Enhancing Tectonics Learning with Web GIS

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Abstract

GIS promotes geospatial thinking by enabling powerful data visualizations and enhancing scientific inquiry in secondary classrooms. Despite its potential, GIS implementation in middle school classrooms faces technological hurdles and teacher training deficits limiting widespread adoption. To address these barriers, we developed tectonics curriculum materials that incorporate JavaScript-based Web GIS activities portable on tablets, laptop and desktop computers. The Web GIS interface is designed for simplicity, intuition, and convenience, making it easier for diverse middle school learners and their teachers to conduct authentic tectonics investigations than is presently possible. The intuitive interface enables diverse learners to develop geospatial thinking skills that are important for understanding Earth's structures and tectonic processes. Our presentation illustrates how students are able to perform tectonics investigations that include geospatial analysis, map visualization and query, and the manipulation of geospatial data.

In 2006, the National Research Council published the report *Learning to Think Spatially: GIS as a Support System in the K-12 curriculum* that called attention to a lack of teaching and learning of spatial thinking in the K–12 curriculum despite its fundamental importance and despite its prominence in the National Science Education Standards (NRC, 2006). This report viewed spatial thinking as a basic and essential skill that can be learned, that can be taught formally to all students, and that can be supported by appropriately designed tools, technologies, and curricula (NRC, 2006, p.6). Despite this, spatial thinking and abilities have not commonly been addressed in traditional science education curriculum (Black, 2005; Mathewson, 1999; Wai et. al, 2009). Therefore, there is an acute, growing, and timely need for the development of innovative teaching curriculum materials to promote spatial literacy in science education (Baker, Palmer, & Kerski, 2009; Bodzin, 2011).

Educators have recognized that geographic information systems (GIS) have the capacity to promote spatial thinking by: a) enabling powerful, multidisciplinary visualization, analysis, and synthesis of data, b) expanding student understandings of Earth science, and c) enhancing inquiry in natural and social sciences (Kerski, 2008; NRC, 2006; Sanders, Kajs, & Crawford, 2002). In addition, GIS are essential tools for Earth, environmental, and ecological science research. Due to their interactive capabilities, GIS provides unparalleled opportunities to change the ways in which students explore, investigate and learn new science subject matter. Now with the widespread availability of classroom Internet access and recent capabilities of new Web GIS applications, the potential finally exists for teachers to readily use GIS for science learning in middle school classrooms. The time is ripe for enhancing secondary science education by preparing teachers to implement Web GIS as an essential learning tool for students to investigate and understand Earth's structures and processes.

To address the issue of readily available "ease-of-use" GIS curriculum materials for teachers to teach important tectonics concepts, we developed six new Web GIS tectonics learning activities and provided professional development to the preservice science teachers at our institution and to all eighth grade teachers in two urban schools in our local school district during this past academic school year.

The overall goal of our project was to develop novel, relevant, and portable Web-based Earth science curriculum materials that focus on promoting spatial thinking and scientific inquiry with new Web GIS visualizations and analysis tools. We designed a new Web GIS interface using JavaScript for simplicity, intuition, and convenience, making it much easier for diverse middle school learners and their teachers to conduct Earth science investigations than would be possible using a burdensome desktop GIS. The Web GIS is designed with an intuitive interface to enable diverse learners to develop spatial thinking skills that are important for understanding Earth's structures and processes and to investigate a range of Earth science issues. Students are able to perform advanced desktop GIS functions including spatial analysis, map visualization and query, and the manipulation of geospatial information. The Web GIS interface integrates graphics, multimedia, and animation in addition to some newly developed features allowing users to explore and discover geospatial patterns that would not be easily visible using typical classroom instructional materials. These include:

• A swipe tool that provides users the ability to "swipe" data layers on the GIS in order to visualize relationships among very graphical colored data layers (such as understanding the spatial relations between the age of the ocean floor and heat flow).
• A subduction profile tool that enables learners to visualize both graphically and in map view the spatial patterns and relational features of overlaying subducting tectonic plates.
• A continental boundary tool that enables users to overlay, rotate and move continents to understand concepts pertaining to plate motions over time.

Since our GIS applications are Web-based, no proprietary software needs to be purchased by a school district for use. Only a computer or mobile device (such as a tablet) with Internet access is needed to access and use the Web GIS.

The tectonics curriculum materials uses a spatial learning design model that incorporates a related set of frameworks and design principles to provide guidance in the development of the geospatial technologies-supported curriculum materials. The framework builds on the work of other successful technology-integrated curriculum projects (Edelson, 2001; Krajcik et. al, 2008; Linn, Davis, and Bell, 2004) and includes:

1. Align materials and assessments with learning goals.
2. Contextualize the learning of key ideas in real-world problems.
3. Engage students in scientific practices that foster the use of key ideas.
4. Use geospatial technology as a tool for learners to explore and investigate problems.
5. Support teachers in adopting and implementing GIS and inquiry-based activities.

We use a series of proven design principles (Bell, Hoadley, & Linn, 2004; Kali, 2006) to promote spatial thinking skills with Earth and environmental science materials:
1. Design curriculum materials to align with the demand of classroom contexts.
2. Design activities to apply to diverse contexts.
3. Use motivating contexts to engage learners.
4. Provide personally relevant and meaningful examples.
5. Promote spatial thinking skills with easy-to-use geospatial learning technologies.
6. Design image representations that illustrate visual aspects of scientific knowledge.
7. Develop curriculum materials to better accommodate the learning needs of diverse students.
8. Scaffold students to explain their ideas.
See Bodzin, Anastasio, & Kulo (in press) for more details.

An instructional model that includes eight key elements is used to guide the development of each geospatial learning activity in the curriculum for promoting geospatial learning and reasoning skills. The instructional model incorporates a sequence of instructional events that are based on current learning theories (Black & McClintock, 1996; Collins & Stevens, 1983; Eisenkraft, 2003; Gagné, 1985; Jonassen, 1997; 1999) that are applied to the design task of promoting teaching and learning of science with GIS. The model includes the following key elements:

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.

Like other curriculum reform initiatives that involve technology-supported curricula (Krajcik, McNeill, & Reiser, 2008; Marx, et al., 2004; Rivet & Krajcik, 2004; Rivet & Krajcik, 2008), the curriculum materials are designed to align instructional materials and assessments with learning goals (Wiggins & McTighe, 2005). National frameworks (AAAS, 1993; NRC, 1996; 2011) are used to provide guidelines for the Earth sciences content in addition to the science inquiry and spatial thinking skills that schools must focus on.

The curriculum materials includes educative materials (Davis & Krajcik, 2005) that are designed to promote and support teachers' learning of important tectonics concepts, geospatial pedagogical content knowledge, and geospatial thinking skills. The materials include instructional guidance for teachers and provides implementation and adaptation guidance for teaching with diverse learners including low-level readers, English language learners and students with disabilities. These materials have been derived from our initial prototype implementation studies in diverse urban classrooms. Our educative materials are a form of embedded teacher professional development. We believe that providing embedded professional development within curriculum materials is a necessary and transformative educational mechanism, since many professional development constraints exist for teachers to adopt and implement reform-based science curriculum in urban school systems (Fishman, et al., 2003).

We use a design partnership model for the development of all curriculum materials that includes science educators, scientists, instructional designers, classroom teachers, and a professional advisory board of experts in science, pedagogy, curriculum design, and teaching and learning with geospatial technologies. Our partnership model focuses on collaborative design and implementation of curriculum in keeping with models of school-based reform. The partnership will leverage the expertise of each contributor to facilitate the transition between the designed curriculum and the implemented curriculum in the classroom.

Each partner brings a unique perspective to the design and development of the curriculum materials. The science educators and instructional designers provide the group with science-specific pedagogical content knowledge and knowledge of effective instructional designs and frameworks, ensuring cognitive flexibility of learning, knowledge representation, and knowledge transfer. The scientists contribute to the design process by ensuring that the content is balanced, current, valid, and essential to the students' enduring understandings of the discipline and promotes authentic skills and scientific habits of mind. The classroom teachers keep the group grounded in the fidelity of implementation realities of the classroom. Throughout our iterative development process, the teachers help the group address many implementation issues including delivery time and scheduling constraints, designing instructional materials for students with special needs and below average reading abilities, and computer and network issues that commonly occur in school settings. Designing the materials in this manner enables teachers to master instructional resources and to adapt the materials to the needs of their students. Consequently, our curriculum materials are easily adaptable across diverse learning contexts, allowing all students to achieve in the learning process.

The Web GISs are available at:
http://www.ei.lehigh.edu/learners/tectonics/

Below are brief descriptions of the six investigations. The Web addresses listed above contain additional information about each learning activity including teacher guides, student guides, and assessments.
Note: At the time of this presentation, the materials have only been pilot-tested in the classroom, and not field-tested.

Geohazards and Me: What geologic hazards exist near me? Which plate boundary is closest to me?
In this investigation students locate geologic hazards created by tectonic forces near their geographic location. They discover where the most recent earthquake occurred near their geographic location and where the nearest volcano is located. They also investigate how geologic hazards are distributed around the globe and infer how this is related to plate tectonics.

How do we recognize plate boundaries?
In this investigation students use tectonics data to identify the eastern and western boundaries of the North American plate. They analyze earthquake epicenter and volcano data to determine the boundaries of the North American Plate and analyze the movement of the surrounding plates to determine plate boundary types (divergent, convergent, or transform).

How does thermal energy move around the Earth?
In this investigation, students locate areas where heat escapes from the Earth's interior and provide evidence for a hot mantle. They investigate how surface heat flow (loss) is distributed around the Earth and its relationship to plate boundaries. They also explore geologic features on the Earth's surface that are associated with heat loss.

What happens when plates diverge?
In this investigation, students locate different divergent boundaries and study their history. They investigate how tectonic stresses are accommodated at the plate boundary by examining earthquake and fault data and calculating the half-spreading rate of a plate boundary. They also investigate features of passive margins, areas along divergent boundaries where continental crust becomes oceanic crust.

What happens when plate move sideways past each other?
In this investigation, students locate oceanic and continental transform boundaries and study their history. They investigate an oceanic transform boundary, the Charlie-Gibbs Fracture zone, using earthquake and age of the ocean floor data. They also investigate a continental transform boundary, the San Andreas Fault zone, and the seismic hazards associated with living in this area using earthquake data and historical photographs.

What happens when plates collide?
In this activity, students analyze the distribution of earthquakes and volcanoes to learn about plate collision at an ocean-ocean subduction zone. They analyze volcanoes and earthquakes near an ocean-ocean subduction zone, determine the slope of subduction along a convergent plate boundary, and discover the relationship between the Aleutian Islands, volcanoes, and the ocean-ocean subduction zone.

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