The Impact of a Geospatial Technologies-Integrated Curriculum to Promote Energy Literacy

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Paper Set Program Abstract:
Studies that focus on promoting geospatial science pedagogical content knowledge with inservice science teachers and resulting effects on student learning in urban science classrooms.

Abstract

This study examined the effectiveness of a geospatial technologies (GT)-integrated energy resources curriculum to promote energy literacy in an urban school district. The purpose of this study was threefold: (1) to investigate whether and to what extent a GT-integrated science curriculum could promote energy literacy with students, (2) to compare energy literacy achievement between students who received instruction with a GT-integrated science curriculum and students who received "business as usual" curriculum instruction, (3) and to examine factors that may account for energy content knowledge achievement. A total of 1,043 eighth grade students divided into two groups participated in the study. Data was gathered using two energy literacy instruments designed to measure students' energy resources content knowledge and energy resources-related attitudes and behaviors. The results of the study found that considerable student learning of important energy concepts occurred with the GT-supported curriculum enactment. Students who learned with a GT-integrated science curriculum had significantly greater energy resources content knowledge and energy-related attitudes and behavior measures than those in classrooms using "business as usual" curriculum instruction. Prior content knowledge and curriculum type were strong significant predictors of energy content knowledge achievement. Students' year-end energy-related attitudes were statistically significant, but not a substantial predictor of energy content knowledge achievement. Gender was not a significant predictor of energy content knowledge achievement, but there was a significant interaction between gender and curriculum. The findings support that the implementation of a GT-integrated science curriculum can improve the energy literacy of urban middle school students.

Introduction

Energy resources are a major staple of our society. Energy is needed to create goods from natural resources and it provides us with many services such as electricity and fuel for transportation that we take for granted in our daily lives. The intense need for energy resources pervades all sectors of our society including industrial manufacturing, transportation, commercial, and residential. The availability of an adequate and reliable supply of energy is important for economic development and improved standards of living. Our food, housing, transportation, communications, recreation, and technologies that we use to make our lives more productive all rely on energy resources. Understanding fundamental knowledge about energy resources including their limitations, as well as the environmental issues of their use, are important for citizens to make informed decisions to effectively confront the energy issues that face the environment (Gambro & Switzky, 1999).

Science education curriculum should have a fundamental goal of promoting energy literacy in the curriculum. Energy literacy involves promoting content knowledge understandings of energy in addition to energy-related attitudes and behaviors (DeWaters & Powers, 2008). Energy literacy goals include providing students with a conceptual knowledge base of energy resources and the issues related to their use in order for them to be able to critically analyze and decipher information to effectively make informed decisions as future citizens (Barrow & Morrisey, 1989; Farhar, 1996; Hofman, 1980; Solomon, 1992; Van Koevering & Sell, 1983). Environmental science topics related to the acquisition of renewable and nonrenewable resources, energy generation, storage, and transport, and energy consumption and conservation are quite established in U.S. science education frameworks, state standards, and environmental science curriculum (American Association for the Advancement of Science [AAAS], 1993; Barrow & Morrisey, 1987; Blum, 1981; National Research Council, 1996). In the U.S. Commonwealth of Pennsylvania, understanding energy resources and associated environmental issues are learning goals that are included in the state academic standards for environment and ecology (Pennsylvania Department of Education, 2009a). Learning goals pertaining to understanding forms of energy, sources, availability, management, and other important factors for both renewable and nonrenewable energy resources are explicitly stated in the state standards. In addition, concepts pertaining to the spatial distribution of nonrenewable and renewable resources are also included in the state geography standards (Pennsylvania Department of Education, 2009b). Appendix A includes energy resources content standards.

Understanding energy resource issues involve spatial analysis and reasoning skills. For example, many countries are currently determining their future energy policies to supply electricity to their citizens and industries. To make an informed decision about the type of energy resources a country may wish to select as source material for a new electrical power generating plant involves examining the spatial relationship among many variables. These include analyzing the locations of energy resource materials and proposed new power plant locations, the existing infrastructure available to transport an energy resource to a power plant, the availability of electrical grid infrastructure to distribute electricity from the power plant to consumers in an efficient way, and analyzing environmental characteristics of an area to consider the impact a new power plant may have on the existing environment.

Geospatial technologies (GT) such as Google Earth and Geographic Information Systems (GIS) can be used to support such spatial analysis in curriculum learning activities. GT, as a curriculum learning technology, can be used to enhance inquiry-based environmental investigations, promote spatial thinking, and draw on skills crucial to developing higher-order thinking and environmental problem solving (Bodzin, 2011a; Bodzin, 2008; Bodzin & Anastasio, 2006).

The adoption of an energy resources curriculum that integrates GT with investigative learning activities to promote energy resources learning goals is timely and leverages current national and global attention on energy resources and related environmental issues such as the contribution of energy consumption to climate change. However, the adoption of such a curriculum is a significant departure from traditional classroom science instruction that typically occurs in the "business as usual" manner in which teachers use an adopted science textbook curriculum program to guide curriculum and instructional decision-making (Driscoll, Moallem, Dick, & Kirby, 1994; Kesidou & Roseman, 2002; Roseman, Linn, & Koppal, 2008; Weiss, Banilower, McMahon, K. & Smith, 2001; Yore, 1991). Studies of middle school science textbook programs (Kesidou & Roseman, 2002; Stern & Roseman, 2004) found that most dealt with an extremely broad range of topics, did not align curriculum with learning goals based on a set of core scientific ideas, and did not provide materials to engage students with relevant phenomena or support students' content understandings and reasoning skills.

In response to these issues, we developed a new GT-integrated middle school science energy resources curriculum unit that aligned to the energy resources learning goals identified in national and Pennsylvania state standards (Kulo & Bodzin, 2011). The unit represents a considerable departure from typical "business as usual" approaches to energy resources instruction since it employs the use of GT including Google Earth and GIS to promote student understandings of the world's energy resources and their impacts on the environment, energy use and misuse practices, and ways to sustain the future of our environment with alternative energy sources. Previous studies have reported that reform-based approaches to science curriculum can significantly improve students' learning gains on standards-based science concepts (Geier et al, 2008; Gerard, Spitulnik, & Linn, 2010; Johnson, Kahle, & Fargo, 2006; Marx et al., 2004). Because our unit was designed to promote a more in-depth understanding of energy resources, we hypothesized that the adoption and implementation of a GT-integrated energy resources curriculum would enhanced the energy literacy of students compared to those who learned about energy resources in the "business as usual" manner with an adopted science textbook curriculum program.

In this article, we describe our curriculum approach for teaching energy resources to middle school students and present the results of an exploratory study in which we compared the energy literacy achievement between students who received energy resources instruction with our GT-integrated science curriculum and students who received "business as usual" energy curriculum instruction in an urban school district. In the study, we examined contributing factors that may account for energy content knowledge achievement.

Energy Literacy

Similar to the domains of environmental literacy (Disinger & Roth, 1992; Wilke, 1995), energy literacy involves content knowledge understandings of energy resources in addition to energy resource-related affective and behavioral aspects. An energy literate person has a sound conceptual knowledge base of energy resources, understands the science concepts and issues pertaining to the acquisition of renewable and nonrenewable resources, energy generation, storage, and transport, and energy consumption and conservation. With regards to the affective and behavioral aspects of energy literacy, an energy literate person would be sympathetic to the needs of energy conservation, cognizant of the impact that personal energy use decisions and actions have on the environment and society, and make choices and exhibit behaviors that reflect these attitudes with respect to energy resources development and energy consumption (Dewaters & Powers, 2008; Kuhn, 1980; Valhov & Treagust, 1988).

The majority of published research indicates a general lack of student conceptual knowledge pertaining to non-renewable and renewable resources. Rule's (2005) interview study with elementary age students reported misconceptions about the origin and sources of petroleum, coal, and natural gas, gasoline manufacture and storage, and the importance of petroleum in our society. This study also found that these misconceptions continue into adulthood. Additional studies of upper secondary learners also revealed that students had knowledge deficiencies about the availability and use of fossil fuel resources (Bodzin, 2011; Boyes & Stanisstreet, 1990; Dewaters & Powers, 2008; Holden & Barrow, 1984; Holmes, 1978; Lawrenz, 1983; National Assessment of Educational Progress, 1975; Richmond & Morgan, 1977). Studies pertaining to nuclear power use demonstrated that both adults and upper secondary students have incomplete understandings about the viability of using nuclear power as an energy source (Arcury & Johnson, 1987; Blum, 1984; Lawrenz, 1983). Holmes' (1978) analysis of NAEP items found that young adults have knowledge deficits about the availability and use of renewable resources. Bang, Ellinger, Hadjimarcou, and Traichal (2000) found that self-reported knowledge levels of U.S. adults about renewable energy sources was low.

Findings from studies that analyzed energy knowledge assessment items reported low understandings about energy consumption and conservation for both secondary students and adults (Barrow & Morrisey, 1989; Bodzin, 2011; DeWaters & Powers, 2008; Holden & Barrow, 1984; Holmes, 1978; National Environmental Education & Training Foundation & Roper ASW, 2002; Valhov & Treagust, 1988). Data from these studies found that most students and adults have incomplete understandings about societal and personal energy consumption patterns. Many do not know which energy sources are used primarily for a given sector (residential, commercial, industrial, transportation), which sources are converted into usable electrical power, are unfamiliar about practical considerations involved in power generation, and lack a fundamental understanding about energy efficiency.

Studies that have investigated affective and behavior domains of environmental literacy have reported mixed findings. Barrow and Morrisey (1987) reported that Maine and New Brunswick secondary students had non-positive, undesirable attitudes toward energy concerns. Vlahov and Treagust (1988) found that Australian high school students exhibited slightly positive attitudes towards energy conservation. Karst (1985) found that southern U.S. high school students had significantly lower affective energy values than northern U.S. high school students who were more energy conscious. Dewaters and Powers (2008) reported that while affective values and behavior intention were not particularly high with New York secondary students, they generally acknowledged the existence of an energy problem and accepted the need to conserve energy and increase the use of renewable resources. Other studies reported that energy resources knowledge was correlated with positive attitudes toward energy conservation (Kuhn, 1979; Lawrenz. 1988; Vlahov and Treagust, 1988).

Teaching Science With Geospatial Technologies

GT encompasses a category of tools that includes GIS and virtual globes (such as Google Earth) that can be used to promote and support geospatial learning. A GIS can be defined as an integrated software system for the handling of spatial information that is georeferenced to locations on Earth's surface (National Research Council, 2006). In instructional settings, it can be viewed as a tool that allows for the processing of geospatial data into visualizations and other forms of information that is used to make decisions about some portion of the Earth. The instructional value of a GIS is in the tools it provides for rapid analysis and visualization displays of large geographic data sets (Heywood, Cornelius, & Carver, 2002). Investigations with a GIS allow students to identify physical and geospatial relationships by constructing multiple representations of data in the form of map representations with thematic layers of data, satellite imagery, data tables and charts (Hall-Wallace & McAuliffe, 2002). A virtual globe is similar to a GIS, but lacks the robust spatial analysis tools. Virtual globes can display satellite imagery at various resolutions, aerial photographs, topographic maps, elevation data, along with GIS data layers such as roads, points of interests, and place names overlaid on each other using a Web-based database.

Science learning with instructional activities that use GT have the potential to impact student learning by reinforcing concepts through investigations that take advantage of the ability to generate and display data visualizations and use tools for data analysis (Barstow, 1994; Salinger, 1994). GT has proven to be valuable in the process of understanding the environment and of making responsible environmental decisions (Carrarra and Fausto, 1995; Heit, Shortried, & Parker, 1991). Embedded tools provide classroom learners with the capability to produce data-based graphical representations and visualizations that make it a potentially valuable support to examine important environmental issues associated with energy resource use. Using GT, one can display geospatial data into graphical visualizations that are pertinent for understanding energy resources potential (e.g. wind speeds at various elevations, average annual percent sunshine, tidal ranges, coal beds, natural gas fields, land cover data and imagery, and transportation infrastructure). Analyzing such geospatial data using GT can provide learners with visual representations that captures the structure of spaces and the locations, relationships, and patterns of energy resources data related to energy resource acquisition, energy generation, storage and transport. GT can enable learners to perform geospatial analyses that permit pattern analysis for important energy resources utilization decision-making such as analyzing suitable locations for the placement of wind power farms, solar farms, hydroelectric dam power plants, geothermal power plants, and biofuels processing centers.

The use of GIS in education is increasingly viewed as a learning technology that can provide students with opportunities for critical thinking (Kerski, 2008). According to Holzberg (2006), working in a GIS environment encourages students to participate in authentic scientific inquiry approaches to learning. When students manipulate and analyze geo-referenced data layers contained in GIS, they can explore complex relationships and patterns in meaningful ways to address investigative questions. Thus, GIS can extend the ability for students to conduct practices that scientists employ as called for by current science education reform efforts (National Research Council, 2011).

While much potential exists for using GT to support science learning, there are not many published studies that have investigated the effectiveness of using GT integrated into science curriculum predominantly due to the fact that there has been inadequate integration of GT into existing school curriculum (Bednarz, 2004; Ebenezar, Kaya, & Ebenezar, 2011). Baker and White (2003) investigated whether or not the use of GIS to support a learning module in science affects the acquisition and use of science process skills and attitude toward science and technology. They concluded that the use of GIS supported scientific inquiry and problem solving and could foster complex cognitive activities by students using sophisticated computer applications and data in an authentic learning environment. Hagevik (2003) concluded that GIS may aid students in constructing concepts and help promote understanding of environmental content, problem solving, experimental design and data analysis, and communicating findings to others. In other studies, researchers concluded that geospatial technologies could increase students' spatial abilities and science content knowledge (Bodzin, 2011a; Bodzin & Cirucci, 2009; Hedley, 2008).

Despite the promising potential of GT to support science learning environments, barriers to implementing them in the K-12 classrooms have been reported. These include technical issues pertaining to the interface design of software, time for classroom teachers to learn to use the software and teach it to students, lack of GT-integrated basal curriculum materials, lack of time to develop learning experiences that integrate easily into existing school curricula, and lack of pedagogical content knowledge conducive to teaching with GT (Baker & Bednarz, 2003; Bednarz, 2003; Keiper, 1998; Kerski, 2003; Meyer, Butterick, Olin, & Zack, 1999; Patterson, Reeve, & Page, 2003; Sanders, Kajs, & Crawford, 2002; Shin, 2006).

Research Questions

The primary aim of this study is to examine the effectiveness of an eighth grade energy resources curriculum that integrates GT to promote energy literacy in an urban school district. Research into science achievement among diverse learners in urban schools is an important priority within the science education community (Fraser-Abder, Atwater, & Lee, 2006). There is limited research that has investigated effective science curriculum for diverse student populations (Lee & Luykx, 2004) and no previous studies have been published that examine the effectiveness of a GT-integrated curriculum to promote energy literacy with urban students. Since energy literacy involves content knowledge understandings in addition to energy-related attitudes and behaviors, this study also examines different factors that may account for student energy content knowledge achievement when using an energy resources curriculum.

This exploratory study is guided by the following research questions:

1. Whether and to what extent can a GT-integrated science curriculum promote energy literacy with students in urban middle schools?
2. Are there any differences in students' energy literacy achievement between using a GT-integrated science curriculum and receiving "business as usual" instruction?
3. Which factors may account for energy content knowledge achievement?

The Energy Resources Curriculum Geospatial Learning Design Model

Oure energy resources curriculum employs a geospatial learning curriculum design model that builds on the work of other successful technology-integrated curriculum projects (Bodzin, 2011a; Edelson, 2001; Krajcik et. al, 2008; Linn, Davis, and Bell, 2004). Our curriculum design model incorporates a curriculum framework, design principles, and an instructional model that provide guidance to the development of the GT-integrated instructional materials. The curriculum framework 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 GIT and inquiry-based activities.

Like other research-based science curriculum projects (Edelson, 2001; Kali, 2006; Lee et al*., 2010*; Linn, Davis, & Bell, 2004) we use a series of design principles (Bell, Hoadley, & Linn,

2004) to promote geospatial thinking skills with the curriculum 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, and Kulo (in press) for a more detailed explanation of each design principle.

We use an instructional model that includes eight key elements to guide the development of each GT-integrated learning activity in our curriculum. The instructional model incorporates a sequence of instructional events that are based on current learning theories that are applied to the design task of promoting teaching and learning of science with GT. The model includes the following key elements:

1. *Elicit prior understandings of lesson concepts*. This element incorporates the first stage Eisenkraft's (2003) "7E" instructional model to strengthen scientific inquiry, *elicit prior understandings*, and a feature of Dick and Carey's (1996) systems approach model, *identifying and analyzing entry behaviors and learner characteristics*. In this stage, the teacher determines what knowledge and skills students bring to the learning task. In our curriculum, this is accomplished by asking learners to respond to questions about the key lesson concepts and through analysis of student-created concept maps.
2. *Present authentic learning task*. An authentic task is presented that learners will complete. This element reflects a feature of Jonassen's (1997) task analysis framework to select an appropriate task for learners to do. Our learning tasks are situated in authentic settings, thereby providing useful and meaningful contexts to the learner (Keller, 1987). We design instructional materials to present geospatial learing tasks in different ways to vary cases systemically (Collins and Stevens, 1983). For example, in some tasks, learners use GT to investigate regional or worldwide geographic cases prior to more local cases. In other tasks, learners analyze local cases prior to regional or worldwide cases.
3. *Model learning task*. The teacher and/or the instructional materials demonstrate to the learners how to perform a learning task with GT through task modeling (Black and McClintock, 1996; Jonassen, 1999). GT investigations involve using specific tools to display data or produce new visualizations that will be analyzed by students. For example, this stage may involve showing how a query tool may be used to examine differences in world-wide fossil fuel production or how to use a suite of analysis tool to produce a new visualization that shows global per capita consumption of a particular fossil fuel for each country.
4. *Provide worked example*. The teacher and/or the instructional materials provide a worked example to help guide the learner in performing a task. Geospatial investigations are often considered to involve complex learning tasks that involve learning outcomes that result from problem solving. As such, this stage incorporates Jonassen's (1997) ideas to provide a worked example to support problem-solving skill devlopment. As an example for our curriculum, students are given the problem to identify a suitable location to place a hydroelectric power plant. When presented with this task, one must consider a variety of factors including topography, an area to make a reservoir upstream from a dam, access to the grid for power

distribution, and an analysis of potential environmental impacts that may result due to dam construction. Our curriculum materials provide a worked example that models how students may approach this problem-solving task using both positive and negative examples to highlight important aspects that will help them complete the learning task (Collins and Stevens, 1983).

5. *Perform learning task*. Learners perform the task in this stage. We design our geospatial learning investigations to involve data explorations and analyses that are tied to investigative questions. In this stage, learners construct their own understandings by being actively engaged with the learning task.

6. *Scaffold learning task*. The teacher and/or the instructional materials provide guidance to the learners as they engage with geospatial learning tasks. Our use of scaffolding emphasizes coaching by the teacher and provisions of instructional materials designed to provide cognitive tools to support learners' performance at critical times (Collins, 1988; Herrington & Oliver, 2000; Jonassen, 1999; Quitana et al., 2004). In our GT investigations, the instructional handouts provide scaffolding in the form of helpful hints and screen shots of visualizations in identified places where learners may have difficulty completing a learning task. The intent of such scaffolds is to provide learners with opportunities to complete learning tasks independently if needed.

7. *Elaborate task with additional questions*. The teacher and/or the instructional materials pose analysis and synthesis questions to foster learners' content and geospatial understandings. This stage reflects the *elaboration* phase of the 5E learning cycle model (Bybee et al., 2006) in which learners apply concepts in varied contexts and extend their content understandings and geospatial thinking and reasoning skills. In our instructional materials, learners repond to higher-ordered questions, formulate conclusions, and reflect on how science concepts are related and interconnected to each other.

8. *Review activity concepts*. The teacher reviews the science concepts learned in the activity to reinforce student learning and to clarify any concepts students did not understand. This instructional element is designed to enhance learner retention and transfer of science concepts and geospatial thinking skills to different situations (Gagné, 1985; Perkins & Salomon, 1996).

Energy Resources Curriculum

The energy resources curriculum (henceforth *Energy*) is a middle school unit designed to promote learner understandings of sustainable and non-renewable energy resources; energy generation, storage and transport; and energy consumption and conservation. The curriculum is aligned to energy resources learning goals that are articulated in the AAAS *Atlas of Science Literacy* (AAAS 2007) and AAAS's Project 2061's (2007) *Communicating and Learning About Global Climate Change*. The learning activities are designed to address common student misconceptions and knowledge deficits about energy resources (see for example Barrow & Morrisey, 1989; Boyes & Stanisstreet, 1990; Farhar, 1996; Holden & Barrow, 1984; National Assessment of Educational Progress, 1975; Rule, 2005). The curriculum includes five interrelated topic areas that include energy and its everyday uses, sustainable energy sources, US energy production and consumption, nonrenewable resources, and energy efficiency and conservation. *Energy* takes approximately 8 weeks to complete in the classroom. Approximately half that time is dedicated to five Google Earth explorations and seven GIS investigations including an extensive culminating project. We developed our GIS investigations with the MyWorld GIS software application since it employs a user-friendly interface designed for use in school settings and can be modified in ways to enhance initial data visualization displays that are provided to learners, thus reducing a significant barrier to GIS implementation that has been reported in previous studies (Baker & Bednarz, 2003; Kerski, 2003).

Students begin the *Energy* curriculum by calculating their personal and household energy use and then analyzing their energy consumption patterns. By the end of this initial activity, they understand that they use energy for many purposes including lighting, heating, transportation, entertainment, food preparation, cleaning, and communications and that there is a monetary cost associated with their consumption habits. They also begin to formulate conservation practices that can reduce both their personal energy use and their household energy use.

The sustainable energy topics include an instructional sequence of geospatial learning activities and "hands-on" inquiry-based laboratories and demonstrations to develop understandings about contemporary energy sources including solar, wind, tidal, hydroelectric, geothermal, and biomass/biofuels. In the first geospatial learning activity, students are presented with the driving question: *Where is the best place to locate a new solar power plant*? In this activity, students use Google Earth to explore solar power plants around the world to examine ground cover, topography, and the space needs of the power plant area. They then use GIS to analyze annual average sunshine data to determine optimal locations to build new very large solar power plants. In the next set of curriculum activities, students learn about wind energy and then investigate, *Where is the best place to locate a new wind farm?* They use Google Earth to view wind farms around the world to examine ground cover, topography, space requirements, and wind speed at each location. Students then examine wind speed and land use patterns in Pennsylvania to determine the optimal places to locate new wind farms in different geographical areas. Students next learn about tidal energy and use Google Earth to determine relational patterns between tidal ranges and shapes of the water bodies. After that, students learn about hydroelectric energy and use Google Earth and GIS to examine features of hydroelectric dams around the world including their widths, height, capacity, surrounding area, shape and size of the reservoir, and the distances of each dam to nearby population centers. The hydroelectric energy activities conclude with students using Google Earth to investigate specific features of five major energy-generating facilities on two major rivers in Pennsylvania. In the next activity, *Where is the best place to locate a geothermal power plant?,* students use Google Earth to identify Earth features that are evident of geothermal activity. They then examine population centers in the northwest USA and areas where the Earth is hot to determine an optimal location to place a geothermal power plant. Students learn about biomass/biofuels and complete a laboratory investigation to learn how raw materials are refined to process liquid fuels.

In next series of learning activities, students explore U.S. energy production and consumption patterns by geographical regions and across industrial, transportation, commercial, and residential sectors. They analyze electricity distribution data to understand that the current U.S. grid for electricity distribution is not efficient. By the end of these learning activities, they learn that coal is the energy source that is used to produce the most energy in the U.S. and that most of this energy is used to generate electricity.

The next topic area focuses on nonrenewable resources. Students learn how fossil fuels originate, how long they take to form, how they are transported from their sources, and how they are altered for energy use. A series of three GIS investigations are completed in which students investigate global coal, petroleum, and natural gas production and consumption patterns. During these investiagtions, they analyze the relationships among countries' coal, petroleum, and natural gas consumption and their populations.

Energy efficiency and conservation is the main topic area of the next set of curriculum activities. Students recalculate their personal and household energy consumption and compare these new values with their initial values that were calculated at the beginning of the curriculum to assess whether any difference in their energy consumption habits have occurred. Students then learn about energy conservation and complete an energy efficiency lab. Next, they learn about the advantages, disadvantages, and environmental impacts of using the various sustainable and nonrenewable energy resources.

In the culminating activity, students use GIS to analyze the energy resources of one of three provinces in a fictitious island and develop an energy policy statement for their province that is based on the energy needs of their province, available energy sources, and infrastructure for production and distribution. For perspective, the population, land area, and energy needs of the island are roughly comparable to those of the state of Pennsylvania. During the activity, students analyze their province's energy resources and determine the optimal locations to place power plants while keeping in mind resource extraction and transportation requirements to move energy source materials to power plants, as well as developing grid infrastructure to deliver usable energy to consumers. They then develop an energy policy for their province that recommends the most efficient combination of energy sources that will have the least impact on the environment. In the process of making these decisions students are confronted with real-world problems including transportation distance, limited infrastructure, and resources located in environmentally sensitive or culturally significant areas. Students recommend the most efficient combination of energy sources and have to justify their choice with the benefits, costs, and environmental impact assessments.

Methods

Study Design

A comparative design study was employed in this investigation. All four middle schools in an urban Pennsylvania school district participated in the study. The four schools were purposely assigned into two equivalent groups based on each school's Pennsylvania System of School Assessment Science test scores. During the 2009-2010 school year, one group implemented the GT-integrated *Energy* curriculum (*GT* group) and the other group implemented their normal science curriculum in the "business as usual" manner using the school district's adopted Prentice Hall Science Explorer (2005) basal textbook program (*Basal* group). In U.S. schools, basal textbook programs play an important role to guide the implemented science curriculum (Roseman, Linn, & Koppal, 2008; Venezky, 1992). They are a main source of content knowledge for teachers and are used as the primary instructional tool in the classroom (Garner, 1992; Posner, 1992). The adopted basal curriculum in this study included an entire chapter on energy with sections titled *What is Energy?*; *Form of Energy*; *Energy Transformations and Conservation*; and *Energy and Fossil Fuels*. The basal curriculum teacher guide included demonstrations of energy concepts and two laboratory activities.

Participants

The *GT* group included five eighth grade earth and space science teachers who taught 429 students (ages 13-15) during the 2009-2010 school year. The *Basal* group included eight earth and space science teachers who taught 614 eighth grade students (ages 13-15). In each group, one school included a high percentage of many economically disadvantaged students (81.2% - *GT* and 66.2% - *Basal*). Ethnic backgrounds varied by school with one *GT* school containing a much higher percentage of Hispanic students (69.3%) than the other schools. The student population in the school district was 57.5% Caucasian, 30.3% Hispanic, 9.2% African American, 2.9% Asian, and 0.1% American Indian. Seven teachers were male and six were female. The teachers had a wide range of teaching experiences from a first year science teacher to a teacher with 36 years of experience. Content area certifications backgrounds were quite varied and included general K-8 certifications, middle school science certifications, and specific secondary-level science content domain certifications. Data attrition resulted from students who were not in school due to suspensions and truancy. In addition, two teachers were unable to administer one of the measures at the end of the school year due to curriculum time constraints.

In the *GT* group, one teacher had implemented the initial prototype *Energy* curriculum materials with her students in the previous school year and worked with the curriculum development team to ensure that the curriculum materials were developmentally appropriate to meet the different ability level needs of the eighth grade students in the school and aligned to state standards. Two teachers had prior experience using Google Earth in their classroom instruction 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 *GT* group teachers attended a 3-day, 12-hour professional development institute to become acquainted with the *Energy* curriculum's geospatial learning activities and laboratory investigations. The two teachers who were unable to attend the summer institute attended two separate, one-day professional development sessions (12 hours total) during the beginning of the academic school year. The goal of the professional development was to prepare teachers to enact the *Energy* curriculum in a manner consistent with its underlying instructional framework while adapting it to accommodate the different ability levels of the students in the classroom. Prior to the curriculum enactment, the professional development providers also met with the teachers every six days during their planning period for two months to help address any technology issues and review any geospatial learning activities that were not covered during the 12-hour professional development sessions.

Energy Literacy Measures

Two separate instruments were used to measure the energy literacy of the middle school students. One instrument was designed to measure students' energy resources content knowledge and the second instrument was designed to measure energy resources-related attitudes and behaviors.

Energy Resources Knowledge Assessment.

The *Energy Resources Knowledge Assessment* is a thirty-nine multiple-choice item measure with items aligned to benchmark ideas from the American Association for the Advancement of Science Atlas of Science Literacy (2007) maps – *Energy Resources* and *Use of Earth's Resources*. These benchmarks are learning goals that should be achieved by students by the completion of eighth grade. The assessment items include distractors that address misunderstandings and knowledge deficits about energy resources from the existing literature (see for example Richmond & Morgan, 1977; Holden & Barrow, 1984; Stubbs, 1985; Arcury & Johnson, 1987; Blum, 1987; Barrow & Morrisey, 1989; Farhar, 1996; Gambro & Switzky, 1996, 1999; National Environmental Education & Training Foundation & Roper ASW, 2002; Rule,

2005; DeWaters & Powers, 2008). The items are grouped into three subscales corresponding to three main energy content areas:
(1) Energy Acquisition - Renewable and Nonrenewable Energy Resources (EA) [13 items]
(2) Energy Generation, Storage and Transport (EGST) [13 items]
(3) Energy Consumption and Conservation (ECC) [13 items]

Each item is assigned one point for a correct answer and 0 points for an incorrect answer or blank response. The maximum achievable score on the total assessment is 39 points. The development of the *Energy Resources Knowledge Assessment* is fully described in Bodzin (2011b). The *GT* group completed the assessment before using the GT-integrated *Energy* curriculum and again at the end of school year. The *Basal* group completed the assessment at the end of school year. Table 1 displays the reliability (Cronbach alpha) of the entire assessment and for each subscale for both the *GT* group and the *Basal* group of students.

-------------------------------------Insert Table 1 About Here----------------------------------

Energy Attitudes and Behavior Measure.

The *Energy Attitudes and Behavior Measure* was designed to assess students' affective and enactive values about energy resource use and conservation. This instrument builds on previous attitudinal and behavior research related to energy resource issues (Barrow & Morrisey, 1987; Blum, 1987; Bogner & Wilhem, 1996; Devine-Wright, Devine-Wright & Fleming, 2004; DeWaters & Powers, 2008; Holden & Barrow, 1984; Kuhn, 1980; Valhov & Treagust, 1988). The attitude items are intended to measure students' thoughts about energy conservation, their beliefs and values with regards to their personal decisions and actions pertaining to energy resource issues, and their ideas about societal responsibilities about these issues. The behavior items are designed to measure students' energy conservation actions and decision-making. A thorough review of the existing literature was conducted to identify energy attitude and behavior measures that related to affective and enactive values about energy resource use and conservation. Thirteen attitude items and seven behavior items were selected from existing energy and environmental attitudes and behavior measures (Bogner & Wilhem, 1996; DeWaters & Powers, 2008; Kuhn, 1979; National Environmental Education & Training Foundation and Roper ASW, 2002;) that aligned to our constructs of affective and enactive energy values. The statements were modified to enhance the readability for English language learners and students whose reading abilities were below grade level. We developed additional items for the instrument.

The instrument consists of two subscales, an attitude and a behavior subscale. The goal of the scaling is to use a multi-item measure for the constructs under the assumption that the errors associated with responses to any single item cancel each other out (Nunnally & Bernstein, 1994). The attitude subscale items use a five-point Likert-type scale with choices including *strongly agree*, *agree*, *no opinion*, *disagree*, and *strongly disagree*. The behavior subscale items use a five- point Likert-type scale with choices including *always*, *almost always*, *sometimes*, *not very often*, and *never*. Values for each Likert item ranged from one (least preferred response) to five (most preferred response). For example, scored responses to the behavior item, *I unplug charging devices (for example, a cell phone charger) to save energy*, ranged from one (never) to five (always). Four attitude scale items are scored in reverse to accommodate negatively phrased items. The total sum on a scale is therefore based on the summative rating of each item. A maximum score of 125 could be achieved on the instrument with 70 as the highest possible score on the attitude subscale and 55 as the highest possible score on the behavior subscale.

Item content validity was established by having the items reviewed by a panel of five earth and environmental scientists and science educators with expertise in energy education to ensure construct validity. Modifications were made to select items based on the expert panel's feedback and recommendations. In addition, to pilot the instrument, we employed a purposeful sampling strategy using intact classrooms of three teachers in two urban middle schools in Spring 2009. These schools were intentionally selected because of their close proximity to our institution. This enabled us to interview the three teachers to ascertain which items students had difficulty understanding. One hundred seventy-nine eighth grade students completed the pilot instrument. Each individual item was removed one at a time to determine if its removal improved the reliability of each subscale and the entire instrument. After considering the results from the statistical item analysis, individual items were also evaluated based on the teacher feedback for items that students had difficulty understanding. Minor editing was made to four items to enhance the readability of those items. T he final instrument consists of fourteen attitude items and eleven behavior items.

The final instrument was completed by the *GT* group during the 2009-2010 school year prior to using the GT-integrated *Energy* curriculum. The measure was again completed at the end of the school year by 296 students in the *GT* group and 545 students in the *Basal* group. Two *GT* group teachers were unable to administer the instrument to their students due to curriculum time constraints at the end of the school year. Table 2 displays the reliability (Cronbach alpha) of the instrument and for each subscale for both the *GT* group and the *Basal* group of students. The items of the instrument are included in Appendix B.

------------------------------------Insert Table 2 About Here-----------------------------------

Teacher Reported Data Sources

During the curriculum enactment, we asked the teachers in the *GT* group to complete bi-weekly surveys that asked them to tell us which curriculum learning activities they completed and to provide us with a rationale to why any learning activity was not implemented with their students.

Data Analysis

Paired-sample *t* tests were conducted in IBM SPSS 19 to examine whether the mean scores of the *GT* group's *Energy Resources Knowledge Assessment* and *Energy Attitudes and Behavior Measure* were significantly different between the pretest and the end of the school year posttest. Independent t-tests were conducted to examine whether the mean scores of the *GT* group's energy literacy measures were significantly different from the *Basal* group's energy literacy measures at the end of the school year.

Hierarchical multiple regression was conducted in IBM/SPSS 19 after checking the model assumptions (e.g., normality, linearity, and homoscedasticity of residuals) to examine a set of variables (gender, curriculum, energy-related attitude, and energy-related behavior) that may account for students' energy content knowledge differences at the end of the school year. Hierarchical multiple regression allowed us to test the effects of the explanatory variables on the outcome in a priority order after controlling for students' demographic characteristics (e.g., gender) and initial differences in energy content knowledge. The effects of each additional variable or block of variables can be inspected by the additional variance that they accounted for in the outcome (e.g., see Tabachnick & Fidell, 2007, chapter 5). The outcome variable was the total raw score on the year-end *Energy Resources Knowledge Assessment* with possible scores ranging from 0 to 39. The explanatory variables, in order, included:

Block 1 - the pretest scores on the *Energy Resources Knowledge Assessment* and gender (1 = Female and 0 = Male)

Block 2 - curriculum (1 = *GT* curriculum and 0 = *Basal* curriculum)

Block 3 - interaction between gender and curriculum, and total rating scores on the energy-related attitude (henceforth Attitude) and behavior (henceforth Behavior) subscales on the *Energy Attitudes and Behavior Measure*

Block 4 - interactions between curriculum and Attitude, and between curriculum and Behavior.

To avoid high correlations between ratings on the Attitude and Behavior subscales and their interaction terms with curriculum, centering was applied by subtracting from each rating total its respective mean. Similarly, the interaction terms in the fourth block were computed as products of the centered rating scores for Attitude and curriculum, and then for Behavior and curriculum. Since the regression output revealed that the fourth block did not significantly account for additional variance in the outcome, $p > .05$, we removed the fourth block and ran the hierarchical regression with no centered predictors in the first three blocks (more details in the forthcoming section).

Results

GT-Integrated Science Curriculum and Energy Literacy

The *GT* group's pretest and posttest data of the *Energy Resources Knowledge Assessment* and *Energy Attitudes and Behavior Measure* were organized and sorted to include only those students who had completed both the pretest and posttest at the end of the school year. Twenty students did not complete the posttest due to school suspensions and truancy. Correct responses were tallied for the items. Paired-sample t-test analyses were conducted to compare the pretest and posttest results. The results of these analyses were used to compare overall gains, as well as gains for each subscale.

The overall pretest/posttest results for all students in the *GT* group who participated in the GT-integrated *Energy* curriculum are shown in Table 3. Effect size is particularly valuable for quantifying the effectiveness of a specific curricular intervention (Coe, 2002; Henson & Smith, 2000; Kantner, 2009) and is reported as a convenient standardized metric for evaluating the strength of student gains in the population across each subscale. The effect size (ES) indicates the average gain on the posttest measured in pretest standard deviation units. To aid interpretation, Cohen (1988) offered conventional definitions for the ES as small (ES = 0.2), medium (ES = 0.5), and large (ES = 0.8). Effect sizes were large (ES > 0.8) and significant ($p < .001$) for the entire assessment and for each subscale.

-----------------------------------Insert Table 3 About Here-----------------------------------

The pretest and posttest of the *Energy Attitudes and Behavior Measure* data were organized and sorted to include only those students who had completed both assessments. Recall that two teachers in the *GT* group were unable to administer the posttest of this measure to their students due to curriculum time constraint issues. Responses were tallied for the items and total instrument and attitude and behavior subscale scores were determined. Paired-sample t-test analyses were conducted to compare the pretest and posttest results. These results are displayed in Table 4. Overall results regarding the use of a GT-embedded *Energy* curriculum showed modest, but statistically significant gains for the entire assessment ($p < .001$) and for the behavior subscale ($p < .01$). The mean increase for the attitudes subscale was not significant.

-------------------------------------Insert Table 4 About Here-----------------------------------

Three of the five *GT* teachers reported that they completed all learning activities in the 8-week curriculum. Two teachers were unable to complete the culminating *Isle of Navitas* GIS activity due to curriculum time constraints.

Energy Literacy Comparison Between the Use of the GT-Integrated Curriculum and "Business as Usual" Curriculum

At the end of the school year, the *Energy Resources Knowledge Assessment* was administered to all 8th grade students in the *GT* and *Basal* groups. An independent *t* test was conducted between the two groups for the entire assessment and for each subscale. Recall that data attrition resulted due to school suspensions and truancy during the school year. The results are displayed in Table 5. Students who used the GT-integrated *Energy* unit had significantly higher scores ($p < .001$) for the entire assessment and for each subscale compared to the students who learned with the "business as usual" curriculum.

-------------------------------------Insert Table 5 About Here-----------------------------------

At the end of the school year, the *Energy Attitudes and Behavior Measure* was administered to 8th grade students in the *GT* and *Basal* groups. One teacher in the *Basal* group in addition to two teachers in the *GT* group were unable to administer this measure to their students due to curriculum time constraint issues. An independent *t* test was conducted between the two groups for the entire assessment and for each subscale. The results are displayed in Table 6. Students who used the GT-integrated *Energy* unit had significantly higher energy-related attitudes and behavior scores on the entire assessment ($p <. 01$) and for each subscale ($p < .05$) compared to those students who learned with the "business as usual" curriculum. Appendix B contains the responses to each item for both groups for the *Energy Attitudes and Behavior Measure*.

-------------------------------------Insert Table 6 About Here-----------------------------------

Regression Analysis on Student Energy Content Knowledge Achievement

Hierarchical multiple regression was conducted to address whether the students' year-end energy content knowledge achievement, after controlling for students' differences in gender and energy content knowledge pretest scores (Block 1), was related to curriculum status (*GT* or *Basal*; Block 2), and the total subscale scores on Attitude and Behavior as well as the interaction between curriculum and gender (Block 3).

In our initial regression analysis, we had tried a fourth block to test the effects of the interactions between curriculum and Attitude (centered), and between curriculum and Behavior (centered). The total rating scores for Attitude and Behavior were centered by subtracting from each score its respective mean (53.713 for Attitude and 31.669 for Behavior). The fourth block did not significantly account for additional variance in the outcome, $R^2 = 0.77$, $\Delta R^2 = 0.001$,

$F_{increment}$ (2, 860) = 1.69, $p = .184$. Therefore, we removed the fourth block and reran the hierarchical regression with no centered predictors in the first three blocks. The Pearson correlations across the explanatory variables and the outcome range from -.003 to .667 (Table 7). Pretest content knowledge and curriculum had the highest correlations with the year-end content knowledge test scores ($r = .677$ and $r = .607$ respectively). The year-end energy-related attitude and behavior were more positively correlated with each other ($r = .537$) than their respective correlation with student content knowledge achievement ($r = .266$ and $r = .203$ respectively). The hierarchical regression results are displayed in Table 8.

-------------------------------------Insert Table 7 About Here-----------------------------------
-------------------------------------Insert Table 8 About Here-----------------------------------

Results from Model 1 revealed that gender and the pretest scores on the *Energy Resources Knowledge Assessment* explained almost half of the variance in the year-end content test scores, $R^2 = 0.46$, $F_{(2, 866)} = 368.26$, $p < .001$.

In Model 2, the curriculum variable contributed a significant additional amount of variance in the outcome, $R^2 = 0.765$, $\Delta R^2 = 0.306$, $F_{increment\,(1, 865)} = 1128.17$, $p < .001$. After controlling for their initial energy content knowledge scores and gender, the students using the GT-integrated curriculum had year-end *Energy Resources Knowledge Assessment* scores significantly higher (by 9.57 points) than those who learned with the "business as usual" curriculum, $p < .001$.

In Model 3, the additional variables, year-end attitude and behavior subscale total ratings and the interaction between curriculum and gender, accounted for a significant, although not substantial, additional amount of variance in the outcome, $R^2 = 0.769$, $\Delta R^2 = 0.004$, $F_{increment\,(3, 862)} = 4.93$, $p = .002$. Pretest energy content knowledge scores and curriculum were strong significant predictors of the outcome: controlling for everything else, each-point increase in the content pretest score was associated with 0.85 point increase in the year-end test score, $\beta = 0.61$, $p < .001$; the students using the GT-integrated curriculum had year-end energy content knowledge scores significantly higher (by 10.11 points) than those learning with the "business as usual" curriculum, $\beta = 0.59$, $p < .001$. Holding everything else constant, the year-end attitude ratings was a statistically significant predictor of the outcome, $\beta = 0.04$, $p = .03$, but the year-end behavior rating scores were not significant, $p = 44$. In this final model, what is interesting is that gender became a non-significant predictor of the outcome, $p = .35$, but the interaction between curriculum and gender was significant, $\beta = -0.06$, $p = .03$, indicating that the effects of the curriculum on the outcome varied with gender. Specifically, holding for everything else, female students who used the GT-integrated curriculum had lower year-end energy content knowledge scores (lower by 1.26 points) relative to other students (basal and/or male; or female using the basal curriculum).

Discussion

Curriculum Design with GT

In this study, we used a series of valid and reliable energy content, attitudes, and behavior measures to examine the effectiveness of a GT-integrated science curriculum to promote energy literacy with urban middle school students. Results from this study show that considerable student learning of important energy concepts occurred by the end of the school year with the GT-integrated curriculum enactment. Student knowledge pertaining to the acquisition of renewable and nonrenewable resources, energy generation, storage, and transport, and energy consumption and conservation increased with significant effect sizes from pretest to posttest. The results also support the effectiveness of the *Energy* curriculum to enhance pro-environmental energy conservation actions and decision-making behaviors of urban middle school students. Students' attitudes about energy conservation and their ideas about societal responsibilities about energy resource issues had a nominal increase, but were not significant. The findings from this study provide support that a GT-integrated curriculum developed with a curriculum design model that incorporated a curriculum framework, design principles, and an instructional model that provided guidance to the development of GT-integrated instructional materials with GIS and Google Earth can be taught to diverse learners in an urban middle school and promote learning of important concepts about energy resources.

Students who learned about energy resources with a GT-integrated science curriculum had significantly greater energy literacy measures, including energy resources content knowledge and energy-related attitudes and behavior, than the students who learned with the "business as usual" curriculum. The *Energy* curriculum was designed to help students to develop deep understandings about important energy resource issues with an integrated, carefully planned interrelated set of conceptual topics, geospatial thinking skills, and learning activities based on important student learning goals. The learning activities integrate energy content and geospatial thinking and reasoning to support the important understandings of energy resources. The curriculum focuses on developing deep and rich understandings of fundamental energy resources concepts in the areas of energy acquisition, energy storage and transport, and energy consumption and conservation. The curriculum makes the connections among these three interrelated areas explicit through the content readings, GT explorations and investigations, inquiry-based laboratories, and other learning activities. This allows for a coherent understanding of a specific set of ideas related to energy resources. Curriculum implementation in the "business as usual" manner often uses existing basal science textbook curriculum programs that have a broad range of topics and do not focus on coherent age-appropriate learning goals (Kesidou & Roseman, 2002; Stern & Roseman, 2004). Furthermore, they are often implemented with a lack of coordination with regards to scope, sequence, and implementation time frames across teachers in a school building.

The findings in this study build on the work of other researchers who have investigated the implementation of technology-integrated science curriculum that have used specific design principles (Casperson & Linn, 2006; Lee, Linn, Varna, & Liu, 2010; Liu, Lee, Hofstettler, & Linn, 2008) and frameworks (Edelson, 2001; Krajcik, McNeill, & Reiser, 2008) that have incorporated interactive visualizations effectively in science curriculum learning activities. GIS and virtual globes are both interactive visualization tools that enable learners to manipulate, analyze, and synthesize spatial data in novel ways (Bodzin, 2011a; Hall-Wallace & McAuliffe, 2002) and can support the development of contextually rich learning environments that promote higher order thinking skills, meaningful learning and authentic scientific inquiry (Bodzin, 2008; Bodzin & Anastasio, 2006). Visualizing the spatial relationships among data sets assists in the cognitive aspect of learning and promotes deeper understanding of content (Kaiser & Wood, 2001; MacEachren, 1995; Stinton & Lund, 2007). In the *Energy* curriculum, interactive visual interfaces and analysis tools that are inherent to GIS and Google Earth provided students with an effective way to analyze spatial data to investigate current energy resources issues. The curriculum included many learning activities that involved spatial decision-making problems that required students to formulate and analyze action plans pertaining to energy resource acquisition and making decisions that involved environmental trade-offs with regards to resource acquisition, generation, transport and consumption.

Contributing Factors to Energy Content Knowledge Achievement

The results of the hierarchical multiple regression in this study revealed that prior student knowledge of energy resources and curriculum type were strong significant predictors of energy content knowledge achievement. Students' year-end energy-related attitudes were statistically significant, but not a substantial predictor of energy content knowledge achievement. Year-end energy-related behavior ratings were not a significant predictor of energy content knowledge achievement. In this model, gender was not a significant predictor of energy content knowledge achievement, but there was an interaction between gender and curriculum. Female students who used the GT-integrated curriculum had lower (by 1.26 points) year-end energy content knowledge scores relative to female students using the basal curriculum as well as male students regardless of their curriculum.

Energy literacy is a component of environmental literacy. Environmental literacy involves a complex relationship among environmental knowledge, attitudes, and behavior (Hungerford & Volk 1990). Positive attitudes towards the environment have been found to be a precursor to pro-environmental behavior (Kaiser, Wolfing, & Fuhrer, 1999) and it has been contended that environmental knowledge must be present for environmentally responsible behavior to occur (Hines, Hungerford, & Tomera, 1986; Maloney & Ward, 1973). Studies have indicated that those who have greater environmental knowledge are more likely to act in a more responsible way (Hines et al., 1986). However, some studies have found no direct relationship between environmental content knowledge and environmental attitudes and behavior (Maloney & Ward, 1973; Schahn & Holzer, 1990). In this study, year-end energy-related attitude and behavior were more positively correlated with each other than their respective correlation with student content knowledge achievement. In our *GT* group, students initially had very positive energy-related attitudes and behaviors that only marginally increased by the end of the curriculum implementation, while the magnitude of their energy content knowledge increased substantially during this time frame. Therefore, our findings are similar to those of others (Maloney & Ward, 1973; Schahn & Holzer, 1990) who did not find strong relationships between environmental content knowledge and environmental attitudes and behavior.

The professional development experiences the *GT* teachers received may also have been a contributing factor to the students' increase in their conceptual knowledge base of energy resources. The goal of the professional development was to prepare teachers to implement the *Energy* curriculum in a manner consistent with its underlying instructional framework and focused on developing teachers' capacity to successfully implement geospatial technologies with urban school learners. Participation of teachers in science curriculum reform that involves the adoption of learning technologies requires professional development connected to teachers' enactment of curriculum (Stolk, Jong, Bulte, & Pilot, 2011). The *GT* group teachers received 12 hours of professional development and additional support sessions prior to the curriculum enactment that focused on developing their comfort and confidence using geospatial learning activities and laboratory investigations with a novel curriculum. Additional supports during the curriculum enactment were provided to the teachers in the form of embedded curriculum materials that were designed to expand teachers' science content knowledge, their geospatial pedagogical content knowledge, and pedagogical capacity for using the curriculum with urban learners of different ability levels. Our findings support work reported in other research studies that have shown that in settings where teachers can be supported directly by the curriculum designers with appropriate professional development experiences and other curriculum implementation supports, science instruction with innovative curriculum in urban classrooms can be successful and result in greater student learning gains (e.g., Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004; Geir et al., 2008; Lee et al., 2008; Warren, Ballenger, Ogonowski, Rosebury, & Hudicourt-Barnes, 2001).

Issues Pertaining to Broader Adoption of GT-Integrated Curriculum

Due to the innovative nature of the GT-integrated curriculum, broader adoption of the *Energy* curriculum to other urban school settings will require administrative infrastructure for sustained professional development and support (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004). Current state science standards and accountability testing require teachers to provide instruction and cover many science topics during the course of the school year. Such content coverage limits that amount of time a teacher may spend to cover a particular topic in much depth and is a main barrier to adoption of a reform-based science curriculum. Adoption of a GT-integrated curriculum also requires a systemic shift of pedagogical practice to move away from a more superficial topical coverage of science that often occurs with basal textbook science curriculum programs. Successful adoption of the *Energy* curriculum, or any other related GT-integrated curriculum, will require administrative support at all levels of a school district. Support efforts will need to include professional development to support teachers with the curriculum adoption. In addition, appropriate technical support to ensure that the geospatial technologies function appropriately on school computers will be needed. In our study, we worked closely with the technology staff at each school to ensure software and hardware needs were met.

Study Limitations

There are limitations to our study. First, our sample size consisted of only two urban schools assigned to each group from the same school district. Including additional schools from other urban school districts would enhance our ability to generalize our findings to other urban middle schools. Second, the design of this study with no random-assigned pretest intervention and comparison groups creates threats to internal validity in terms of establishing the causality of the curriculum on student energy literacy outcomes, although we controlled for the initial energy content difference in the regression analysis. Despite this limitation the effectiveness of the *Energy* curriculum was demonstrated by consistent patterns of positive student achievement outcomes across the teachers during the implementation and with additional survey data responses from the teachers that supported curriculum effectiveness.

Conclusion

This study showed that the implementation of a GT-integrated science curriculum improved the energy literacy of urban middle school students. Recent studies have shown that U.S. students' knowledge about energy resources is quite low (Gambro & Switzky, 1999; DeWaters & Powers, 2008; Bodzin, 2011a). Learning with a GT-supported science curriculum significantly enhanced students' knowledge about important energy resource concepts. The curriculum enactment also improved students' pro-environmental energy conservation actions and decision-making behaviors. The findings from this study contribute to the literature by providing support that energy literacy can be promoted with a GT-integrated curriculum in urban middle schools with appropriately designed curriculum. This research also informs curriculum developers with a design model that can be used to guide the development of GT-integrated science curriculum.

This study focused on the effectiveness of a GT-integrated science curriculum to promote energy literacy with students in urban middle schools. Additional studies are encouraged to examine the effectiveness of different forms of curriculum designs and frameworks coupled to GT-integrated energy and other environmental science curriculum. In addition, future research is needed to examine teachers' fidelity of implementation when enacting GT-integrated science curriculum. Such studies might examine the adherence to the elements of the instructional model and explore pedagogical practices that occur during teachers' curriculum enactment.

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Tables

Table 1

Reliability (Cronbach alpha) of the Energy Resources Knowledge Assessment

	***GT* group (n= 418)**	***Basal* group (n= 596)**
Entire Assessment (n=39)	.886	.798
EA Subscale (n=13)	.760	.636
EGST Subscale (n=13)	.726	.605
ECC Subscale (n=13)	.699	.506

Table 2

Reliability (Cronbach alpha) of the Energy Attitudes and Behavior Measure

	***GT* group (n= 296)**	***Basal* group (n= 545)**
Entire Instrument (n=25)	.845	.875
Attitudes Subscale (n=14)	.809	.818
Behavior Subscale (n=11)	.755	.826

Table 3

GT group's Energy Resources Knowledge Assessment overall and subscale achievement for pre/posttest. (N = 398)

	Pretest Mean (SD)	**Posttest Mean (SD)**	**t-Value[a]**	**Effect Size[b]**
Entire Assessment (39 items)	15.02 (5.56)	23.68 (7.55)	24.848***	1.56
EA Subscale (13 items)	5.39 (2.43)	8.45 (2.95)	20.525***	1.26
EGST Subscale (13 items)	5.09 (2.27)	8.21 (2.75)	22.822***	1.37
ECC Subscale (13 items)	4.54 (2.11)	7.02 (2.79)	16.707***	1.18

[a] One-tailed paired t-test.

[b] Effect size: Calculated by dividing the difference between posttest and pretest mean scores by the pretest standard deviation.

***$p < .001$.

Table 4

GT group's Energy Attitudes and Behavior Measure for pretest and posttest. (N = 296)

	Pre-test Mean (SD)	**Post-test Mean (SD)**	**T-stat**	**Sig**
Entire Assessment	84.96 (11.36)	86.89 (11.73)	3.261	.001
Attitudes Subscale	53.37 (6.06)	54.27 (6.26)	2.531	.12
Behavior Subscale	31.59 (11.36)	32.62 (7.11)	2.655	.008

Note: Likert item values ranged from 1 (least preferred response) to 5 (most preferred response).

Table 5

Energy Resources Knowledge Assessment overall and subscale achievement by group

	Group	**N**	**Mean (SD)**	**T-Stat**	**Sig**
Entire Assessment (39 items)	*GT*	412	23.82 (7.57)	20.259	.000
	Basal	596	14.77 (6.00)		
EA Subscale (13 items)	*GT*	412	8.50 (2.96)	16.758	.000
	Basal	596	5.49 (2.57)		
EGST Subscale (13 items)	*GT*	412	8.25 (2.75)	19.216	.000
	Basal	596	5.00 (2.47)		
ECC Subscale (13 items)	*GT*	412	7.06 (2.79)	17.658	.000
	Basal	596	4.27 (2.21)		

Note: Each item was assigned one point for a correct answer and 0 points for an incorrect answer or blank response.

Table 6

Energy Attitudes and Behavior Measure overall and subscale scores by group

	Group	**N**	**Mean (SD)**	**T-Stat**	**Sig**
Entire Measure (25 items)	*GT*	296	86.92 (11.88)	2.890	.004
	Basal	545	84.18 (13.75)		
Attitudes Subscale (14 items)	*GT*	296	54.46 (6.27)	2.564	.011
	Basal	545	53.20 (7.08)		
Behavior Subscale (11 items)	*GT*	296	32.46 (7.26)	2.522	.012
	Basal	545	30.98 (8.56)		

Note: Likert item values from 1 (least preferred response) to 5 (most preferred response).

Table 7

Pearson correlations among variables predicting year-end Energy Resources Knowledge Assessment total scores (N = 869)

	YE_Cont	Pre_Cont	Gender	Curriculum	YE_ATT	YE_BEH
Pre_Cont	.677					
Gender	-.096	-.092				
Curriculum	.607	.082	-.003			
YE_ATT	.266	.275	.127	.092		
YE_BEH	.203	.203	.072	.078	.537	
Curr_Gen	.312	.016	.447	.618	.080	.071

Notes. YE_Cont = Year-end total score on the *Energy Resources Knowledge Assessment*; Pre_Cont = Pretest total score on the *end Energy Resources Knowledge Assessment*; YE_ATT = Year-end total rating score on the attitudes subscale of the *Energy Attitudes and Behavior Measure;* YE_BEH = Year-end total rating score on the behavior subscale of the *Energy Attitudes and Behavior Measure;* Gender (Female=1 and Male=0); Curriculum (GT=1 and Basal=0); Curr_Gen = Curriculum by Gender (GT and Female = 1, GT and Male = 0, Basal regardless of gender = 0).

Table 8

Hierarchical regression analysis for factors predicting year-end Energy Resources Knowledge Assessment total scores (N = 869)

	Model 1			Model 2			Model 3		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Intercept	4.331	0.599		2.158	0.400		-0.864	1.060	
Gender	-0.549	0.406	-0.034	-0.590	0.268	-0.036*	-0.306	0.328	-0.019
Pre_Cont	0.933	0.035	0.674***	0.870	0.023	0.628***	0.849	0.024	0.613***
Curriculum				9.572	0.285	0.555***	10.109	0.393	0.586***
YE_ATT							0.051	0.024	0.043*
YE_BEH							0.015	0.019	0.015
Curr_Gen							-1.260	0.566	-0.057*
R^2			0.460***			0.765***			0.769***
ΔR^2						0.306***			0.004**

Notes: *B* = unstandardized regression coefficient; *SE* = standard error; *β* = standardized regression coefficient; Pre_Cont = pretest total score on the *Energy Resources Knowledge Assessment*; YE_ATT = Year-end total rating score on the attitudes subscale of the *Energy Attitudes and Behavior Measure;* YE_BEH = Year-end total rating score on the behavior subscale of the *Energy Attitudes and Behavior Measure;* Gender (Female=1 and Male=0); Curriculum (*GT*=1 and *Basal*=0); Curr_Gen = Curriculum by Gender (*GT* and Female = 1, GT and Male = 0, Basal regardless of gender = 0).

p* < .05; **p < .01, * *p* < .001.

Appendix A. Energy resources content in the Pennsylvania state science and geography standards

3.2.4.B2. Identify types of energy and their ability to be stored and changed from one form to another.
3.2.5.B2. Examine how energy can be transferred from one form to another.
3.2.7.B2. Describe how energy can be changed from one form to another (transformed) as it moves through a system or transferred from one system to another system.
3.2.8.B2. Identify situations where kinetic energy is transformed into potential energy, and vice versa.
3.2.3.B6. Recognize that light from the sun is an important source of energy for living and nonliving systems and some source of energy is needed for all organisms to stay alive and grow.
3.3.8.A2. Describe renewable and nonrenewable energy resources.
3.3.8.A6. Explain changes in earth systems in terms of energy transformation and transport.
3.4.3.E3. Recognize that tools, machines, products, and systems use energy in order to do work.
3.4.3.E3. Recognize that tools, machines, products, and systems use energy in order to do work.
3.4.4.E3. Identify types of energy and the importance of energy conservation.
3.4.6.E3. Investigate that power is the rate at which energy is converted from one form to another or transferred from one place to another.
3.4.7.E3. Examine the efficiency of energy use in our environment.
4.3.4.A. Identify ways humans depend on natural resources for survival.
  - Identify resources used to provide humans with energy, food, employment, housing and water.

4.3.7.A. Explain how products are derived from natural resources.
  - Describe the process of converting raw materials to consumer goods.
  - Differentiate between renewable and nonrenewable resources.

4.3.7.B. Explain the distribution and management of natural resources.
  - Differentiate between resource uses: conservation, preservation, and exploitation.

4.3.8.A. Compare and contrast alternative sources of energy.
4.3.8.B. Analyze how humans manage and distribute natural resources.
  - Describe the use of a natural resource with an emphasis on the environmental consequences of extracting, processing, transporting, using, and disposing of it.

7.3.3.D Identify the human characteristics of places and regions by their economic activities.
- Spatial distribution of resources
- Non-renewable resources
- Renewable resources

Appendix B. Item response summary by group *Energy Attitudes and Behavior Measure*

Attitude Subscale	**Group**	**Strongly Agree**	**Agree**	**No Opinion**	**Disagree**	**Strongly Disagree**
1. I would do more to save energy if I knew how.	*GT*	n= 59 (19.9%)	n= 150 (50.7%)	n= 69 (23.3%)	n= 16 (5.4%)	n= 2 (0.7%)
	BASAL	n= 95 (17.5%)	n= 289 (53.0%)	n= 131 (24.0%)	n= 25 (4.6%)	n= 5 (0.9%)
2. Saving energy is important.	*GT*	n= 153 (51.7%)	n= 128 (43.2%)	n= 15 (5.1%)	n= 0 (0%)	n= 0 (0%)
	BASAL	n= 268 (49.1%)	n= 224 (41.1%)	n= 44 (8.1%)	n= 7 (1.3%)	n= 2 (0.4%)
3. The way I personally use energy does NOT really make a difference to the energy problems that face the USA.	*GT*	n= 8 (2.7%)	n= 37 (12.5%)	n=112 (37.8%)	n= 107 (36.2%)	n= 32 (10.8%)
	BASAL	n= 26 (4.8%)	n= 94 (17.2%)	n= 196 (36.0%)	n= 167 (30.6%)	n= 62 (11.4%)
4. I do NOT need to worry about turning the lights off in my home, because someone else pays for the electricity.	*GT*	n= 3 (1.0%)	n= 18 (6.1%)	n= 43 (14.5%)	n= 120 (40.5%)	n= 112 (37.9%)
	BASAL	n= 27 (5.0%)	n= 46 (8.4%)	n= 63 (11.6%)	n= 175 (32.1%)	n= 234 (42.9%)
5. Americans should conserve more energy.	*GT*	n= 128 (43.2%)	n= 127 (42.9%)	n= 36 (12.2%)	n= 3 (1.0%)	n= 2 (0.7%)
	BASAL	n= 193 (35.4%)	n= 243 (44.6%)	n= 92 (16.9%)	n= 11 (2.0%)	n= 6 (1.1%)
6. I do NOT have to worry about conserving energy, because new technologies will be developed to solve future energy problems.	*GT*	n= 3 (1.0%)	n= 16 (5.4%)	n= 73 (24.7%)	n= 155 (52.4%)	n= 49 (16.5%)
	BASAL	n= 9 (1.7%)	n= 40 (7.3%)	n= 156 (28.6%)	n= 248 (45.5%)	n= 92 (16.9%)
7. The government should force car builders to make their cars get BETTER gas mileage.	*GT*	n= 60 (20.3%)	n= 112 (37.8%)	n= 100 (33.8%)	n= 16 (5.4%)	n= 8 (2.7%)
	BASAL	n= 129 (23.7%)	n= 201 (36.9%)	n= 170 (31.2%)	n= 29 (5.3%)	n= 16 (2.9%)
8. We should make more of our electricity from	*GT*	n= 113 (38.2%)	n= 139 (46.9%)	n= 40 (13.5%)	n= 2 (0.7%)	n= 2 (0.7%)

renewable energy sources (such as solar, wind, biofuels, and tidal power).	*BASAL*	n= 205 (37.6%)	n= 229 (42.0%)	n= 92 (16.9%)	n= 13 (2.4%)	n= 6 (1.1%)
9. Efforts to develop renewable energy technologies (such as solar, wind, biofuels, and tidal power) are more important than efforts to find and develop new sources of fossil fuels (coal, oil, and natural gas).	*GT*	n= 56 (18.9%)	n= 110 (37.2%)	n= 111 (37.5%)	n= 19 (6.4%)	n= 0 (0%)
	BASAL	n= 93 (17.1%)	n= 152 (27.9%)	n= 253 (46.4%)	n= 28 (5.1%)	n= 19 (3.5%)
10. I can contribute to solving energy problems by making appropriate energy-related choices and actions.	*GT*	n= 53 (17.9%)	n= 157 (53.0%)	n= 70 (23.7%)	n= 14 (4.7%)	n= 2 (0.7%)
	BASAL	n= 104 (19.1%)	n= 287 (52.7%)	n= 114 (20.9%)	n= 29 (5.3%)	n= 11 (2.0%)
11. The government should invest more money in research and development of renewable energy sources such as solar, wind, and tidal power.	*GT*	n= 69 (23.3%)	n= 119 (40.2%)	n= 90 (30.4%)	n= 18 (6.1%)	n= 0 (0%)
	BASAL	n= 115 (21.1%)	n= 222 (40.7%)	n= 160 (29.4%)	n= 33 (6.1%)	n= 15 (2.7%)
12. People have the responsibility to analyze their energy use and to change their habits to waste less energy.	*GT*	n= 64 (21.6%)	n= 158 (53.4%)	n= 61 (20.6%)	n= 11 (3.7%)	n= 2 (0.7%)
	BASAL	n= 107 (19.6%)	n= 267 (49.0%)	n= 136 (24.9%)	n= 21 (3.9%)	n= 14 (2.6%)
13. A dripping hot water faucet uses too little energy to worry about.	*GT*	n= 5 (1.7%)	n= 19 (6.4%)	n= 77 (26.0%)	n= 140 (47.3%)	n= 55 (18.6%)
	BASAL	n= 22 (4.0%)	n= 46 (8.4%)	n= 143 (26.3%)	n= 233 (42.8%)	n= 101 (18.5%)
14. The government should make sure that all appliances are energy efficient.	*GT*	n= 54 (18.2%)	n= 142 (48.0%)	n= 78 (26.4%)	n= 17 (5.7%)	n= 5 (1.7%)
	BASAL	n= 99 (18.2%)	n= 223 (40.9%)	n= 170 (31.2%)	n= 34 (6.2%)	n= 19 (3.5%)

Behavior Subscale	**Group**	**Always**	**Almost Always**	**Sometimes**	**Not Very Often**	**Never**
1. When I leave a room, I turn off the lights.	*GT*	n= 83 (28.0%)	n= 95 (32.1%)	n= 97 (32.8%)	n= 18 (6.1%)	n= 3 (1.0%)
	BASAL	n= 144 (26.4%)	n= 206 (37.8%)	n= 139 (25.5%)	n= 44 (8.1%)	n= 12 (2.2%)
2. I turn down the heat in the winter to conserve energy.	*GT*	n= 16 (5.4%)	n= 34 (11.5%)	n= 119 (40.2%)	n= 85 (28.7%)	n= 42 (14.2%)
	BASAL	n= 47 (8.7%)	n= 58 (10.6%)	n= 163 (29.9%)	n= 132 (24.2%)	n= 145 (26.6%)
3. I turn down the air conditioning in the summer to conserve energy.	*GT*	n= 20 (6.7%)	n= 34 (11.5%)	n= 100 (33.8%)	n= 74 (25.0%)	n= 68 (23.0%)
	BASAL	n= 34 (6.2%)	n= 61 (11.2%)	n= 165 (30.3%)	n= 138 (25.3%)	n= 147 (27.0%)
4. I encourage my family to buy energy efficient compact fluorescent light bulbs.	*GT*	n= 36 (12.2%)	n= 36 (12.2%)	n= 69 (23.3%)	n= 64 (21.6%)	n= 91 (30.7%)
	BASAL	n= 70 (12.9%)	n= 51 (9.4%)	n= 100 (18.3%)	n= 113 (20.7%)	n= 211 (38.7%)
5. I encourage my family to buy appliances that are energy efficient.	*GT*	n= 23 (7.8%)	n= 35 (11.8%)	n= 86 (29.1%)	n= 70 (23.6%)	n= 82 (27.7%)
	BASAL	n= 42 (7.7%)	n= 58 (10.7%)	n= 113 (20.7%)	n= 129 (23.7%)	n= 203 (37.2%)
6. I fill up the washing machine with as many clothes as possible before running the laundry load.	*GT*	n= 84 (28.4%)	n= 75 (25.3%)	n= 73 (24.7%)	n= 32 (10.8%)	n= 32 (10.8%)
	BASAL	n= 75 (13.8%)	n= 47 (8.6%)	n= 128 (23.5%)	n= 148 (27.2%)	n= 147 (26.9%)
7. I take quick showers to conserve energy.	*GT*	n= 24 (8.1%)	n= 37 (12.5%)	n= 87 (29.4%)	n= 81 (27.4%)	n= 67 (22.6%)
	BASAL	n= 176 (32.3%)	n= 127 (23.3%)	n= 136 (25.0%)	n= 60 (11.0%)	n= 46 (8.4%)
8. I unplug charging devices (for example, a cell phone charger) to save energy.	*GT*	n= 47 (15.8%)	n= 49 (16.6%)	n= 68 (23.0%)	n= 72 (24.3%)	n= 60 (20.3%)
	BASAL	n= 68 (12.5%)	n= 72 (13.2%)	n= 116 (21.3%)	n= 121 (22.2%)	n= 168 (30.8%)
9. I separate our trash into different containers so some materials can be recycled. For example: glass, cans, or paper.	*GT*	n= 101 (34.1%)	n= 58 (19.6%)	n= 58 (19.6%)	n= 37 (12.5%)	n= 42 (14.2%)
	BASAL	n= 195 (35.8%)	n= 103 (18.9%)	n= 89 (16.3%)	n= 55 (10.1%)	n= 103 (18.9%)
10. If I had to go five blocks to the store, I would rather walk or ride my bike instead of finding a car ride.	*GT*	n= 104 (35.1%)	n= 63 (21.3%)	n= 83 (28.0%)	n= 31 (10.5%)	n= 15 (5.1%)
	BASAL	n= 165 (30.3%)	n= 113 (20.7%)	n= 164 (30.1%)	n= 47 (8.6%)	n= 56 (10.3%)

11. If bus service were available, I would use a bus rather than a car to get around town.	*GT*	n= 20 (6.7%)	n= 24 (8.1%)	n= 89 (30.1%)	n= 78 (26.4%)	n= 85 (28.7%)
	BASAL	n= 40 (7.3%)	n= 38 (7.0%)	n= 146 (26.8%)	n= 122 (22.4%)	n= 199 (36.5%)