Educative Curriculum Materials as Science Teacher Professional Development for Environmental Curriculum Adoption

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Abstract

Environmental issues including climate change, energy use, and land use change are quite complex, involve understanding new scientific research findings, and may entail thinking skills for interpreting data results that are spatial in nature. Developing skills for understanding and addressing environmental issues is a key component of science teacher education and environmental literacy, and is advocated by ASTE and NAAEE as an essential component of preparing science teachers (ASTE, 2009; NAAEE, 2004). Teaching and learning about environmental issues require that science teachers possess environmental content knowledge and understand effective science pedagogical approaches. Science teacher professional development is highly effective when designed to accompany particular curriculum materials that will be adopted and implemented in the classroom. To address the need to provide effective professional development to educate middle school science teachers about important environmental topics and to help them develop and teach spatial skills that are important for investigating a range of environmental issues in our society, we have designed and developed educative curriculum materials as a form of science teacher professional development. This effort is part of a science education systemic curriculum reform initiative to promote environmental literacy and inquiry and the development of spatial thinking with geospatial learning tools such as Google Earth and GIS as an essential component of the middle school curriculum. Specific pedagogical supports in our *Environmental Literacy and Inquiry* curriculum materials designed to help teachers with making productive adaptations in their science instruction are presented. Examples highlight instructional resources designed to promote teacher content knowledge of environmental science content and pedagogical supports within the curriculum to promote spatial thinking.

Environmental issues including climate change, energy use, and land use change are quite complex, involve understanding new scientific research findings, and may entail thinking skills for interpreting data results that are spatial in nature. They frequently involve inter-relationships between scientific, economic, social, cultural, and political factors. Such environmental issues include open-ended problems in which there is rarely one correct solution to solve the problem and concern multiple stakeholders who view the issue from varying perspectives. Solving an environmental issue requires a knowledge base of environmental science content, understanding the issue context, seeing the problem from varying perspectives, and exploring different possibilities (Environmental Literacy Council, 2007). Many environmental issues associated with energy and climate change involve spatial thinking abilities and skills that recognize spatial distribution and spatial patterns in the environment, associating and correlating spatially distributed phenomena, imaging maps, and comparing maps (Bednarz, 2004).

Developing skills for understanding and addressing environmental issues is a key component of science teacher education and environmental literacy, and is advocated by ASTE and NAAEE as an essential component of preparing science teachers (ASTE, 2009; NAAEE, 2004). Studying environmental issues provides learners with meaningful contexts by connecting their daily lives and local contexts to science content of study (Pennock & Bardwell, 1994). In addition to understanding underlying science, investigating environmental issues and their solutions actively involves learners in practicing and improving skills such as critical reflection, problem-solving and decision making - each important skills inherent to science teacher education.

Teaching and learning about environmental issues require that science teachers possess environmental content knowledge and understand effective science pedagogical approaches. The use of geospatial information technologies (GIT), such as Google Earth or a geographic information system (GIS), to spatially explore environmental issues during classroom investigations has proven to be effective in the development of accurate scientific understandings about complex environmental concepts (Bednarz, 2004; Bodzin, in press; Bodzin & Cirruci, 2009; NRC, 2006). Unfortunately, many science teachers have not had professional development experiences that foster sufficient pedagogical content knowledge to implement environmental education curriculum that use GIT to promote environmental science learning and the development of spatial thinking. Furthermore, few science teacher preparation programs integrate environmental education, and even fewer integrate environmental education and technology simultaneously (Bodzin, 2010; Heimlich, Braus, Olivolo, McKeown-Ice, & Barringer-Smith, 2004).

Science teacher professional development is highly effective when designed to accompany particular curriculum materials that will be adopted and implemented in the classroom. To address the need to provide effective professional development to educate middle school science teachers about important environmental topics and to help them develop and teach spatial skills that are important for investigating a range of environmental issues in our society, we have designed and developed educative curriculum materials as a form of science teacher professional development. This effort is part of a science education systemic curriculum reform initiative in an urban school district to promote environmental literacy and inquiry and the development of spatial thinking with geospatial learning tools such as Google Earth and GIS as an essential component of the middle school curriculum.

ELI Educative Curriculum Materials

Educative curriculum materials are features of curriculum materials designed to support teacher pedagogical content knowledge in addition to student learning (Ball & Cohen, 1996; Scheidner & Krajcik, 2002). Educative curriculum materials have the potential to support teacher learning in a variety of ways. For example, they may help teachers learn how to anticipate and interpret what learners may think about or do in response to instructional activities (Ball & Cohen, 1996; Collopy, 2003; Heaton, 2000; Remillard, 2000). They may also support teachers' learning of subject matter (Ball & Cohen, 1996; Heaton, 2000; Schneider & Krajcik, 2002; Wang & Paine, 2003). Educative materials can also include rationales for suggestions provided in the materials in order to engage teachers in the ideas underlying curriculum developers' decisions (Davis and Krajcik 2005; Remillard 2000). In these ways, educative curriculum materials can promote a teacher's pedagogical design capacity, or his or her ability to use instructional resources and the supports embedded in curriculum materials to adapt curriculum to achieve productive instructional ends (Brown, 2009; Brown & Edelson, 2003).

In designing educative curriculum materials, our *Environmental Literacy and Inquiry* (ELI) science teacher educators, curriculum developers, researchers, and teacher partners recommend baseline instructional guidance for teachers, as well as implementation and adaptation guidance (Ball & Cohen, 1996; Davis and Krajcik, 2005). We design instructional materials to anticipate and interpret what learners might think or do in response to a learning activity and provide support materials to expand teachers' content knowledge and geospatial pedagogical content knowledge. Our educative curriculum materials also provide teachers with rationales for instructional decisions. Teachers are known to draw on their own resources and capacities to read, make meaning, evaluate and adapt curriculum materials to the needs of their students (Remillard, 2005). If teachers understand the rationale behind a particular instructional recommendation, they may be more likely to enact the curriculum in keeping with the developers' intent (Davis & Varma, 2008). We develop our instructional materials in such a way that makes the instructional design model visible to teachers. This design feature provides teachers with an understanding of the rationale to how materials are intended to be used with classroom learners.

Our materials are designed to promote and support teachers' learning of interdisciplinary Earth and environmental science subject matter, geospatial pedagogical content knowledge, and teacher learning of spatial thinking skills that are geographic (see Gersmehl & Gersmehl, 2006). The instructional materials are designed to provide additional supports for teachers who work with diverse learners. They include learning tools that enable access to learner ideas and attitudes that students bring to the classroom (for example the use of concept maps and pre-assessments).

The use of educative curriculum materials in and of themselves provides a form of professional development since they include designs to promote teacher learning and support teacher decision-making for implementing curriculum materials. These materials may be used independently or with other forms of teacher learning such as face-to-face or Web-based professional development experiences. Remillard (2000) describes using curricular materials to "speak to" teachers about rationales behind instructional decisions. Since the classroom teacher is the agent who ultimately decides and structures what is to be taught, our ELI educative curriculum materials should help teachers to understand how geospatial learning technologies fit contextually within the instructional design of the curriculum. For example, in the ELI *Land Use Change* curriculum, Google Earth is used to explore urban heat island concepts through geospatial-supported investigations. Consequently, our instructional materials are designed to help teachers learn how image displays in Google Earth, when used with overlay features such as terrain, roads, and 3-D buildings in urban areas, provide support for students to identify and interpret land-cover features.

Educative curricular materials can be used to help teachers promote spatial thinking skills with their students. When using geospatial technologies to promote spatial thinking skills, there is a need for explicit instruction in spatial analysis to help diverse learners understand visual representations in remotely sensed images (Bodzin, in press; Bodzin & Cirucci, 2009). In land use change investigations, much structure is needed to guide students to observe spatial patterns in land use, especially in areas that are unfamiliar to them. Furthermore, unlike adults who have developed better locational skills as automobile drivers, middle school students typically have a myopic view of their world, so spatial locations are more difficult for them to comprehend. Our geospatial learning activities in *Land Use Change* allow learners to view their world close up as they normally encounter it and to pan back to see relationships between things they only know previously in isolation. In our curriculum materials, we provide instructional recommendations encouraging teachers to model the processes of analyzing and interpreting such relationships to their students. In addition, we design educative curricular materials to help teachers provide appropriate scaffolds to students when they examine images with different land use types, especially in areas that include environmental contexts that are unfamiliar to students.

The teacher guides in addition to student instructional handouts for the ELI learning activities are highly scaffolded and include many design elements to facilitate instruction. Instructional supports in the ELI *Energy* curriculum include screenshots of GIS data layers with added graphical arrows adjacent to the instructions in order to simplify the procedures involved with the learning task or to assist in learning new GIS software applications (see Figure 1). Such design features are key elements to assist teachers who work with below grade-level readers and students with disabilities to help them to understand how to manipulate the GIS for displaying spatial data of interest. For each energy geospatial learning activity, teachers are provided with instructional prompts for each GIS data layer they need to focus on to observe spatial relationships.

Look at the **status bar** (arrow #1 below).
The **Cursor Location** displays two values.
The value that ends with **°W** is the **longitude** and the value that ends with **°N** is the **latitude**.
Above the **status bar**, you will see the colored **percent_sunshine.shp bar** that ranges from 17 to 88% (arrow #2).

The location in the diagram below displays **52** (arrow #3) on the **percent_sunshine.shp** bar. This means **that this location receives an average of 52% of sunshine during the day each year**.

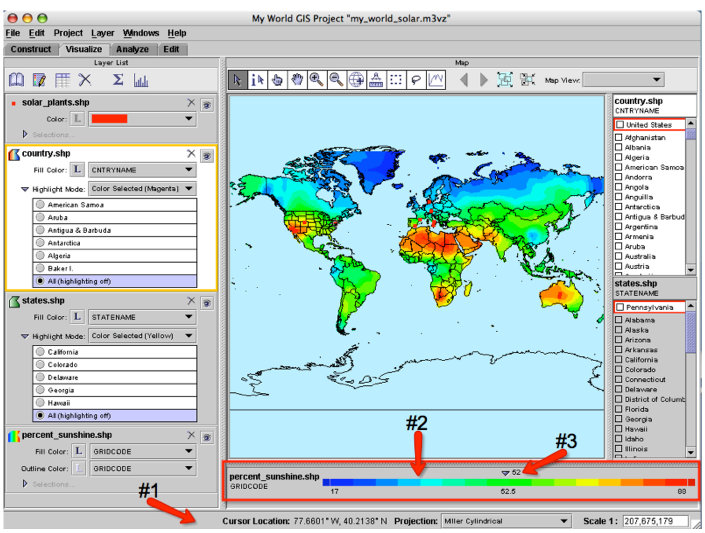

Figure 1. Instructional support with MyWorld GIS to examine annual percent sunshine.

Instructional guidance to assist teachers with spatial analysis is also provided. For example, in the *Isle of Navitas* activity, to analyze whether hydroelectric energy is a viable energy resource for their province, the teacher guide models a thought process for determining suitable locations for the placement of a hydroelectric dam:

> The factors needed to determine the ideal location of a hydroelectric dam include the topography, a canyon that can be dammed, and an area to make a reservoir upstream of the dam. Zoom in to where the streams start in the mountainous areas (light green or white). Hydroelectric power requires a power plant at the dam site and access to the grid for power distribution.

Teachers are prompted to display the lakes, major rivers, electrical grid, and the national significance layers in their GIS. The national significance layer contains areas that are environmentally sensitive or culturally significant.

In addition to the instructional scaffolds in the *Isle of Navitas* teachers guide, we developed a series of teacher supporting materials that include visual guides of each province that contain important background information of each energy resource. The visual guides include a screenshot of the location of each energy resource and discuss the feasibility of each energy resource use for the provinces. If an energy resource is available in a province, we indicate the most ideal location to place a power plant with regards to the proximity of the electrical grid, transportation infrastructure, and the city locations. The visual guides also include examples of tradeoffs that students may need to consider if they choose various energy resources for their province. For example, a location may receive enough average annual sunshine to make it suitable for solar power generation but the area is under cultivation. Teachers, therefore, need to consider the tradeoffs involved in converting productive farmland into a solar power plant or using that area for growing food or switchgrass for biomass/biofuels production.

Evidence of Effectiveness

All five eighth grade earth and space science teachers in two different urban middle schools in the same school district in the northeast region of the United States implemented the 40-day ELI *Energy* curriculum with their students during the 2009-2010 academic school year. The teachers had a wide range of teaching experiences and content backgrounds. One teacher had implemented the initial prototype *Energy* curriculum materials with her students in the previous school year and worked with our curriculum development team to ensure that the curriculum materials were developmentally appropriate to meet the diverse needs of the eighth grade students in the school and aligned to state standards. In addition, the teacher provided valuable information to the development team about practical learning activity implementation ideas that address common issues that typically occur in the middle school classroom such as time constraint and technology issues. Two teachers had prior experience using Google Earth in their classroom instruction when they implemented the ELI *Land Use Change* unit with their students during the previous school year, but had no prior experience using GIS in their instruction. The other two teachers had no prior experience using any geospatial technologies in their classroom instruction. This was the first time that four of the five teachers enacted the *Energy* curriculum with their classes and used GIS as a learning technology in their instruction.

During the summer of 2009, three of the five teachers attended a 3-day, 12-hour professional development institute to become acquainted with the ELI *Energy* curriculum's geospatial learning activities and laboratory investigations. To provide professional development to the two teachers who were unable to attend the summer institute, we conducted two separate, one-day professional development sessions (12 hours total) during the academic year with these teachers. During the curriculum enactment, we met with the teachers every six days during their planning period to help address any technology issues and review any geospatial learning activities that were not covered during the 12-hour professional development sessions. We also assisted three teachers with laboratory preparation upon request.

During the curriculum enactment, we asked the teacher to complete a weekly survey that included a series of Likert scale items that asked them to rate their students' interactions with the curriculum and their own interactions with the curriculum. Table 1 displays the results of three survey items that pertained to our educative curriculum materials. The data summaries show that during the curriculum enactment, the teachers perceived the educative curriculum materials to support them with content knowledge, pedagogical implementation ideas, and using geospatial technologies with their students.

Table 1

Weekly survey response summary to educative curriculum materials.

N=23 responses from 5 teachers. *Scale: 1 (Strongly Disagree) to 5 (Strongly Agree)*

Item **Please rate your interactions with the curriculum.**	**Strongly Disagree % (n)**	**Disagree % (n)**	**No Opinion % (n)**	**Agree % (n)**	**Strongly Agree % (n)**	**Mean**
The curriculum and support materials provided me with appropriate content knowledge.	0.0% (0)	0.0% (0)	4.3% (1)	65.2% (15)	30.4% (7)	4.26
The curriculum and support materials provided appropriate teaching ideas to help me use the instructional materials.	0.0% (0)	0.0% (0)	21.7% (5)	65.2% (15)	13.0% (3)	3.91

Please rate your interactions with the curriculum.	**Strongly Disagree % (n)**	**Disagree % (n)**	**No Opinion % (n)**	**Agree % (n)**	**Strongly Agree % (n)**	**N/A**	**Mean**
The curriculum and support materials helped me use geospatial-learning tools with my students.	0.0% (0)	0.0% (0)	0.0% (0)	52.2% (12)	26.1% (6)	21.7% (5)	4.33

We developed a second survey that the teachers completed at the end of the curriculum enactment that included items designed to help determine how useful the curriculum support materials were to the them and if they perceived any professional growth through the use of the curriculum materials. Table 2 displays the responses to the survey items pertaining to the usefulness of the curriculum support materials. Data results show that the teachers perceived the educative curriculum materials to be quite useful for a variety of science pedagogical strategies, providing them with sufficient content knowledge, and teaching with geospatial technologies. Table 3 displays the teacher responses to the survey items pertaining to their perceived growth through their use of the curriculum materials. The survey item responses show that the teachers perceived that the educative curriculum materials helped them to grow professionally in their knowledge about geospatial technologies, geospatial technology skills, energy content knowledge, and technological pedagogical understandings with geospatial technologies.

Concluding Thoughts

The design of our educative curriculum materials supported five urban middle school science teachers' learning of important environmental science subject matter, teaching science with geospatial technologies, and promoted spatial thinking skills that are important for the teaching and learning of environmental issues. The curriculum supports helped to promote the geospatial pedagogical content knowledge of the teachers; thus, enhancing their pedagogical design capacity to use geospatial technologies in the teaching of environmental science to their diverse classroom learners. We contend that educative curriculum materials are an important form of professional development since they promote teacher learning and support teacher decision-making for implementing curriculum materials.

Educative curriculum materials by themselves may not guarantee successful implementation of a GIT-integrated environmental curriculum. Key to successful adoption of such curriculum is administrative support within the school system that includes invested professional development support. We worked closely with the school district's administration to provide additional professional development support in the form of 12 hours of professional development sessions prior to the curriculum enactment and meetings with teachers on a regular 6-day basis during their planning periods.

The reality of time constraints for professional development within a school district limits the extent to which schools can adopt and sustain the needed professional development for new science reform-based curriculum that takes advantage of geospatial technologies to promote learning. Without other forms of support, such as the use of educative curriculum materials as a form of professional development, successful implementation of reform-based science curriculum may be compromised. Therefore, developing educative curriculum materials as a form of professional development as a component of curriculum materials contributes meaningfully to the science pedagogical content knowledge and science content knowledge base of teachers.

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Table 2

End of Energy unit implementation survey responses pertaining to the usefulness of curriculum supports

N= 5 teachers. Scale: 1 (Strongly Disagree) to 5 (Strongly Agree)

Item **CURRICULUM MATERIALS** **Please indicate your agreement with the following statements:**	**Strongly Disagree % (n)**	**Disagree % (n)**	**No Opinion % (n)**	**Agree % (n)**	**Strongly Agree % (n)**	**Mean**
The teacher support materials (teacher guides, content materials, FAQs) alerted me to and provided suggestions to address potential student misconceptions or naïve conceptions about specific concepts.	0.0% (0)	0.0% (0)	20.0% (1)	20.0% (1)	60.0% (3)	4.40
The teacher support materials provided me with sufficient content background to implement the ELI unit.	0.0% (0)	0.0% (0)	0.0% (0)	40.0% (1)	60.0% (3)	4.60
The curriculum materials provided me with information to model scientific inquiry processes and skills during the ELI unit.	0.0% (0)	20.0% (1)	0.0% (0)	20.0% (1)	60.0% (3)	4.20
The teacher support materials (teacher guides, content materials, FAQs) enabled me to help my students understand connections between concepts in this unit and others throughout the school year.	0.0% (0)	20.0% (1)	0.0% (0)	40.0% (2)	40.0% (2)	4.00
The teacher support materials helped me to use geospatial learning tools (Google Earth or GIS) with my students.	0.0% (0)	0.0% (0)	0.0% (0)	20.0% (1)	80.0% (4)	4.80
The teacher support materials (teacher guides, content materials, FAQs) provided pedagogical supports for me to think about how I might adapt my instructional practices to meet the needs of my students.	0.0% (0)	20.0% (1)	20.0% (1)	20.0% (1)	40.0% (2)	3.80
The ELI materials introduced me to new ways of teaching environmental science with geospatial learning technologies.	0.0% (0)	0.0% (0)	20.0% (0)	20.0% (1)	60.0% (4)	4.40

Table 3

End of Energy unit implementation survey responses pertaining to perceived growth of teachers

N= 5 teachers.   Scale: 1 (Strongly Disagree) to 5 (Strongly Agree)

Item	**Strongly Disagree % (n)**	**Disagree % (n)**	**No Opinion % (n)**	**Agree % (n)**	**Strongly Agree % (n)**	**Mean**
My knowledge about geospatial technologies increased as I used the curriculum support materials provided in the ELI unit.	0.0% (0)	0.0% (0)	0.0% (0)	40.0% (1)	60.0% (3)	4.40
My geospatial technology skills increased as I used the curriculum support materials provided in the ELI unit.	0.0% (0)	0.0% (0)	0.0% (0)	20.0% (1)	80.0% (4)	4.80
My content knowledge about the topics presented in the ELI unit I just completed increased as I used the curriculum support materials provided in the ELI unit.	0.0% (0)	0.0% (0)	20.0% (1)	20.0% (1)	60.0% (3)	4.40
My understanding to why certain technologies were used in the curriculum to promote science learning increased as I used the curriculum support materials provided in the ELI unit.	0.0% (0)	20.0% (1)	0.0% (0)	40.0% (2)	40.0% (2)	4.00
My understanding of how and when to adapt my instruction while using geospatial learning tools (Google Earth or GIS) increased as I used the curriculum support materials provided in the ELI unit.	0.0% (0)	0.0% (0)	20.0% (1)	20.0% (1)	60.0% (3)	4.40

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