Integrating geospatial technologies to examine urban land use change: A design partnership

Alec M. Bodzin, Lehigh University
Lori Cirucci, Broughal Middle School

Paper presented in the multiple paper set, *Professional Development Models Using Geospatial Technologies* (Trautmann, Bodzin, Blank, & MaKinster) at the 2008 Association for Science Teacher Education (ASTE) Annual Meeting in St. Louis, MO.

Abstract:

This paper describes a design partnership that investigated how to integrate Google Earth, remotely-sensed satellite and aerial imagery with other instructional resources to investigate ground cover and land use in a technology-enhanced middle school classroom of diverse learners. The design of an instructional unit to investigate environmental issues relating to land use change is presented. The experiences related to the development of students' spatial thinking skills with Google Earth and remotely sensed images are discussed. Findings revealed that specific instructional strategies and techniques appear to have assisted diverse learners in developing certain spatial thinking skills.

Geospatial technologies and their products such as Google Earth, remotely sensed satellite and aerial images, and Geographic Information Systems (GIS) have become readily accessible, widely available, and more apparent in our daily lives than ever before. These tools allow for visualizing, mapping, and analyzing multiple layers of georeferenced data. Geospatial technologies have proven to be a valuable tool in the process of understanding the environment and of making responsible environmental decisions (Heit, et al. 1991; Carrarra and Fausto, 1995; National Research Council, 2006). The ability to use, analyze and interpret images and maps is becoming more and more important in many scientific and industrial fields. In addition, some contend that the ability to use images and spatial technologies intelligently and critically is becoming a requirement to participate effectively as a citizen in modern society. (Bednarz, Acheson, and Bednarz 2006).

Spatial thinking is the knowledge, skills, and habits of mind to use spatial concepts, maps and graphs, and processes of reasoning in order to organize and solve problems (National Research Council 2006). Spatial thinking skills that are used as *geographic* (see Gersmehl and Gersmehl 2006) are important for investigating a range of environmental issues including land use change in urban environments. Most urban areas face the growing problems of sprawl that may result in a loss of natural vegetation, agricultural lands, and open space due to commercial, industrial, and residential development that often occurs due to population growth and expansion. Such growth is often accompanied by a general decline in the extent and connectivity of wildlife and wetland habitat. Land cover and land use changes can be substantial but are difficult to grasp when they occur incrementally (Laymon 2003). The availability of satellite data and aerial photographs from different periods of time dramatically illustrates the rates at which these land use changes are occurring in urban areas. Analyzing such spatial data temporally provides one with a visual depiction of geographic growth patterns, and conveys how changes to the landscape occur over time.

Recent education reform initiatives emphasize the significance of developing thinking skills, data analysis skills, understanding real-world applications, and utilizing the power of technology in teaching and learning (International Society for Technology in Education 2000; National Research Council 1996; North American Association for Environmental Education 2000). Integrating geospatial technologies that focus on the development of spatial thinking skills may provide a platform for effectively achieving these education goals (Geography Education Standards Project, 1994). However, there have been many challenges to implementing geospatial technologies into K-12 classrooms. These include technical issues pertaining to the interface design of software, time for classroom teachers to learn to use the software, lack of existing basal curricular materials that integrate geospatial technologies, and lack of time to develop learning experiences that integrate easily into existing school curriculum (Meyer *et al*. 1999; Baker and Bednarz 2003; Bednarz 2003; Kerski 2003; Patterson *et al*. 2003). While we acknowledge these barriers, new Web-based geospatial tools and instructional resources integrated with appropriately designed instructional materials show much potential to be used with urban middle school students to promote spatial thinking.

In this article, an investigation to explore how to best integrate Google Earth, a relatively new Web-based geospatial tool, with other instructional resources in a technology-enhanced urban middle school classroom is described. The primary goal of this study was to determine optimal ways of implementing Google Earth and time-sequenced satellite imagery in a diverse learning environment to investigate ground cover features and land use patterns. We describe a design partnership to rapidly develop a prototype unit on land use change by enhancing an existing environmental change curricular module with Google Earth, satellite images from NASA and USGS, and locally-based Web resources. Experiences relative to the development of students' spatial thinking skills with Google Earth and remotely sensed images are described. Classroom adaptations and instructional strategies teachers may use to assist in promoting spatial thinking skills with these geospatial tools with diverse middle school learners are discussed.

Context

A design partnership was formed between an educator/researcher and a classroom teacher to collaboratively design and develop an instructional unit that focused on environmental issues relating to land use change. The partnership was initiated through the NASA Explorer School program (Loston *et al.* 2005) with a main goal to enhance student learning by engaging learners to understand and be able to apply STEM-G (Science Technology Engineering Mathematics – Geography) content and skills into real-world applications and experiences. To achieve this goal, we have adopted a partnership model that focuses on collaborative design and implementation of curriculum in keeping with models of school-based reform (Shear *et al.* 2004, 289). As a NASA Explorer School, we were interested in designing activities that would use NASA data and resources to support student learning. Our partnership was a mechanism to leverage the diverse expertise of each contributor. Such partnerships facilitate the transition between the designed curriculum and the implemented curriculum in the classroom (Cohen *et al*. 2001, 30). These collaborations also promote the learning of each partner in a process of co-developing the curriculum and instructional practices that will be implemented in the classroom (McLaughlin and Mitra 2001).

A design-based curricular implementation study was conducted as part of the partnership. Design-based studies combine inductive qualitative approaches with quantitative and quasi-experimental approaches, varying the method to suit investigative questions that present themselves over the life of the collaboration (Barab and Squire 2004; Cobb *et al*. 2004). This work can involve the implementation of technological tools and curriculum in school settings that can be used to understand and support learning. Because design experiments are set in learning environments, there are many variables that cannot be controlled. In these investigations, the researcher establishes a regular presence in the classroom to support the use of an innovation and work as essential partners to promote effective learning strategies. In part, this serves to temporarily establish conditions that are favorable to the innovation's success. Without these conditions, it would not be possible to study the phenomena or ideas of interest. Design-based studies are often reported as design narratives that may take the form of case studies that do not necessarily include research designs that involve comparing experimental group interventions with control groups (Bell *et al*. 2004, 79; Collins *et al*. 2004). A goal of design research is to improve the way a design operates in practice.

Four earth and space science classes mainly composed of students from low-income households, in an urban middle school of 630 students in the northeast United States participated in this implementation study. The sample consisted of 83, eighth grade students from four classes with diverse ethnic backgrounds (67% Hispanic, 19% White, 13% Black, 1% Asian) and included six students with Individual Education Programs (IEPs). The students had no prior experience using geospatial technologies including Google Earth, remotely sensed satellite or aerial images, or GIS in their classroom curriculum. The school contains a large migratory population, with 20% of the students transferring to the school during the academic year. 19% of the students are learning English as a second language (ESL). Every teacher and student in the school has a laptop. The classroom contained wireless Internet access and an LCD projector that can interface with the teacher's laptop computer. The classroom teacher was proficient in technology use and had her own server Web space that was often used for instructional purposes.

Curricular Design

The educator/researcher met almost daily with the teacher to collaborate on the design and development of the unit for three weeks. To begin the process, a series of design principles were agreed upon to guide the development of the unit:

1. *Adapt existing curricular materials to align with the demand of the local classroom context*. We acknowledge that one instructional model or distinct set of learning activities may not accommodate every

learner, classroom teacher's pedagogical style, or classroom learning environment. Activity structures from available curricula, whether designed by commercial publishers or from developers of grant-funded projects vary significantly. We recognize that developers of such activities have an intended target audience and that audience may not have the same prerequisite skills or content background of our own classroom learners. In addition, such curricula may not take into consideration of curricular time constraints that are often placed on teachers who need to ensure that certain content is covered in an academic school year.

2. *Use motivating contexts to engage learners*. It is important to provide middle school learners with a motivating entry point to set the stage for their investigations. Using a locally relevant problem or real-life occurrence that a student can easily experience is important to engage students in learning (Bodzin and Shive 2004). Such motivating contexts provide students with reasons to want to learn more about a particular environmental issue such as land use change.

3. *Design activities to incorporate two main properties: scalability and portability*. Scalability refers to the need for the investigative experiences addressed by the learner to be small enough that they can derive conclusions in a reasonable length of time, but also of sufficient detail that in completing them will understand concepts that apply to larger and more complex environmental problems. Portability means the problems addressed in the activities should involve concepts and practices that apply to diverse locations and situations, allowing learners to extrapolate their derived understandings to problems other than those to which they were exposed (Bodzin and Anastasio 2006). Experiences should be structured in ways that allow students to see connections from local to global, between the specific cases and generalized settings in order to maximize educational value (Bednarz 2004).

4. *Promote spatial thinking skills with easy to use geospatial technologies tools*. Instructional activities should include easy to use tools to support spatial thinking and reasoning activities. We identified readily available remotely sensed aerial and satellite images from the Internet and Google Earth as tools to be used to support such learning. Remotely sensed images have been used in educational settings as tools

for learners to identify and interpret land cover features and view changes on the earth's surface over time (Huber 1983; Kirman and Nyitrai 1998; Klagges *et al*. 2002). Google Earth is a relatively new geospatial technology that is changing how people can interact with remotely sensed aerial and satellite images. Many scientists are currently using Google Earth to visualize data for studying a variety of environmental issues including sea ice distribution patterns and local weather phenomena (Butler 2006). Google Earth is a virtual globe that contains remotely sensed images taken by satellites and aircraft at different points in time. An easy-user interface enables one to observe an earth feature from any direction or angle. One can zoom in on many major urban areas where the resolution may be about 1 m/pixel, permitting users to identify roadways, buildings, vegetation, and small water bodies. In areas where such high resolution is not available, the resolution is typically 15 m/pixel, enabling users to identify physical features such as volcanoes, canyons, and ski slopes. Recently, Google Earth is being used by secondary classroom educators for virtual explorations of geologic features to enhance learner understandings of geologic processes (Fermann 2006; Stahley 2006).

We reviewed existing environmental issues-based curricula and resources related to land use change from a variety of peer-reviewed national databases including the Digital Library of Earth Systems Science Education (http://www.dlese.org), NASA (National Aeronautics and Space Administration) Educational Resources (http://education.nasa.gov), and local resources available at the Lehigh Environmental Initiative Web site (http://www.ei.lehigh.edu/). As we reviewed materials, we discussed how they promoted spatial thinking skills, took advantage of using geospatial technologies to promote learning, aligned to national science, technology, and geography reform initiatives, and provided learners with appropriately designed activities and resource provisions for investigating land use change and related environmental issues.

We identified a module titled "Human footprints on Earth as seen by NASA scientists" from the NASA/GENIP (Geography Education National Implementation Project) Mission Geography curriculum (http://missiongeography.org/) to use as a vehicle for initiating the design of our unit. This Mission Geography module contained curricular activities to investigate land use change primarily in urban areas using NASA satellite imagery. The module consists of four inter-related investigations. The activities use sound pedagogy to promote spatial thinking and involve the use of geographic skills to investigate real-world problems pertaining to human impacts on the environment (Bednarz and Butler 1999). The materials include instructional objectives, geography standards alignment (Geography Education Standards Project 1994), background content information, instructional procedures, student handouts, and embedded assessments that are formative in nature. The module's investigations are described in Table 1.

---------------------------INSERT TABLE 1 ABOUT HERE--------------------------------------

We discussed how to adapt the curricular materials to better accommodate the learning needs of the students. Our discussions included providing necessary prerequisite skills for interpreting remotely sensed images, providing additional content knowledge students would need to better understand how remotely sensed images are generated, exposing learners to additional examples of land use changes over time, and how to use features of Google Earth to better support the learning experience. We discussed the limitations of implementing the Mission Geography module as designed. It was decided that two main activities would not be used. The activity of interpreting day and night thermal images was perceived as being to difficult for the students to understand the main concepts. In addition, a quadrant mapping activity to highlight land use change in the Atlanta area would not be used due to the costs involved with preparing materials.

Our main implementation concerns included a lack of materials for our students to investigate how their own local area had changed over time and a lack of content background to understand how remotely sensed satellite images are created. We believed it was important for the students to understand the main processes of how these images were created using technology. We identified materials on the Earth System Science Education (ESSE) at Lehigh University Web site (http://www.ei.lehigh.edu/esse/) that sufficiently addressed these concerns. The site contained a content module on remote sensing that included Flash animations to illustrate the process of data processing and image generation and a case study that introduces learners to the application of remote sensing for the study of changing land use patterns using an example of farmland loss to urbanization in part of the students' main watershed area. An animated GIS map of land use coverages highlights temporal changes over time.

The issues of using some of the Mission Geography materials with students and identifying additional remotely sensed images to highlight land use changes over time in different urban areas of the world was of lesser concern. Some of the Mission Geography learning activities relied heavily on PDF versions of colored NASA satellite images with cited sources that were not present on the referenced Web sites. It wasn't financially feasible to produce numerous colored copies of materials for students to use. So materials had to be located on NASA and USGS Web sites and transferred to the teacher's classroom Web space for instructional use. The source Web site of Mission Geography's Rondonia images, EarthShots: Satellite Images of Environmental Change (http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents), contained additional remotely sensed image pairs that included background content highlighting land use changes due to urban growth in different parts of the world.

Learning outcomes for the instructional unit were developed. These included:

1. Identify features in remotely sensed images.
2. Describe land use changes over time using remotely sensed images.
3. Describe environmental changes that would take place if a new shopping mall would be located in our area.
4. Describe major changes in land use in our area from 1945 to today.

Implementation

An initial instructional sequence outline was developed for the unit and was modified many times while the curricular unit was implemented. The resulting unit was implemented for fourteen days in the classrooms. A one-week school break occurred after the sixth day. Table 2 lists the scope and sequence of the activities in the resulting instructional unit.

---------------------------INSERT TABLE 2 ABOUT HERE--------------------------------------

Research methods were embedded in the partnership that focused on student learning outcomes and how to best integrate geospatial tools including Google Earth and time-sequenced images in the classroom. The educator/researcher observed the classes as a participant observer each day. During class activities, the educator/researcher would question students individually and in small groups to determine how they were learning with the classroom activities. After the classes, the educator/researcher and the classroom teacher met to candidly discuss the day's lesson and share their perspectives about what worked, what did not work, what should be changed and why.

Student learning was measured with a summative assessment containing specific items aligned to the learning outcomes of the unit, analysis of the work that students completed throughout the unit, field observation notes, and responses to interview questions with select students while working with geospatial tools.

Integrating Google Earth

Google Earth was used multiple times throughout the unit for student investigations. When students used Google Earth, they were highly engaged in their instructional tasks and were very enthusiastic. A few minutes overview of the basic search and navigation tools was all that was needed to get students started in exploring the mad-made and natural features in the Madison Square Mall area in Huntsville, Alabama. The teacher used direct (highly organized, teacher-led) instruction to illustrate how to "fly to" different areas using name and zip code searches, how to zoom-in and out of an area, and tilt the landscape. Google Earth enabled the students to explore many in-depth details of the landscape by zooming in and out at different magnifications. Students were able to identify many more specific features than would have been possible using the 1994 ATLAS (Airborne Thermal/Visible Land Application Sensor) aerial image of the same area that was provided by the Mission Geography materials (see Appendix A, question 1). For example, using Google Earth, students identified a swimming pool embedded between two building sections next to the mall parking lot and inferred this was likely a hotel. Students were also able to zoom-in on the mall parking lot and identify individual trees, lampposts, and parked cars. Adjacent residential areas were explored and students noted the presence of tennis courts, swimming pools, and nearby fields that could be used for recreational purposes. Google Earth also provided students with a means to expand their explorations to nearby areas beyond the scope of the provided aerial image. Across the highway, students noted a business park area that contained buildings located around multiple ponds with walking trails. Open space areas next to the business park were also noted and provided opportunities to discuss issues of preserving open space in contrast to expanding businesses to this area.

An “Urban Sprawl” worksheet was developed to assist students in using Google Earth and NASA land use classification images of Atlanta to explore patterns of city development and guide learners to discover relationships among population growth, land use, and urban heat islands. Direct instruction was used to help develop student skills in using the Google Earth tools. Students began this activity by using the Google Earth “*Fly To*” feature to locate Atlanta and record its geographic coordinates. To determine the distance and direction from the students’ school to Atlanta, the “directions” tab of Google Earth was used to create a route map display. The students were then instructed to locate the CNN Center in the downtown Atlanta area using the search function. Once located, students were instructed to zoom-out and expand the area until they could locate an interstate highway. They were then told to turn on the “roads” layer. The “roads” layer displayed a road map overlay containing information for the viewing area, including major highways, county roads, and city streets. The resulting image displayed a dense pattern of urban streets surrounded by a semi-circle of a highway system. Students were then instructed to turn on the “3D Buildings” layer. Some geographic areas in the Google Earth database, including the downtown area of Atlanta displays simple 3D buildings. Students were shown how to zoom-in and tilt the image to explore the cityscape features from a perspective similar to that of a low flying helicopter. The teacher displayed to the class a Google Earth image that showed the major highways systems converging on the downtown Atlanta (see Figure 1) and then guided learners with instructions to replicate that image on their laptops. Coaching (structured questioning techniques) was used to assist students in identifying specific features and functions of the street and highway design of the downtown Atlanta area. The exaggerated 3D buildings of Google Earth emphasized the amount of concrete materials that were present in the city. Discussion ensued on how the absorption and resulting radiation of heat in the evenings from downtown Atlanta buildings and roads leads to the formation of an urban heat island. Cool spots that may result from the shadows of tall buildings were also noted.

---------------------------INSERT FIGURE 1 ABOUT HERE--------------------------------------

To investigate how the Atlanta area had changed over time, students accessed a time-lapse movie of a series of NASA classification maps of Atlanta land use for the years 1973, 1979, 1983, 1987, 1992, and 1997. Coaching was used to help students note that much forest area was being lost to urban areas. The environmental impacts due to loss of trees were discussed. Urban growth areas north of the city were noted to be more prolific than such areas to the south of the city. Population growth in Atlanta was discussed and the teacher introduced many talking points related to the recent population growth of the students' own area.

Students were then instructed to locate the Atlanta airport using Google Earth. They noticed that the size of the airport encompassed an area just as big as the downtown. Students commented that the pavement, runways, parking lots, and buildings of the Atlanta airport area were a very large hot spot. Coaching was used to help students identify and describe the patterns of the Atlanta area interstate highway system in the greater metropolitan area. The activity concluded with students describing accurately the relationships among factors that contribute to the formation of urban heat islands.

Using time-sequenced satellite imagery

Using time-sequenced satellite images of a particular area provided learners with opportunities to describe observable changes in conditions that occurred between those times. We observed that some students had much difficulty interpreting colored satellite images of areas that were not familiar to them. Even with direct instruction and coaching techniques, a few students had difficulty understanding what colors represented in false color images. For example, when viewing a primarily red colored 1992 Landsat satellite image of Rondonia, Brazil, a few students had difficulty understanding that red color represented a large forested area even after reading text from the USGS Web site stating that the red color represented a large vegetative area. It appeared that even after learning about how remotely sensed satellite images were produced from the "Remote Sensing" module, a few students still had difficulty understanding what the false color in the these images actually represented. In addition, some students had difficulty understanding that the fishbone patterns in the Rondonia image indicated the systemic cutting of forests. Much teacher guidance was needed to specifically point out how this image denoted clear-cutting practices in a forest.

Students had less difficulty interpreting the time-sequenced images from Las Vegas, Nevada and Riyadh, Saudi Arabia, areas that had experienced major population growth and expansion. We observed that the use of very structured, guided questions while pointing to specific features in the satellite images was effective in helping students understand specific reasons why land use pattern changed in these areas. For example, guiding questions about specific color differences in the Las Vegas Landsat 5 images helped students to understand what a non-developed desert area looked like in comparison to areas of intense residential development and golf courses. That said, students did have difficulties in identifying and understanding land cover features they were not familiar with such as circular objects in the Riyadh image that were indicating irrigation systems. In addition, students had difficulty understanding color variations in the Las Vegas images that represented differences between new and established neighborhood areas.

Assessment Results

An eight item, 30-point unit assessment was developed consisting of a combination of open-response and multiple-choice items that aligned to the unit's learning outcomes. Some items included analyzing data sets and graph interpretation to provide students with practice for similar items they would take later in the year on the state science assessment. Select items are listed in Appendix A. Eighty-three students completed the assessment at the end of the unit.

Criterion-based checklists were used to score each open-response item. The classroom teacher and the educator/researcher read and scored each student's assessment individually. After their individual assessments, the two met and compared their ratings of each question's score. If there was disagreement in the scoring of a response, the answer was reread and discussed until a unanimous consensus was reached for that particular score.

The mean score of the summative assessment was 23.47 with a standard deviation of 3.71. Scores ranged from 15 – 30 points, with a median of 24 and a mode of 27.

Fifty students (60.2%) were able to identify eight features successfully in a black and white remotely sensed aerial image of the Madison Square Mall area in Huntsville, Alabama (see Appendix A, question 1). Seventeen students (20.5%) identified 7 features, 12 students (14.5%) identified 6 features, 3 students (3.6%) identified 5 features, and one student (1.2%) identified 4 features. The eight most commonly identified features included trees (77 responses), highway (70 responses), mall (68 responses), parking lot (65 responses), park/field area (56 responses), buildings (51 responses), roads (47 responses), and homes (43 responses). Students also responded with specific features that could not have been identified without prior exploration with Google Earth. These included a strip mall, industrial park area, sidewalks, driveways, ponds, and a hotel. Consequently, some students also listed features that could not be viewed in the aerial image alone that were observed with Google Earth. These included cars and bushes. Seventy-one students (85.5%) correctly identified the mall as a “heat island” in the satellite image, and 57 students (68.7%) were able to correctly identify a “cool spot” in the mall parking lot. Only 21 students (25.3%) were able to articulate accurately that cools spots occur because they absorb less heat than the surrounding materials.

Almost half of the students (49.4%) provided an exemplary response, receiving all possible points, describing the types of environmental changes that would take place if a new shopping mall would be located in the students’ area (see Appendix A, question 2). Twenty-five students (30.1%) provided a proficient response, and 17 student responses (20.5%) were scored as below proficient. The most common environmental changes described included forest depletion (54 responses), habitat destruction (40 responses), wildlife affected through migration or mortality (27 responses), increase in pollution (26 responses), effects of sprawl including increases in population, residential development, and roads (25 responses), increase in area traffic (25 responses), and a slight increase in temperature due to heat island effects (24 responses).

Assessment results indicated that most students developed skills for understanding land use change in their area. Sixty-nine students (83.0%) accurately described a major change in a time sequence pair of satellite images of a nearby area showing agricultural land being converted into a residential area (See Appendix A, question 3). In addition, 65 students (78.3%) were able to sufficiently interpret a land cover graph of their geographic area, noting that urban areas have increased while agricultural areas and forest areas have decreased since 1945.

Discussion

A main purpose of this implementation study was to explore how to best integrate Google Earth, time-sequenced satellite imagery with other instructional resources to investigate ground cover and land use in a technology-enhanced middle school classroom of diverse learners. Our observations and findings revealed that specific instructional strategies and techniques appear to have assisted diverse learners in developing certain spatial thinking skills. Direct instruction was used to assist learners with determining location and assessing distances in Google Earth. The use of coaching with teacher-led questioning helped focus student attention to identify visual representations with Google Earth and with time-sequenced satellite images. During instruction, the teacher modeled how to think about analyzing land use patterns and demonstrated how to think through steps to classify observable image features so patterns could be more easily identified. Highly organized, teacher led instruction about specific observable features in remotely sensed images assisted students with identifying and comparing locations, comparing sizes of particular areas, recognizing land use patterns, and interpreting representations of land use characteristics in urban growth areas.

The results from the summative assessment and analysis of the work students completed during the unit revealed that many students acquired skills for identifying and interpreting features in remotely sensed images. Concepts of space that include distance and direction were facilitated when moving from one place to the next or when plotting direction pathways. Many students were able to identify distribution patterns of major land use types in urban areas. Using Google Earth, students were able to see how urbanization can dramatically alter a land surface that was once historically forest or farmland. This was noted during the exploration of the students' geographic area when the teacher was able to illustrate a pattern of how city and town clusters had spread into adjacent farmland areas.

Many students showed much interest and motivation when using Google Earth to investigate specific areas. It was observed that most students were very focused in their exploration tasks, especially when they sought to identify specific buildings and discover features in residential neighborhoods.

Enthusiasm was especially highly when learners used Google Earth to identify their homes and explore their neighborhoods. We think the use of this tool may have had an impact on the students' ability to remember physical features in and around the Madison Square Mall that they were able to recall three weeks later on the summative assessment.

Students perceived Google Earth to be beneficial for examining the landscape of a particular area and found the tool to be helpful in their learning activities. In interviews, some students stated that Google Earth was a useful way to explore Earth features. One student commented: "I liked it because it was more interesting." A student noting the tool set features said, "I learned better because I can move around and explore things better. Seeing the pop-up buildings and tilting the buildings on the computer helped me see things better." Another students stated, “Zooming-in on things helped me see it better.”

While interacting with Google Earth visualizations tend to grab students' attention, it is necessary to integrate this spatial tool into well-designed curricular learning activities. An advantage of our design partnership was being able to share common goals and perceptions of how students might use geospatial tools to enhance their learning. We were able to leverage our shared expertise to locate and review appropriate learning materials. We identified a suitable curriculum as a starting point to collaboratively design a prototype unit on land use change and located available resources to provide suitable content background for students to understand how remotely sensed satellite images are created. In designing the unit, we adapted existing materials to align with the demand of the local classroom context. We took advantage of motivating contexts to engage the students. For example, the initial investigation to examine a shopping mall provided an authentic context to capture the interest of the students. We identified and modified case studies to promote the integration of Google Earth into instruction. We believed that the Huntsville shopping mall and the Atlanta case studies would both be effective contexts for students to learn important concepts about the formation of urban heat islands and resulting environmental consequences. Our findings from our implementation study reveal that many students were able to apply these concepts later to their own local environment.

We found it challenging for some students to grasp the significance of spatial and temporal change in areas that had only a limited perspective. Students in the classroom struggle with content and activities when they do not have sufficient background knowledge to complete a particular task

(Kame'enui and Simmons 1998). This was quite evident when some students had difficulty understanding clear-cutting practices while examining time-sequenced images of Rondonia, and understanding the appearance of irrigation systems in Riyadh. This issue could be addressed in the future by providing more scaffolding and guidance in our instructional materials to highlight specific observational patterns in the images and also by enhancing the readability of the text from the USGS host Web site to be more appropriate for diverse middle school learners.

Conclusion and next steps

We view our design partnership as an effective means to create a prototype unit on land use change by adapting an existing curricular module with Google Earth, satellite and aerial images from NASA and USGS, and locally-based Web resources. Our design principles served as effective guidelines to create and modify instructional materials to support the development of students' spatial thinking skills with Google Earth and other remotely sensed images. We believe that the developed activities helped middle school students gain an appreciation for using geospatial technologies and their products for studying landscapes and investigating land use change.

Google Earth has much potential to be an effective tool for promoting certain spatial thinking skills with diverse middle school learners. Google Earth is a user-friendly tool for diverse students to use to investigate land use features. Using appropriate pedagogical strategies, it can be used effectively to highlight the impacts of human processes on land areas associated with developing urban areas. In many urban area locations, Google Earth resolution may be about 1 m/pixel, permitting users to identify specific detailed landscape features. This high-resolution image quality provides better opportunities for image interpretations of an area compared to that which is capable from time-sequenced images alone that may be of inferior quality, especially those taken before students were born.

In combination with time-sequenced images, Google Earth shows much potential to aid learners in observing land use changes over time. We found that remotely sensed aerial photographs and satellite images that are available on NASA and USGS Web sites at times might be limiting with regards to the area and resolution they display. Google Earth can be used in conjunction with these images to assist learners with an enhanced qualitative analysis of land use on the earth's surface that results due to urban development. Image displays in Google Earth when used with overlay features such as roads and 3D buildings in urban areas provides additional support for identifying and interpreting land cover features.

When using technology-based tools 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. We discovered that much structure is needed to guide students to observe spatial patterns in land use, especially in areas that were unfamiliar to them. In such cases, we recommend that instruction be clearly stated and the process of analyzing images be specifically modeled.

We now have a better insight to the difficulties diverse learners experienced when using the prototypes materials. We plan to modify certain activity structures for future classroom instruction. First, we intend on providing learners with additional exploration time with Google Earth in combination with time-sequenced images of their geographic area available from the ESSE Web site and other available remotely sensed images. We felt that curricular time constraints did not permit students to have enough time to explore their own vicinity during the prototype unit implementation. Additional exploration activities might provide learners with a better understanding of current urban sprawl issues that are resulting from commercial, industrial, and residential development in their geographic area. Second, more explicit instruction is needed to enhance learner understanding of main scientific concepts pertaining to heat absorption and cooling by different materials that are observed in landscapes. Third, we intend to adapt other instructional materials containing time-sequenced images of areas and land use practices that are unfamiliar to students. These materials would provide requisite content background and offer more guidance on interpreting images to help students understand diverse land use practices in different regions of the world. We believe locating and incorporating high-resolution images of these areas within Google Earth and using this resource in combination with time-sequenced images has the potential to assist learners with a better understanding of land use change in those areas. Lastly, we intend on enhancing the assessment to provide additional items to measure students' ability to identify, interpret and analyze remotely sensed satellite and aerial imagery. In the next iteration, the development of spatial thinking skills when using geospatial technologies and their products will be measured with a pretest-posttest comparison assessment strategy.

References

Baker, T. R., and S.W. Bednarz. 2003. Lessons learned from reviewing research in GIS education. *Journal of Geography* 102(6):231-233.

Barab, S., and K. Squire. 2004. Design-based research: Putting a stake in the ground. *Journal of Learning Sciences* 13(1):1-14.

Bednarz, S. W. and D. R. Butler. 1999. "Mission Geography" and the Use of Satellite Imagery in K-12 Geographic Education - A NASA - GENIP Partnership. *Geocarto International* 14 (4):85-90.

Bednarz, S. W. 2003. Nine Years On: Examining Implementation of the National Geography Standards. *Journal of Geography* 102(3):99-109.

Bednarz, S. W. 2004. Geographic information systems: A tool to support geography and environmental education? *GeoJournal* 60:191-199.

Bednarz, S. W., G. Acheson, and R.S. Bednarz. 2006. Maps and Map Learning in Social Studies. *Social Education* 70(7):398-404.

Bell, P., C.M. Hoadley, and M.C. Linn. 2004. Design-based research in education. In *Internet environments for science education*, ed. M.C. Linn, E.A. Davis, and P.Bell, pp. 73-85. Mahwah, NJ: Lawrence Erlbaum Associates.

Bodzin, A., and D. Anastasio. 2006. Using Web-based GIS For Earth and environmental systems education. *The Journal of Geoscience Education* 54(3): 295-300.

Bodzin, A., and L. Shive. 2004. Watershed Investigations. *Science Scope* 27(7):21-23.

Butler, D. 2006. The web-wide world. *Nature* 439:776-778.

Carrarra, A., and G. Fausto, eds. 1995. *Geographical Information Systems in Assessing Natural Hazards*. Boston: Kluwer Academic Publishers.

Cobb, P., J. Confrey, A. diSessa, R. Lehrer, and L. Schauble. 2003. Design experiments in educational research. *Educational Researcher* 32(1):9-13.

Cohen, D. K., S. W. Raudenbush, et. al. 2002. Resources, instruction, and research. In *Evidence Matters: Randomized Trials in Education Research*, ed. T. Boruch, and F. Mosteller, pp. 30-119. Washington, DC: Brookings Institute.

Collins, A., D. Joseph and K. Bielaczyc. 2004. Design research: Theoretical and methodological issues. *Journal of the Learning Sciences* 13(1):15-42.

Digital Library of Earth Systems Science Education. http://www.dlese.org.

Environmental Initiative at Lehigh University. Earth System Science Education at Lehigh University. http://www.ei.lehigh.edu/esse/.

Fermann, E.J. 2006. Google Earth-based lessons and lab activities for earth science classes. Poster presented at the 2006 Geological Society of America annual meeting, October, 22-25, in Philadelphia, PA.

Gersmehl, P.J., and C.A. Gersmehl. 2006. Wanted: A concise list of neurologically defensible and assessable spatial thinking skills. *Research in Geographic Education* 8:5-38.

Geography Education Standards Project. 1994. *Geography for life: National geography standards*. Washington DC: National Geographic Society.

Heit, M., A. Shortried, and H.D. Parker, eds. 1991. *GIS Applications in Natural Resources*. Fort Collins, CO: GIS World.

Huber, T.P. 1983. Remote sensing in environmental education. *The Journal of Environmental Education* 14: 33-36.

International Society for Technology in Education. 2000. *National educational technology standards for students: Connecting curriculum and technology.* Eugene, OR: International Society for Technology in Education.

Kame'enui, E. J., and D.C. Simmons, D. 1998. *Effective teaching strategies that accommodate diverse learners*. Upper Saddle River, NJ: Prentice Hall.

Kerski, J. 2003. The implementation and effectiveness of Geographic Information Systems technology and methods in secondary education. *Journal of Geography,* 102(3):128-137.

Kirman, J. M. and L. Nyitrai. 1998. The ability of sixth grade children to use Radarsat satellite images. *Journal of Geography* 97: 56-62.

Klagges, H., J. Harbor, and D. Shepardson. 2002. Teachers as learners examine land-use change in the local environment using remote sensing imagery. *Journal of Geography* 101(4): 137-143.

Laymon, C. 2003, July 23. Satellite remote sensing of land use change. *Directions Magazine*. http://www.directionsmag.com/article.php?article_id=365 (accessed May 1, 2007).

Loston, A. W., P. L. Steffen, and McGee, S. 2005. NASA education: Using inquiry in the classroom so that students see learning in a whole new light. *Journal of Science Education and Technology* 14(2):147-156.

McLaughlin, M.W., & D. Mitra. (2001). Theory-based change and change-based theory: Going deeper, going broader. *Journal of Educational Change 2*(4):301-323.

Meyer, J., J. Butterick, M. Olin, and Zack, G. (1999) GIS in the K-12 curriculum: A cautionary note. *Professional Geographer,* 51(4), 571-578.

National Aeronautics and Space Administration. NASA Educational Resources. http://education.nasa.gov.

National Aeronautics and Space Administration. NASA's El Niño Southern Oscillation project. http://education.gsfc.nasa.gov/ESSSProject/NewLessons/hydrosphere/ENSO/.

National Research Council. 1996. *The National Science Education Standards*. Washington, DC: National Academy Press.

National Research Council (2006). *Learning to think spatially: GIS as a support system in K-12 education*. Washington, DC: National Academy Press.

North American Association for Environmental Education. 2000. *Excellence in Environmental Education - Guidelines for Learning (K-12)*. Rock Springs, GA: North American Association for Environmental Education.

Patterson, M. W., K. Reeve, and D. Page, D. 2003. Integrating Geographic Information Systems into the secondary curricula. *Journal of Geography,* 102(6): 275-281.

Shear, L., P. Bell, and M.C. Linn. 2004. Partnership models: The case of the deformed frogs In *Internet environments for science education*, ed. M.C. Linn, E.A. Davis, and P.Bell, pp. 289-314. Mahwah, New Jersey: Lawrence Earlbaum Associates.

Stahley, T. (2006). Earth from Above. *The Science Teacher* 73(7):44-48.

U.S. Department of the Interior, U.S. Geological Survey. EarthShots: Satellite Images of Environmental Change. http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents.

Figure 1. Downtown Atlanta as seen with Google Earth. Roads and 3D Buildings are layered on the landscape.

Table 1. Description of investigations in the *Human footprints on Earth as seen by NASA scientists* Mission Geography module

Investigation	**Description**
1. Let's go to the mall	Introduces a case study of the spatial and environmental aspects of a shopping mall in Huntsville, Alabama. Students explore how a mall is spatially related to the location of other land use zoning areas (e.g. residential, commercial and recreational areas). Instructional materials prompt learners to think about advantages and disadvantages of having commercial and residential areas being located near a mall. Students then analyze a 1994 black and white NASA remotely sensed ATLAS (Advanced Terrestrial Land Applications Sensor) image to identify the mall and surrounding features.
2. What's hot at the mall?	Students investigate how natural landscapes change as a result of mall construction. They are introduced to the concept of hot spots – heat build-ups in areas that contain buildings and pavement. They then examine ATLAS thermal images of the Huntsville shopping mall to examine the heat differences between trees and pavement.
3. Why is the city hot?	The city of Atlanta, Georgia is used as a case study to investigate urban heat islands that result from sprawl and deforestation in urban environments. Students use series of land use classification maps of the Atlanta metropolitan area from 1973-1997 to identify changes of time.
4. Where in the world are major environmental changes?	Students are asked to consider significant environmental changes in different parts of the world. NASA satellite images of Rondonia, Brazil are used to provide a case study of deforestation as one type of a major environmental change.

Table 2. Instructional activity outline for the implemented land use change unit.

Day	Activity
1	Began *Let's go to the mall*. Discuss important land use features near a mall. Mission Geography materials used as intended.
2	Google Earth used to investigate human-built and natural features in the area surrounding the Madison Square Mall in Huntsville, Alabama.
3	Began *What's hot at the mall?* Satellite photos of Madison Square Mall accessed on teacher's Web site. Heat absorption of buildings and pavement emphasized. Urban heat island formations introduced.
4	Google Earth unstructured exploration of students' area. Developed guided worksheet on the "Electromagnetic Spectrum". NASA educational resources at http://imagers.gsfc.nasa.gov/ems/ used.
5	Developed "Urban Sprawl" worksheet used in place of *Why is the city hot?* materials. Emphasis on population growth and land use. Used Google Earth to locate and study Atlanta, Georgia. Land use change investigated with a NASA time-lapse movie of land use classification maps of Atlanta from http://svs.gsfc.nasa.gov/search/Keyword/Atlanta.html
6	Continued work on the "Urban Sprawl" worksheet. Google Earth exploration of Atlanta. Emphasis on developing the concept of an urban heat island.
7	Developed guided worksheet on "Remote Sensing". Pennsylvania Sprawl and Remote Sensing online modules from the ESSE Web site at Lehigh University (http://www.ei.lehigh.edu/esse/) used as content resources. Emphasis on using aerial photographs over time to detect land use change and how land use classification maps are developed.
8	Continued work on the "Remote Sensing" worksheet. Emphasis on land use change in a sub-basin of the students' watershed and understanding the main processes involved with remote sensing.
9	Concluded "Remote Sensing" worksheet. Tracked satellites at NASA Earth Observatory Web site (http://earthobservatory.nasa.gov/). Emphasis on satellites that house remote sensing instrumentation and data processing and image generation.
10	Began *Where in the world are major environmental changes?* Environmental changes and issues were discussed. Investigated land use changes in Rondonia, Brazil. Satellite images accessed online at http://edcwww.cr.usgs.gov/earthshots/slow/Rondonia/Rondonia
11	Land use change over time analysis with satellite images. Developed handouts for Riyadh, Saudi Arabia, the Mississippi River, and Las Vegas, Nevada. Google Earth and Web-based materials from USGS Earthshots (http://edcwww.cr.usgs.gov/earthshots/slow/tableofcontents) and NASA's El Niño Southern Oscillation project (http://education.gsfc.nasa.gov/ESSSProject/NewLessons/hydrosphere/ENSO/)
12	Concluded work on the land use change over time analysis activity.
13	Urban changes: Spread of a city activity sheet from Earth Systems Connections (http://www.earthsystemsconnections.com/). Students analyzed a data set of populations and land area of 16 urban areas between 1970 and 1990.
14	Summative assessment administered.

Appendix A. Select Summative Assessment Items

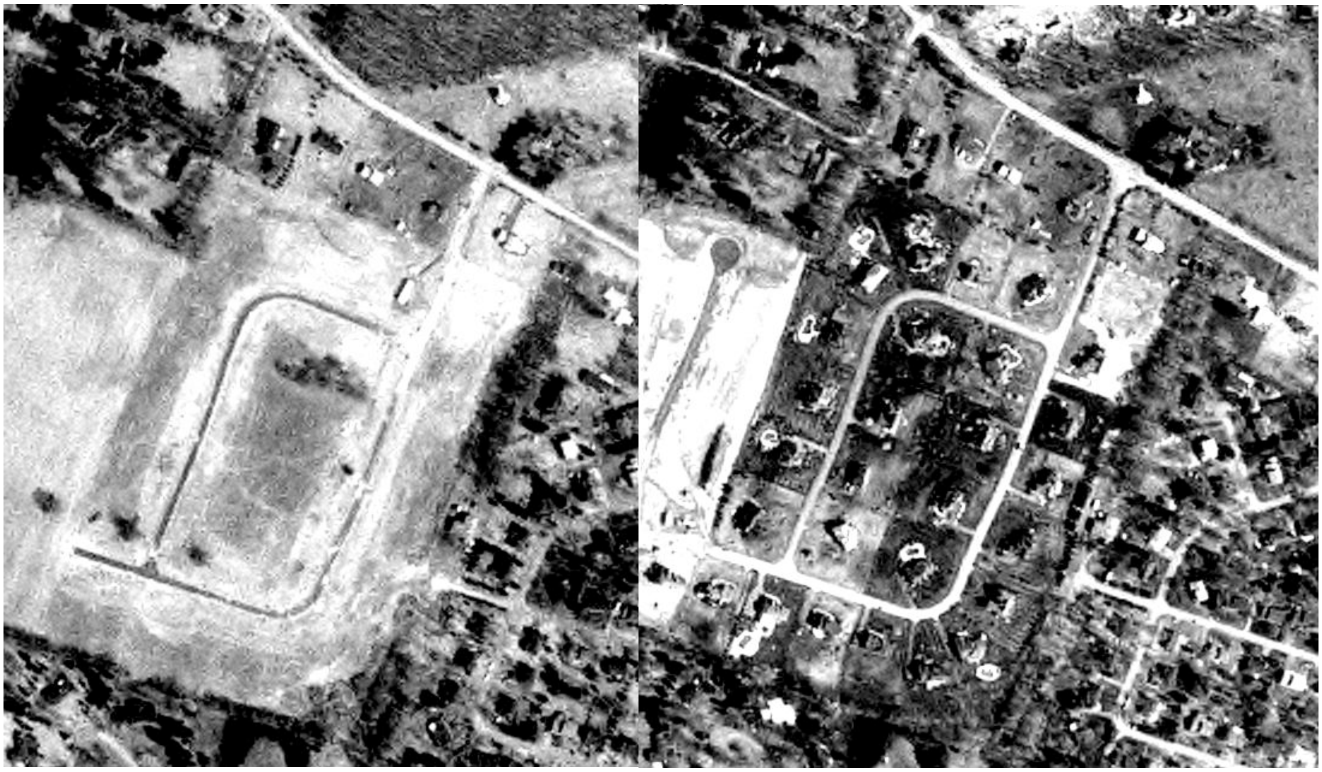
1a. Look at the above picture of Huntsville, Alabama, **list 8 features** that you can identify.

1b. Circle a "**heat island**" in this picture.

1c. Can you find any "cool spots" in the mall parking lot? Identify these cool spots and explain why they occur.

2. a. How would **building a mall on the top of South Mountain** where the Bethlehem Star is located, affect your local environment?

b. What **types of environmental changes** would take place?



3. The picture on the left was taken **5 years earlier** than the picture on the right. They are of exactly the **same area**. What do you think has changed over the 5 year interval? Select the best response below.

A. The pictures do not show any changes
B. A manmade lake was built here for recreation.
C. Agricultural land was developed for suburban homes.
D. A racecar speedway has been converted into an amusement park.