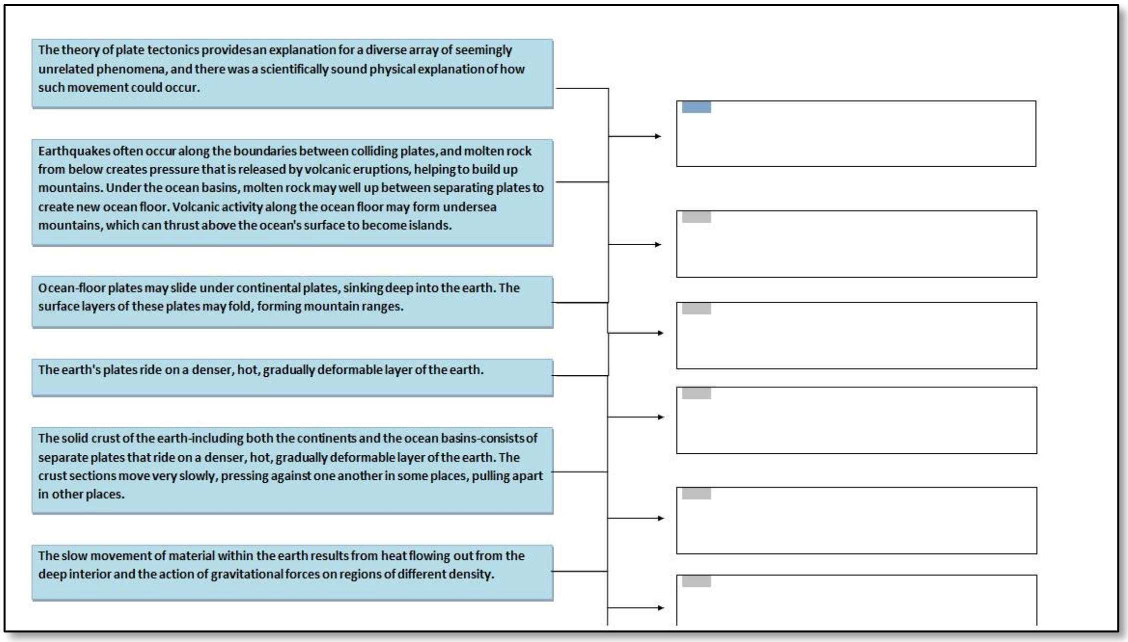


Figure 7. Excerpt of the NSDL list/write view.

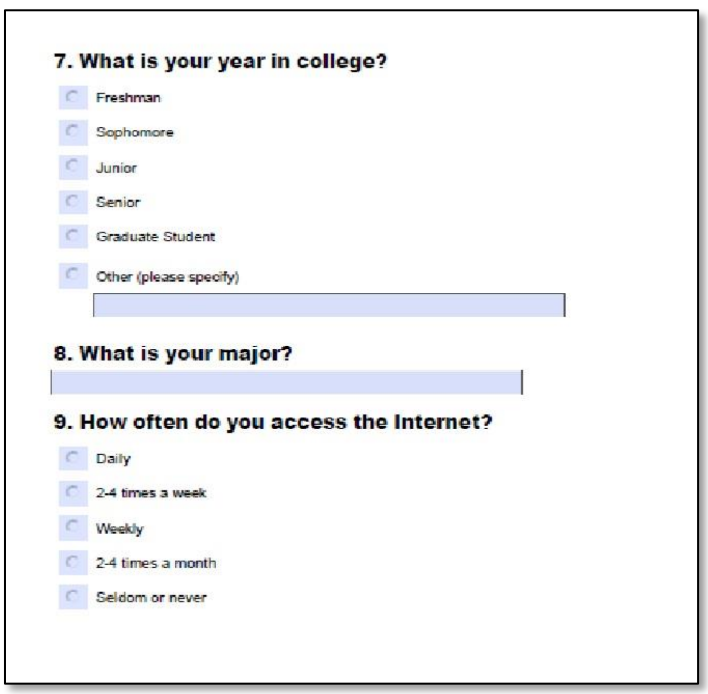


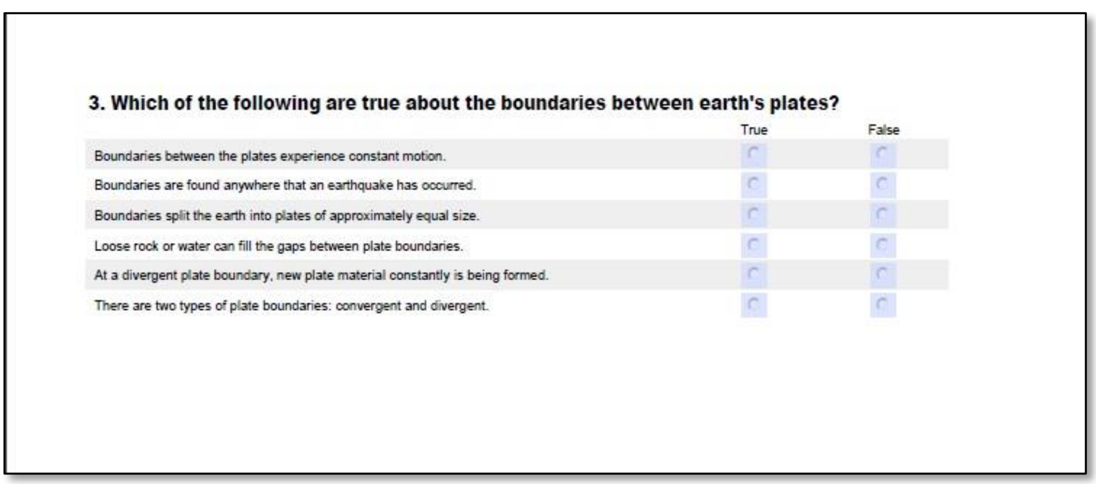
Figure 8. Example questions from the demographic survey.

2.3.2 Pretest

A pretest was given to each participant to assess prior knowledge at the start of the experiment. The pretest consisted of three types of assessment items: multiple choice assessment items, visual assessment items, and paired concept assessment items. Each of these items is described below.

2.3.2.1 Multiple choice assessment items

Participants were given a multiple choice test to assess factual knowledge. The multiple choice pretest had two sections. The first section asked participants to select which statements about plate tectonics were true and which were false (see Figure 9). The second section presented a question with five possible answers. Students had to choose the one correct answer from those five (see Figure 10). Every correct answer was awarded one point while every incorrect answer was awarded no points for a maximum of 43 points.



3. Which of the following are true about the boundaries between earth's plates?

	True	False
Boundaries between the plates experience constant motion.		
Boundaries are found anywhere that an earthquake has occurred.		
Boundaries split the earth into plates of approximately equal size.		
Loose rock or water can fill the gaps between plate boundaries.		
At a divergent plate boundary, new plate material constantly is being formed.		
There are two types of plate boundaries: convergent and divergent.		

Figure 9. Example true/false item from the multiple choice assessment.

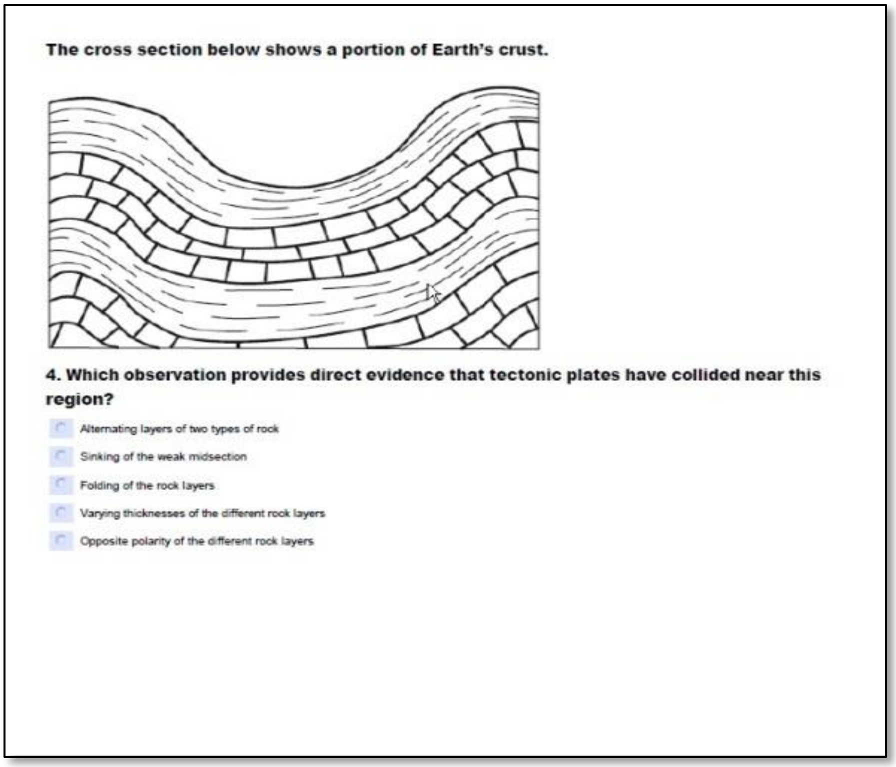


Figure 10. Example of a five-option multiple choice assessment item.

<u>2.3.2.2 Visual assessment items</u>

For these items, participants were asked to label various diagrams as well as to type explanations of their understanding of various concepts about plate tectonics. These two different portions of the assessment targeted factual recall and deeper understanding, respectively. One point was awarded for each correct answer for a possible total of 13 points. Partial answers were awarded half a point each. For example, in Figure 11, students were given a diagram and told to label it with the correct terminology. The arrow is indicating that the participant should label an event that is happening near the crust. The correct answer would be “divergent boundary,” while a partially correct answer would be “boundary.”

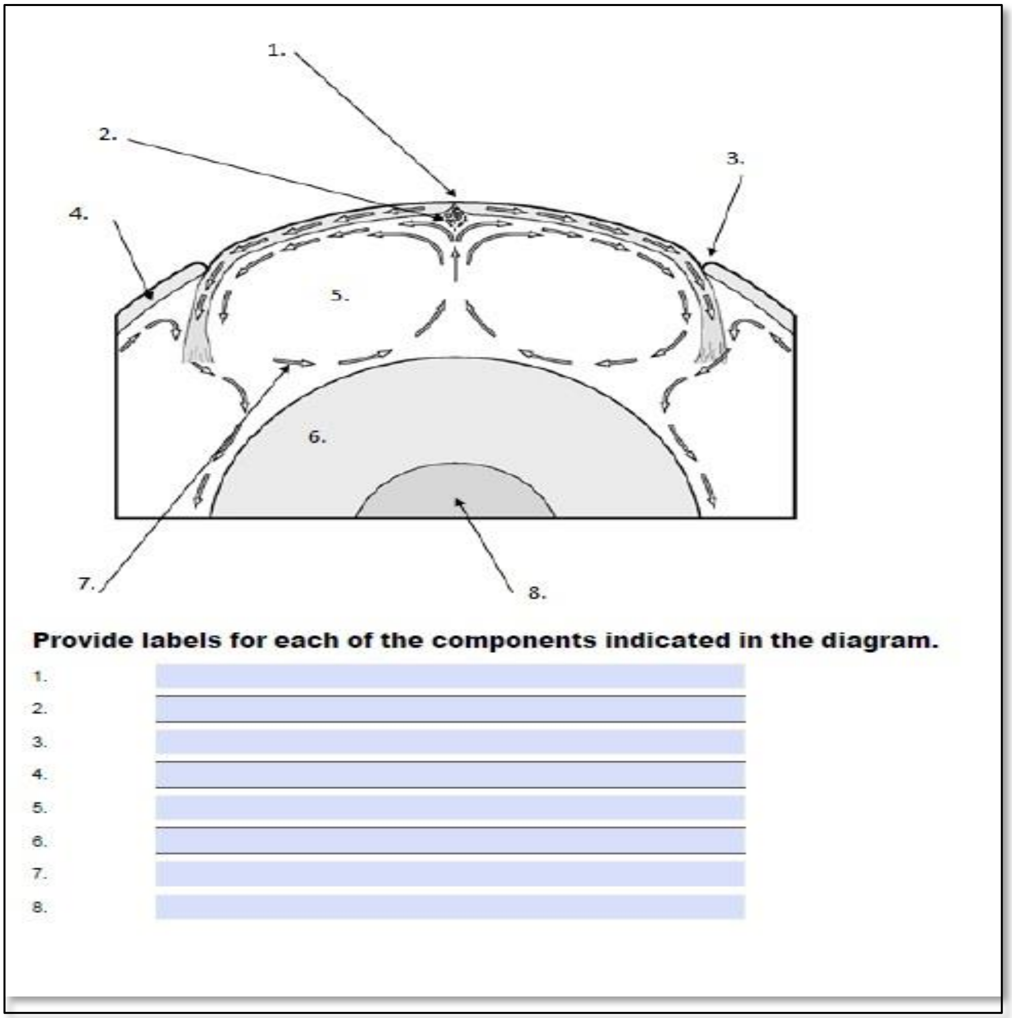


Figure 11. An example item from the visual assessment.

2.3.2.3 Paired concept assessment items

For these assessment items, participants were asked to answer questions about the relationship between two concepts that were drawn from the learning goals presented in the NSDL Science Literacy Maps. These items were chosen to be either closely associated in the original map (i.e., directly linked) or distantly associated (i.e., linked via one or more intervening concepts). Participants first rated the relationship between the two concepts on a Likert scale (1 = Not very related, 6 = Very related).

They also chose two items that best described the reasons why they chose the numbers they did (see Figure 12). For example, they could choose an answer based upon understanding of conceptual connections between the nodes like “There is a logical or causal relationship between the two ideas” or they could choose a more shallow answer like “Both ideas are about the same general topic, as indicated by the keywords.” Being able to recognize the causal relationship between two concepts shows deeper thinking than just noticing that two concepts share scientific terms. Participants were assessed by the percentage of shallow, moderately deep, or deep reasons that they chose for their ratings.

If the participants rated the relationship as 3 or higher, they were asked to type an explanation of what an ideal student should understand about the connection between the two concepts. If they rated the relationship as 2 or lower, the participants were asked to type an explanation of what a student should understand about how the ideas are conceptually different or not related (see Figure 13). These free-form explanations were not analyzed in the current study.

2.3.3 Posttest

A posttest was used to assess learning following the experimental intervention. The multiple choice, visual, and paired concept posttests were identical to their pretest counterparts, except that the paired concept posttest asked participants to answer six questions instead of three. In addition, the posttest included short answer assessment items as described below.

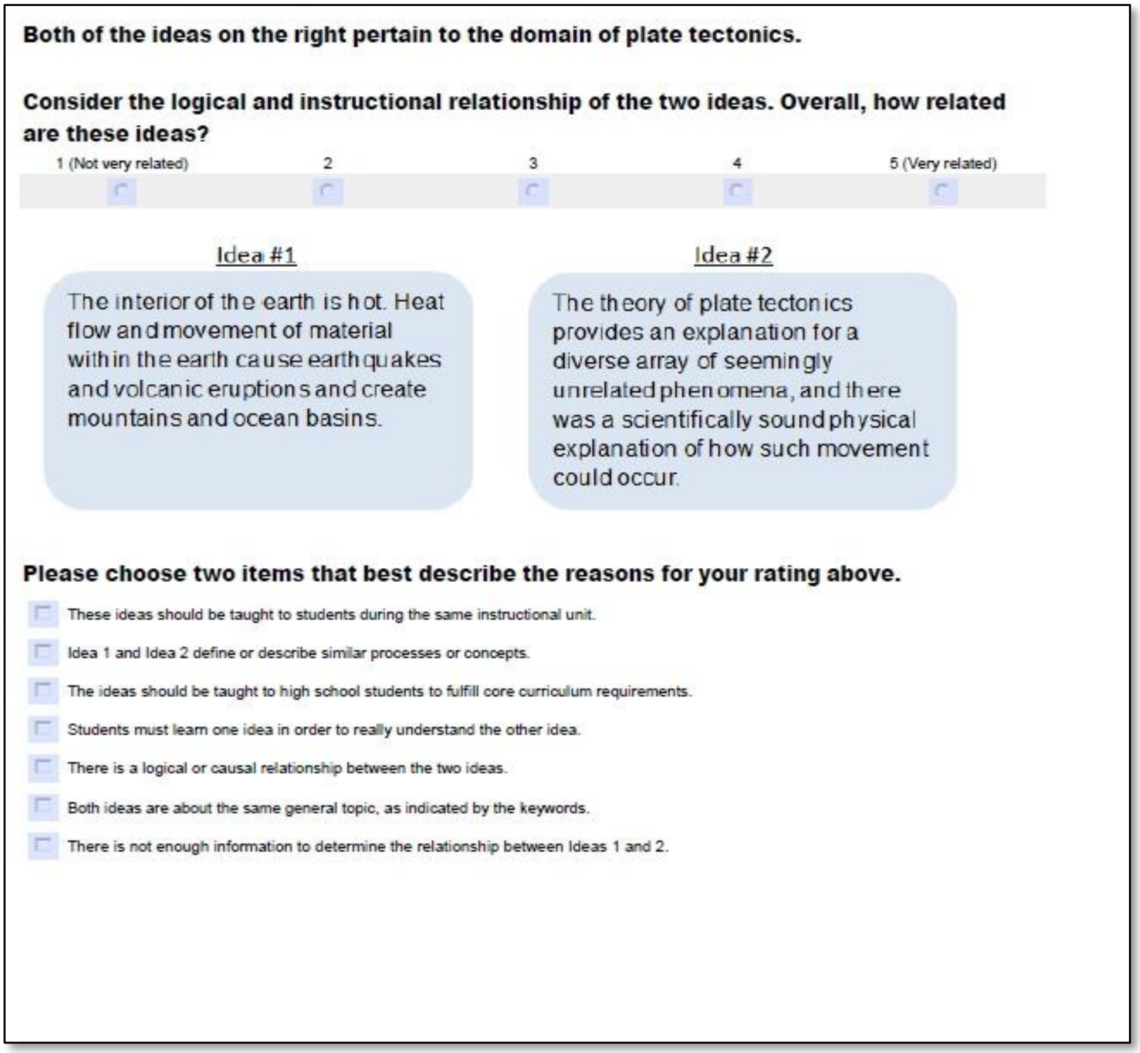


Figure 12. A paired concept item that asks participants to rate the relationships between concepts and to select two reasons for their rating.

2.3.3.1 Short answer assessment items

Participants were presented with four application questions. Application questions presented students with hypothetical scenarios for which students were asked to write a short answer in response to each question or problem (see Figure 14). These questions required the participant to show that they were able to apply their knowledge to new situations. Note that the short answer assessment was given only at posttest.

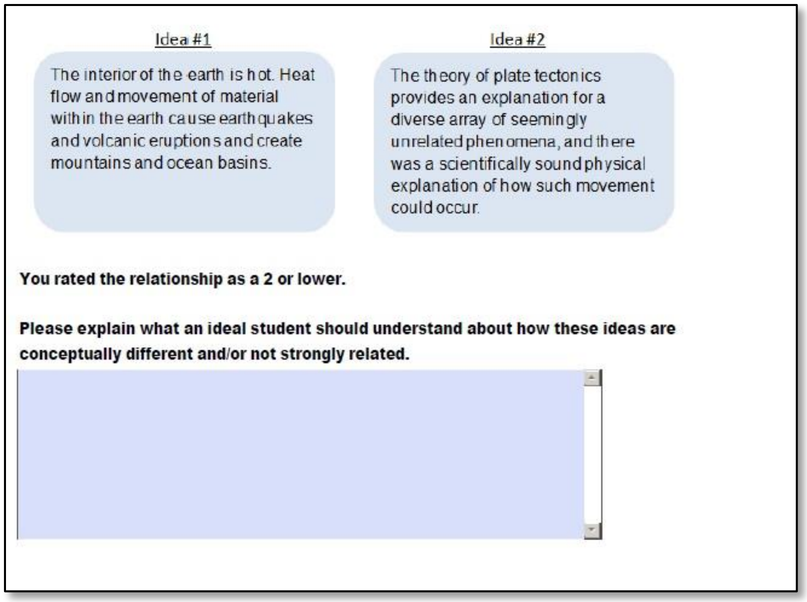


Figure 13. An example of the free-form explanation in which participants explain their rating of two concepts.

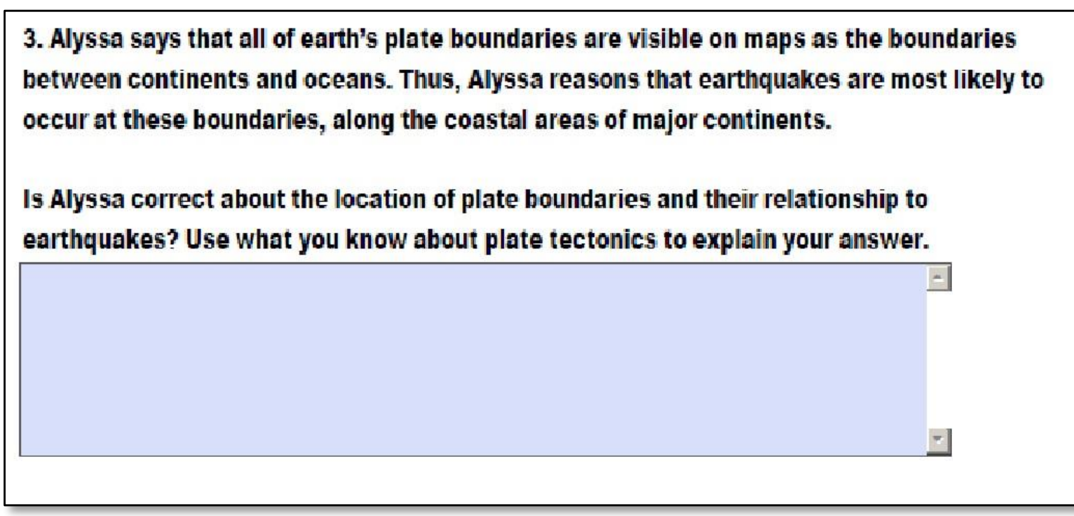


Figure 14. An example short answer item.

2.4 Procedure

Participants were run individually through the research protocol using a computer with a dual-monitor setup. The entire study took 3 hours to complete.

After completing an informed consent procedure, participants were given an identification number that was used on all data produced during the study. The participants next completed the demographics survey. After the demographic survey, participants completed the pretest assessments presented on the computer screen in the following order: multiple choice assessment (10 min); visual assessment (15 min); paired concept assessment (10 min).

Once the pretests were completed, participants were trained on how to read the concept map or list view with which they would be interacting. In both the map and the list views, participants were walked through how to click a concept box, what the information they found there meant, and how they could find more information or switch back to older sources of information (see Figure 3). The participants were shown what the URLs mean, that the nodes all displayed descriptions, and that there were multiple tabs worth of information that could be accessed. Participants then were instructed on how to self-explain as well as shown some good and bad examples of the technique. Participants were asked to practice the self-explanations while the experimenter gave feedback on performance. The training and practice took 15 minutes to finish.

Participants next were presented with either the list view or map view and instructed to self-explain for 10 minutes. The research assistant would prompt students to think more deeply in times when the student was struggling with making inferences or recognizing relationships between concepts. Self-explanations were not analyzed as part of this research, and therefore are not discussed further.

Participants then were instructed to move into the learning task. Students were given a printed scenario that instructed them about their task and their goals. They were instructed to think like a teacher and approach the map view or list view as if they were preparing for a lesson. They were then given 45 minutes to find and learn from online materials catalogued in the NSDL and returned by the map or list view (each view contained links to the same digital resources). The participants who were assigned to the write conditions also were instructed to fill in as many blank boxes as they could, using 1-2 sentences to explain the relationship between linked concepts.

Upon completing the learning task, participants were instructed to self-explain again for 10 minutes, again with either the map or list view. Those in the write condition were presented with a map or list view without their previously typed explanations (after saving their previous user-generated content). After this self-explanation task, participants were allowed a 5-minute break.

Next, participants completed the posttest assessments. Procedures were the same for the pretest. After completing the multiple choice questions and the visual assessment, participants completed a 10-minute short answer assessment that was not included in the battery of pretests. The paired concept assessment posttest included more questions than the pretest and took 25 minutes to complete. After all posttests had been completed, participants were debriefed for 2 minutes.

During this experiment, participants' screen was recorded at three different times. The first recording was done while they were taking their pretests. The second was taken while they did their first self-explanation, their learning task, and their second think-aloud. The last recording was taken while they completed their posttests. The recordings captured everything that happened on their screen as well as everything that was said during self-explanations or when they asked questions.

2.5 Data Analysis

Measures assessed at pre- and posttest (multiple choice items, visual item labels, and paired concept reasons) were assessed by a repeated measures multivariate-analysis of variance (RM-MANOVA). The between subjects factors were spatial organization (map or list) and generation of information about the relationships between concepts (write or no write). The repeated factor was test time (pretest and posttest). Data tested at posttest only (short answer items) were tested by an ANOVA. Alpha level was set at p =.05 for the RM-MANOVA and p = .025 for the ANOVA.

CHAPTER 3

RESULTS

3.1 Factual and Deep Knowledge Outcomes

A repeated measures multivariate analysis of variance (RM-MANOVA) was used to analyze knowledge change from pre- to posttest for multiple choice items (factual knowledge), visual item labels (factual knowledge), and explanation of visual items (deeper understanding). For the between-subjects effect, there was no significant main effect of view (map vs. list: $F_{(3, 46)} = 1.07$, $p = .37$, $\eta_p^2 = .065$) or generation (write vs. no write: $F < 1$). However, there was a significant interaction between view and generation ($F_{(3, 46)} = 2.81$, $p = .05$, $\eta_p^2 = .16$). The significant interaction is interpreted using univariate analyses for each dependent measure as shown in the subsections below.

For the within-subjects effects, there was a significant effect of test time ($F_{(3, 46)} = 39.84$, $p < .01$, $\eta_p^2 = .72$). Participants performed better at posttest than at pretest (see Tables 2 and 3). There were no significant two-way interactions (test time and view: $F_{(3, 46)} = 1.85$, $p = .15$, $\eta_p^2 = .11$, test time and generation: $F_{(3, 46)} = 1.12$, $p = .35$, $\eta_p^2 = .068$), and the three-way interaction between test time, view, and generation also was not significant ($F_{(3, 46)} = 2.06$, $p = .12$, $\eta_p^2 = .12$).

3.1.1 Multiple choice assessment items

Univariate tests showed that there was a significant effect of test time ($F_{(1, 48)}$ = 25.4, p < .001, η_p^2 = .35). Participants performed better during the posttest than the pretest (see Table 2). There was not a significant effect of view or generation on multiple-choice performance (Fs < 1). There was a nonsignificant trend for the interaction of view and generation on factual, multiple choice items ($F_{(1, 48)}$ = 2.9, p = .09, η_p^2 = .06). As seen in Table 2, the pattern of means shows that when students generate relationships, they perform better with the list than the map view, but when students do not generate relationships, they perform better with the map compared to the list view.

3.1.2 Visual assessment items

Univariate tests showed that there was a significant effect of test time on visual labels ($F_{(1, 48)}$ = 83.8, p < .001, η_p^2 = .64) as well as visual explanations ($F_{(1, 48)}$ = 82.3, p < .001, η_p^2 = .63). In both cases, participants performed better during the posttest phase than at pretest (see Table 2). There were no main effects of view (map vs. list) or generation (write vs. no write): Fs < 1. Univariate analyses did not show a significant interaction between view and generation for either labels on visual items ($F_{(1, 48)}$ = 2.26, p = .14, η_p^2 = .05) or explanations of visual items (F < 1).

3.1.3 Paired concept assessment

A RM-MANOVA was used to analyze the total number of deep, moderate, and shallow reasons selected to explain relationships between concepts on the paired

Table 2. Means (and standard deviations) for percent correct on assessments at pre- and posttest.

	Map View				List View			
	No Write		Write		No Write		Write	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Multiple Choice Test	.56 (.12)	.62 (.13)	.51 (.12)	.60 (.09)	.53 (.11)	.56 (.06)	.56 (.09)	.64 (.11)
Visual Items: Labeling	.29 (.19)	.41 (.19)	.20 (.13)	.38 (.21)	.15 (.10)	.38 (.16)	.26 (.19)	.41 (.21)
Visual Items: Explanation	.17 (.18)	.34 (.24)	.16 (.13)	.28 (.24)	.14 (.08)	.38 (.19)	.15 (.15)	.39 (.23)

concept items at pre- and posttest. For the between-subjects comparisons, the multivariate analysis showed no significant main effect of view ($F_{(3, 46)} = 1.21$, $p = .32$, $\eta_p^2 = .07$) or generation ($F < 1$), nor a significant two-way interaction ($F < 1$). For the within-subjects comparisons, the multivariate analysis showed no significant main effect of test time ($F_{(3, 46)} = 1.85$, $p = .15$, $\eta_p^2 = .11$) nor significant interactions: test time and view ($F < 1$), test time and generation ($F < 1$), or test time and view and generation ($F_{(3, 46)} = 1.95$, $p = .13$, $\eta_p^2 = .11$). Because the multivariate tests were not significant, the univariate tests were not interpreted. Table 3 shows the pattern of means for the percent of deep, moderate, and shallow reasons chosen at pre- and posttest.

3.1.4 Short answer assessment

An analysis of variance (ANOVA) was used to examine scores given to short answer assessment questions; a repeated measures analysis was not used because this assessment was given at posttest only. There were no main effects of view or generation, nor a significant interaction between view and generation (*F*s < 1).

3.1.5 Follow-up assessment

Since we found a nonsignificant trend for the interaction of view and generation on multiple choice items, a simple effects follow-up analyses (F calculated with the error term from the interaction) was conducted. It showed that there was no significant difference between the write and no write conditions when viewing a concept map or when viewing the list view ($F < 1$). Both of the recalculated F values from the simple

Table 3. Means (and standard deviations) for the percent of deep, moderate, and shallow reasons chosen to explain concept relationships at pre- and posttest.

	Map View				List View			
	No Write		Write		No Write		Write	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Deep Reasons	.30	.33	.37	.31	.38	.37	.32	.42
	(.22)	(.16)	(.15)	(.14)	(.16)	(.14)	(.19)	(.18)
Moderate Reasons	.44	.41	.37	.49	.43	.47	.43	.40
	(.22)	(.17)	(.14)	(.16)	(.18)	(.13)	(.16)	(.18)
Shallow Reasons	.27	.25	.26	.19	.19	.16	.25	.18
	(.17)	(.14)	(.16)	(.11)	(.16)	(.14)	(.11)	(.15)

means analysis were lower than the critical F value ($F_{\alpha=.05,\ 1,\ 49}$ = 4.04); thus, there was no significant difference.

3.2 Power Analysis

A post-hoc power analysis was conducted to determine the observed power of the interaction between the view and generation conditions. The sample size used was 53. The analysis revealed the statistical power to be .42 for the interaction found in the between-subjects analysis. This is far lower than the recommended .80 level (Cohen, 1988) and indicates that a much larger sample size would be needed in future research of this type.

CHAPTER 4

DISCUSSION

4.1 Findings

This study found a significant, but weak, interaction between the view and generative factors. There was a nonsignificant trend showing that participants who generated information during the session showed greater recall of information while learning from the list view. Those participants who did not generate information showed greater recall while learning from the map view, though a follow-up analysis shows that the difference is not significant. Though these results are weak, they are nonetheless in direct opposition with the study's third hypothesis, which stated that participants would do better with factual learning when assigned to the list view and the no write view. However, this result is consistent with prior research showing that recall of a text macrostructure can be facilitated by a concept map representation (Chimelewski & Dansereau, 1998; Rewey et al., 1989). The present results may indicate that providing students with a conceptual overview in the form of a Science Literary map facilitates factual knowledge of key domain concepts. The present results also may indicate that students can learn factual content from a sequentially-organized list when students are prompted to interact with the list in useful ways. The current study showed that students who generated reasons when working with a list view maybe have been able to remember more factual content from the domain of study. Therefore, there may be merit both in providing organized graphical overviews of domain content as well as facilitating student interaction with more traditional views. The current results showed no significant interactions between the view and generative factors when analyzing deeper level understanding. Thus, the study materials and strategies observed in the current research did not trigger the development of deep knowledge.

It is possible significant effects were not observed because the available assessments did not capture what the participants understood about the subject matter or meaningful interactions between the concepts. For example, it may be the case that asking participants to select from a set of provided reasons to explain their understanding of the relationship between concepts is not a sensitive measure of deep, conceptual reasoning about concept relationships. That is, the reasons provided to students might not have captured the intricacies of participant thinking about the relationship between the concepts. Therefore, additional analyses on student-generated reasons and explanations are warranted in the future.

It also is possible that the complexity of the subject matter (plate tectonics) meant that participants were able to form only a limited understanding of the relationships between domain concepts during the experimental session. Future research should explore the view and generate factors with different (less-complex) materials or more expert learners. Previous research into spatial organization during learning showed that students who engaged in learning using concept maps had positive effects on learning gains (Nesbit & Adescope, 2006), especially with recall (Chimelewski &

Dansereau, 1998; Rewey et al., 1989). Also, research on the impact of student generation typically has demonstrated positive effects when students are provided with significant support (Gurlitt & Renkl, 2008). Although this study did not find evidence that students would learn better with concept maps than with sequential list views, it did demonstrate that facilitating generation (via writing relationships) can facilitate student memory for text content. Conversely, students who are provided with a complex map view may be best served by providing time for mental activity; i.e., providing a map view without additional generation tasks that may distract students from processing visible spatial relationships. According to previous research (Butcher et al., 2006), node-link diagrams can increase the depth with which learners engaged with domain content as they searched for and selected digital resources for online learning. However, this previous research also showed that the benefits of the node-link diagram did not extend to students' processing of resource content. This finding is consistent with the current results showing that the list and the map views did not differ on measures of understanding following a learning experience. It is possible that students need more or better scaffolding during learning with digital resources than what is provided by prior study of a list- or map-based domain representation.

More research needs to be done to understand whether deeper understanding can be affected by the presentation of organizational materials prior to learning combined with the types of activity in which students engage during learning. Although this study found no effects for deep understanding, using more sensitive measures designed to assess students' processing (e.g., participant explanations or verbal protocols) may shed light on the issue.

4.2 Limitations

The research had several limitations. First, the study was limited by low statistical power. A larger sample size would have been necessary to detect an effect in this research. Given effect sizes observed in this study, a sample of approximately 145 participants would be necessary to achieve statistical power at the .80 level that is recommended (Cohen, 1988).

Limited exposure to the domain during a single experimental session could also be a limitation. It is possible that students did not engage with learning materials for a long-enough period of time; thus, allotting a longer time period to the research phase of the study may have facilitated increased opportunities for learning deeply about the domain.

It also is possible that learners with additional background knowledge may work with the provided materials in different ways. Recruiting more advanced learners – such as science majors – to participate would have made it possible to determine if the potential benefits of spatial organization and student generation are limited to learners with higher prior knowledge.

4.3 Conclusion

Online learning allows students to investigate information using varied sources and methods. Successful online and self-regulated learning requires a degree of structure. Understanding what kind of structures are necessary to facilitate successful online learning and what different structures could do for learners will help educators and instructional designers to more effectively develop material that facilitates learning.

The current research demonstrated that the spatial organization of information as well as student generation both are important aspects of effective digital learning, but that they may not have additive effects on students' understanding of domain content. Both of these supports may require significant processing that requires attentional focus; thus, processing spatial organization and generating conceptual relationships may not be compatible forms of learning support. Rather, each form of support may facilitate memory for domain concepts, but only when one form of support is provided (and therefore can be processed fully).

REFERENCES

Alverman, D. E. (1981). The compensatory effect of graphic organizers on descriptive text. *Journal of Educational Research*, *75*, 44-48

American Association for the Advancement of Science. (2013). *Scientific inquiry: Evidence and reasoning in inquiry*. Retrieved from http://www.project2061.org/publications/atlas/sample/1_1_ER.pdf

Ausubel, D. (1963). *The psychology of meaningful verbal learning*. New York: Grune & Stratton.

Ausubel, D., Novak, J., & Hanesian, H. (1978). *Educational psychology: A cognitive view* (2nd ed.). New York, NY: Holt, Rinehart & Winston.

Bergmark, D., Lagoze, C., & Sbityakov, A. (2002). Focused crawls, tunneling, and digital libraries. *Proceedings of the 6th European Conference on Research and Advanced Technology for Digital Libraries (ECDL '02)*, 91-106.

Browne, M. N., Freeman, K. E., & Williamson, C. L. (2000). The importance of critical thinking for student use of the Internet. *College Student Journal*, *34*(3), 391–398.

Butcher, K. R. (2006). Learning from text with diagrams: Promoting mental model development and inference generation. *Journal of Educational Psychology*, *98*(1), 182-197.

Butcher, K. R., Bhushan, S., & Sumner, T. (2006). Multimedia displays for conceptual search processes: Information seeking with strand maps. *ACM Multimedia Systems Journal*, *11*(3), 236-248.

Butcher, K. R., Davies, S., Crockett, A., Dewald, A., & Zheng, R. (2011). Do graphical search interfaces support effective search for and evaluation of digital library resources? *Proceedings of the 11th annual international ACM/IEEE-CS Joint Conference on Digital Libraries (JCDL '11)* (pp. 315-324). New York: Association for Computing Machinery.

Butcher, K.R., & Kintsch, W. (2012). Text comprehension and discourse processing. In A.F. Healy & R. W. Proctor (Eds.), *Experimental psychology. Volume 4* in I. B. Weiner (Editor-in-Chief), Handbook of psychology (2nd ed.). New York: Wiley.

Butcher, K. R., & Sumner, T. (2011). Self-directed learning and the sensemaking paradox. *Human Computer Interaction, 26*(1), 123-159. doi: http://dx.doi.org/10.1080/07370024.2011.556552

Chmielewski, T. L., & Dansereau, D. F. (1998). Enhancing the recall of text: Knowledge mapping training promotes implicit transfer. *Journal of Educational Psychology, 90*(3), 407-413.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Graham, L., & Metaxas, P. T. (2003). "Of course it's true; I saw it on the internet!" Critical thinking in the internet era. *Communications of the ACM*, *46*(5), 70-75.

Gray, L., Thomas, N., & Lewis, L. (2010). *Teachers' use of educational technology in U.S. public schools: 2009 (NCES 2010-040)*. Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Retrieved from http://nces.ed.gov/pubs2010/2010040.pdf

Gurlitt, J., & Renkl, A. (2008). Are high-coherent concept maps better for prior knowledge activation? Differential effects of concept mapping tasks on high school vs. university students. *Journal of Computer Assisted Learning*, *24*(5), 407-419.

Idling, M. K., Crosby, M. E., Auernheimer, B., & Klemm, E. B. (2009). Web site credibility: Why do people believe what they believe? *Instructional Science*, *37*, 43-63.

Internet World Stats (26 December, 2012). Usage and Population Statistics. Retrieved from: http://www.internetworldstats.com/

Kastens, K. A., & Liben, L. S. (2007). Eliciting self-explanations improves children's performance on a fieldbased map skills task. *Cognition and Instruction*, *25*, 45–74.

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction-integration model. *Psychological Review*, *95*(2), 163-182.

Kintsch, W. (1994). Text comprehension, memory, and learning. *American Psychologist*, *49*(4), 294-303.

Kintsch, W. (1998), *Comprehension: A paradigm for cognition*. Cambridge, UK: Cambridge University Press

Koedinger, K. R., & Aleven, V. (2007). Exploring the assistance dilemma in experiments with cognitive tutors. *Educational Psychology Review, 19*(3), 239-264.

Lynch, C. (2008). Digital libraries, learning communities, and open education. In T. Iiyoshi & M. S. V. Kumar (Eds.), *Opening up education* (pp. 105-118). Cambridge, MA: MIT Press.

Marchionini, G. (2006). Exploratory search: From finding to understanding. *Communications of the ACM, 49*(4), 41-46.

Marchionini, G., & Maurer, H. (1995). The roles of digital libraries in teaching and learning. *Communications of the ACM, 38*(4), 67-75.

Marchionini, G., & White, R. (2007). Find what you need, understand what you find. *International Journal of Human-Computer Interaction, 23*(3), 205-237.

McCown, F., Bollen, J., & Nelson, M. (2005). Evaluation of the NSDL and Google for obtaining pedagogical resources *Proceedings of ECDL '05* (pp. 344-355). Vienna, Austria: Wiley.

McCrudden, M.T., Schraw, G., & Lehman, S. 2009. The use of adjunct displays to facilitate comprehension of causal relationships in expository text. *Instructional Science 37,* 1, 65-86. DOI= 10.1007/s11251-007-9036-3

Moore, D. W., & Readance, J. E. (1984). A quantitative and qualitative review of graphic organizer research. *Journal of Educational Research, 78,* 11-17.

Moravcsik, J. E., & Kintsch, W. (1993). Writing quality, reading skills, and domain knowledge as factors in text comprehension. *Canadian Journal of Experimental Psychology, 47,* 360–374.

National Science Digital Libraries. (2013). *Human organism disease concept map*. Retrieved from http://strandmaps.nsdl.org/?id=SMS-MAP-1446

National Telecommunications and Information Administration. (1999). *Falling through the Net: Defining the digital divide*. Retrieved May, 2000 from US Department of Commerce Web site: www.ntia.doc.gov/ntiahome/fttn99/execsummary.html.

Nesbit, J. C., & Adesope, O. O. (2006). Learning with concept and knowledge maps: A meta-analysis. *Review of Educational Research, 76*(3), 413-448.

O'Donnell, A. M., Dansereau, D. F., & Hall, R. H. (2002). Knowledge maps as scaffolds for cognitive processing. *Educational Psychology Review, 14*(1), 71-86.

Patterson, M. E., Dansereau, D. F., & Wiegmann, D. A. (1993). Receiving information during a cooperative episode: Effects of communication aids and verbal ability. *Learning and Individual Differences*, *5*, 1-11.

Pew Research Center (15 September, 2002). *The Internet goes to college: How students are living in the future with today's technology*. Retrieved from: www.pewinternet.org/reports/pdfs/PIP_College_Report.pdf

Rewey, K. L., Dansereau, D. F., Skaggs, L. P., Hall, R. H., & Pitre, U. (1989). Effects of scripted cooperation and knowledge maps on the processing of technical material. *Journal of Educational Psychology, 81*(4), 604-609.

Salmerón, L., Baccino, T., Cañas, J. J., Madrid, R. I., & Fajardo, I. (2009). Do graphical overviews facilitate or hinder comprehension in hypertext? *Computers & Education, 53*(4), 1308-1319.

Zia, L. L. (2000). The NSF national science, mathematics, engineering, and technology education digital library (nsdl) program: A progress report. *D-Lib Magazine*, *6*(10), Retrieved from http://www.dlib.org/dlib/october00/zia/10zia.html

Zia, L. L. (2001). The NSF national science, technology, engineering, and mathematics education digital library (nsdl) program: New projects and a progress report. *D-Lib Magazine*, *7*(11), Retrieved from http://www.dlib.org/dlib/november01/zia/11zia.html