Teacher Enactment of Web GIS Tectonics Investigations

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Abstract
A potential method for teaching geospatial thinking and reasoning is through spatially-enabled learning technologies. We developed four Web GIS (Geographic Information Systems) tectonics investigations using an instructional model with eight key elements for teaching science with spatially-enabled learning technologies such as GIS. This study investigated the variations of implementation fidelity when four urban middle school teachers enacted the Web GIS tectonics investigations. Twenty-nine observations were conducted in the classrooms of the four teachers with an observational protocol. Pedagogical implementation was mostly consistent for each teacher for each ability track level they taught. There was little variability among the teachers with regards to adherence to the key elements of the instructional model during the curriculum enactment. The teachers did not modify the instructional materials and predominantly enacted the investigations as designed. Curriculum time constraint played a large role when the last key element of the model was not implemented. The findings provide support that geospatial thinking and reasoning related to a science content area can be taught formally to students in an urban middle school and can be supported by appropriately designed curriculum materials and Web GIS.

Geospatial thinking, a subset of spatial thinking, is a skill that necessitates knowledge about space, the ability to use tools of representation properly, and reasoning skills (National Research Council [NRC], 2006). Geospatial reasoning skills provide a means for manipulating, interpreting, and explaining structured information and are involved in higher-order cognitive processes that include solving problems and making decisions. One potential method for teaching geospatial thinking and reasoning is through spatially-enabled learning technologies, such as Geographic Information Systems (GIS) (Battersby, Golledge, & Marsh, 2006). GIS may enhance science curriculum learning by adding an emphasis on geographic space, visualization, scale, representation, and spatial thinking and reasoning skills. While these technologies show promise to support the development of geospatial thinking and reasoning, the NRC (2006) report *Learning to Think Spatially: GIS as a Support System in the K-12 curriculum*, pointed out that we still lack specific knowledge on how to infuse geospatial thinking and reasoning into the science curriculum and how to best use GIS when teaching urban classroom learners.

A GIS is a software application that organizes Earth's features into thematic layers and then uses computer-based tools to aid one with examining their patterns, linkages, and relationships (Kerski, 2008). Using two- and three- dimensional visualization and analytical software, the GIS tool set enables learners to view, manipulate, and analyze rich data sets from local to global scales, including data pertaining to population, seismic hazards, plate vectors, lithosphere thickness, surface heat flow, land cover, and elevation. GIS visualizations and its interactive visual interfaces can effectively provide material for analysis and reasoning in geospatial contexts (Andrienko et al., 2007). The capacity to visualize data patterns and relationships is integral to the process of geospatial thinking and involves spatial abilities such as spatial visualization, orientation and spatial relations (Albert & Golledge, 1999). The capability to manipulate structural relations in data to produce new graphical representations of data makes GIS a valuable tool to support geospatial thinking and reasoning in a school setting (Edelson, 2001; Schultz, Kerski, & Patterson, 2008).

Reform-based science curriculum materials are viewed by many as an important mechanism for change in science education. Such materials are tangible tools designed for impacting what teachers do, and therefore, what students learn. Research has shown that when teachers enact reform-based science materials, variations with regards to implementation and fidelity are likely to occur (Fogleman, McNeill, & Krajcik, 2011; Lynch, Pyke, & Grafton, 2012). The adoption of new science curriculum materials by classroom teachers involves making decisions about which instructional features are the best to implement into their classrooms as a means to achieve the desired student learning goals. Such decisions are guided by a teacher's pedagogical content knowledge, instructional beliefs, intentions, pedagogical implementation skills and teaching goals (Tarr et al., 2008). How teachers perceive and understand various instructional design features is determined in part by how the intended use of the learning activities aligns to a teacher's capacity to implement the instructional materials into an actual classroom setting (Stein, Remillard, & Smith, 2007). During this process, a teacher must perceive and interpret existing curriculum resources, evaluate the constraints of the classroom and school setting, and reconcile their perceptions of the intended goals of the curriculum materials with their own instructional goals and capacities (Brown, 2009). Throughout curriculum enactment, teachers may adapt and modify the intended instructional design of curriculum materials in order to meet the needs of the students or the instructional setting. They may modify existing components that are beyond their own capacities or the capabilities of their students and may well omit components that do not interest them or that they may be unable to implement due to time constraints in the school setting (Kulo, 2011).

Researchers of curriculum innovations have been concerned with studying variations in the fidelity of implementation or enactment of reform-based curriculum materials (Lynch et al., 2012). While studies have reported that teachers adapt new innovative materials during curriculum enactments (Brown, 2009; Fogleman et al., 2011), it is unknown how urban middle school science teachers enact curriculum materials designed with Web GIS technologies to promote geospatial thinking and reasoning. In this exploratory study, we investigated how urban middle school teachers implement and vary Web GIS learning activities designed with an instructional model (see Kulo & Bodzin, in press) containing eight key elements for promoting geospatial thinking and reasoning skills. This exploratory study is guided by the following research questions:

(1) What variations in fidelity occur when middle school teachers enact Web GIS tectonics investigations*?*

(2) How do teachers perceive the key elements in the geospatial learning instructional model to enhance student learning?

Method

Four eighth grade Earth and space science middle school teachers in two urban schools in the northeast region of the United States implemented four new Web GIS tectonics investigations with their students during the 2011-2012 academic school year. The investigations are available online at: **http://www.ei.lehigh.edu/eli/tectonics**. The majority of the students were from low-income households. Student classes included three different academic tracked ability levels that are determined by mathematics achievement on the state standardized test. One teacher taught science to a class solely composed of eight students with IEPS and four English language learners.

Fidelity of implementation (FOI) in curriculum enactment studies is often viewed as being complex and multi-dimensional involving components that focus on program integrity (Dane & Schneider, 1998; O'Donnell, 2008). Measuring FOI involves identifying the critical components of the curriculum innovation and determining if they are present or not during enactment (Mowbray, Holter, Teague, & Bybee, 2003). In this study, the critical components included the eight key elements of the instructional model for each Web GIS investigation:

1. Elicit prior understandings of lesson concepts.
2. Present authentic learning task.
3. Model learning task.

4. Provide worked example.

5. Perform learning task.

6. Scaffold learning task.

7. Elaborate task with additional questions.

8. Review activity concepts.

Twenty-nine observations were conducted in the classrooms of the four teachers. An observational protocol was used to measure adherence to the eight key elements of the instructional model and to capture specific teaching practices that occurred.

Teachers also completed a survey that included a series of Likert-type and open-response items to share their perspectives on how the key elements in the geospatial learning instructional model improved their students' understandings of tectonics concepts and processes.

Data Analyses and Findings

Table 1 displays a summary of the teachers' enactments of the spatial learning instructional model. The key element numbers (#1-8) are listed above. The teachers enacted all eight key elements of the instructional model for more than half (58.6%) of the observed investigations. The last key element, *review activity concepts*, was omitted for ten observed investigations due to time constraint issues; that is, the 46-minute class period ended before the concept was reviewed and was not revisited during the next class meeting. Pedagogical implementation was mostly consistent for each teacher for each ability track level they taught. There was little variability among the teachers with regards to adherence to the key elements of the instructional model during the curriculum enactment. The teachers did not modify the instructional materials and predominantly enacted the investigations as designed.

Table 1. Teacher enactment summary of Web GIS tectonics investigations

Teacher/Ability track	Investigations Observed	Elements Implemented	Element Omitted	Teaching Practices Summary
Teacher 1/ low ability track	2	8; 7	0; 8	Instruction was highly structured with much explicit modeling using a projected image. Much whole-group scaffolding used for spatial analysis. Students worked on individual laptops.
Teacher 2/ low ability track	2	8; 7	0; 8	Much time spent reviewing prior knowledge. Task modeling occurred using a projected image – not very scaffolded. Scaffolding occurred in small groups or with individual students. Students worked in dyads on laptops.
Teacher 2/ high ability track	4	8; 8; 8; 7	0; 0; 0; 8	Same as above for this ability track.
Teacher 3/ middle ability track	3	8; 6; 6	0; 1, 2; 1, 8	For two investigations: Explicit modeling occurred using a projected image – not very scaffolded. Scaffolding occurred in small groups or with individual students. Students worked in dyads on laptops. For one investigation: Each section of the investigation was explicitly modeled with much scaffolding. After modeling, students worked independently, followed by a review of questions before moving on to the next section of the investigation.
Teacher 3/ low - middle ability track	6	8; 8; 8; 7; 7; 5	0; 0; 0; 8; 8; 1, 2, 8	Same as above for this ability track.
Teacher 4/ low ability track	4	8; 8; 8; 7	0; 0; 0; 8	Explicit modeling and highly scaffolded throughout the entire lesson. One-computer classroom model implementation – no student investigation sheet distributed. Students worked on individual laptops. Questions reviewed for each section before moving on to the next section. Explanations to analysis questions were scaffolded.
Teacher 4/ middle ability track	4	8; 8; 8; 7	0; 0; 0; 8	Same as above for this ability track.
Teacher 4/ high ability track	4	8; 8; 7; 7	0; 0; 0; 8	Task modeling and scaffolding occurred with spatial tool use and with discussion of spatial patterns for certain analysis questions.

Analysis of the teachers' survey responses indicated that they perceived the eight key elements of the instructional model would improve their students' understandings of Earth science concepts and processes. Teachers also noted a variety of ways that learning about tectonics using

Web GIS enables geospatial thinking highlighting relationships and patterns among different data layers and providing learners with a tool that enables students to work with data both visually and kinesthetically. All teachers also noted that they believed that using Web GIS tectonics investigations enhanced what they typically did in their classrooms to teach Earth science.

Conclusion

Adopting new reform-based science curriculum materials that use Web GIS is a significant change from the types of science classroom teaching that typically occurs in urban schools. Time for teachers to become comfortable with implementing reform-based geospatial science curriculum materials may be an important contextual factor for successful Web GIS adoption. When the teachers implemented the curriculum materials for their first time, they became familiar with a new spatially-enabled learning technology, content, learning materials, and instructional activities. The lack of teacher modifications to the instructional materials reported in this study tend to suggest that teachers may implement the individual learning activities predominantly as intended for their first time without substantial adaptations. Teachers may need to enact Web GIS investigations more than one or two times in order to become confident to make adaptations to the geospatial learning materials.

This study contributes to the literature on science curriculum material design and development with spatially-enabled learning technologies. The instructional design approach resulted in middle school teachers implementing reform-based geospatial learning activities with Web GIS in urban classrooms. The findings from this exploratory study provide support that geospatial thinking and reasoning related to a science content area can be taught formally to students in an urban middle school and can be supported by appropriately designed curriculum materials and Web GIS. This research informs curriculum developers with an instructional design model that can be used in the development of geospatial science learning activities.

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