Designing Google Earth Activities for Learning Earth and Environmental Science

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Abstract

Web-based geospatial tools such as Google Earth and instructional resources integrated with appropriately designed instructional materials show great potential in promoting spatial thinking with diverse learners. This chapter describes two instructional middle school modules, *Environmental Issues: Land Use Change* and *Energy* that use Google Earth as a learning technology to promote understandings of earth and environmental science concepts. The design principles used to guide the development of the instruction are described. Recommendations for other curriculum developers interested in using Google Earth as a learning tool to foster spatial thinking skills are presented. The role of using educative curriculum materials as a form of professional development with Google Earth is discussed.

Designing Google Earth Activities for Learning Earth and Environmental Science

Geospatial technologies including geographic information systems (GIS), global positioning systems (GPS), Global Visualization Tools (such as Google Earth, WorldWind, ArcGIS Explorer, etc.), and Web-based 2D and 3D visualizations of Earth's landscapes, oceans and associated geographic data have become readily accessible, widely available, and more apparent in our daily lives than ever before. These tools allow for visualizing, mapping, organizing and analyzing multiple layers of georeferenced data. Geospatial technologies have proven to be a valuable tool for understanding the environment and of making responsible environmental decisions (Heit, et al. 1991; Carrarra & 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, & Bednarz, 2006).

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 and as a beneficial byproduct, environmentally literate citizens (Geography Education Standards Project, 1994). There have been many challenges, however, to implementing geospatial technologies in 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 curriculum materials that integrate geospatial technologies, and lack of time to develop learning experiences that integrate easily into existing school curricula (Meyer *et al*., 1999; Baker & Bednarz, 2003; Bednarz, 2003; Kerski, 2003; Patterson *et al*., 2003). While we acknowledge these barriers, new Web-based geospatial tools such as Google Earth and instructional resources integrated with appropriately designed instructional materials show much potential to be used with diverse learners to promote spatial thinking (Bodzin & Cirucci, in press).

We have developed middle school curriculum modules that use Google Earth as a primary tool to promote learning of earth and environmental science concepts as part of a school-based reform initiative that was initially supported by a NASA Explorer School grant. 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 and integrates a wide arrangement of remotely sensed and modeled images created with satellite and aircraft data at different points in time. Aerial photography and satellite image data have various resolutions and depending on the user's virtual angle above the Earth, one is able to observe an earth feature from any direction or angle with an easy to use interface. 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. A fully functioning version is free and available for Linux, Macintosh, and Windows operating systems (http://earth.google.com/intl/en/download-earth.html). The free version of Google Earth is currently being used in secondary classrooms for virtual explorations of geologic features to enhance learner understandings of geologic processes (Fermann, 2006; Stahley, 2006). While Google Earth is a less robust tool than GIS for performing spatial analysis, it is also a much less complex tool to learn. Its basic tool set features are easy to use, enabling teachers to adopt it in their classrooms without having to spend significant time learning many procedural steps as is common with GIS applications. As a result, Google Earth has been adopted in a variety of classroom contexts including urban elementary school learners to assist with inquiry-based investigations. (Bodzin, 2008). A variety of third party users release additional applications to enhance the effectiveness of the tool through an online Google Earth community (see http://earth.google.com/). Another version of Google Earth with enhanced features, such as 3D modeling tools, is available for commercial applications for a modest cost.

1 Curriculum Materials Design

Our curriculum modules are designed to align instructional materials and assessments with learning goals (Wiggins & McTighe, 2005). We use national and state standards (AAAS, 1993; Geography Education Standards Project, 1994; NRC, 1996) to provide guidelines for the science and geographic content in addition to the science inquiry and spatial skills that schools must focus on. The curricula include educative curriculum materials: that is, curriculum materials designed to promote teacher pedagogical content knowledge in addition to student learning (Davis & Krajcik, 2005). In designing such materials, curriculum developers and researchers recommend providing baseline instructional guidance for teachers, and implementation and adaptation guidance (Ball & Cohen, 1996; Davis and Krajcik, 2005). Educative curriculum materials also provide rationales for instructional decisions. If teachers understand the rationale behind a particular instructional recommendation, they may be more likely to enact the curriculum in keeping with the developers' intent (Davis & Varma, 2008).

Our materials are designed to promote teacher learning of spatial thinking skills that are geographic (see Gersmehl & Gersmehl, 2006) in addition to supporting teachers' learning of earth and environmental science subject matter (Schneider & Krajcik, 2002). The instructional materials are designed to provide additional supports for teachers who work with diverse learners. They include tools that enable access to learner ideas and attitudes that students bring to the classroom. The materials include an instructional design model (Appendix A) to provide teachers with an understanding of the rationale to how materials are intended to be used with classroom learners.

We use a design partnership model for the development of the materials that includes science educators, scientists, instructional designers, and classroom teachers. Our partnership model focuses on collaborative design and implementation of curricula in keeping with models of school-based reform (Shear *et al.,* 2004). Our partnership is a mechanism for leveraging 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). 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 & Mitra, 2001).

Each partner brings a unique perspective to the design and development of the modules and activities. The science educator provides the group with science-specific pedagogical content knowledge and knowledge of instructional designs and frameworks that were successfully used in past science curriculum projects for diverse learners (see for example Bodzin *et al*., 2007; Bodzin & Anastasio, 2006; Bodzin & Shive, 2004). The scientists contribute to the design process by ensuring that the content is current, valid, and essential to the students' enduring understandings of the discipline. The instructional designer assists the group with ensuring that the overall design framework conforms to proven educational technology instructional design theories such as incorporating facets of Gagné's nine significant events model (Gagné, Briggs, & Wager, 1992), Gardner's theory of multiple intelligences (Gardner, 1999), incorporating constructivist models to enhance the social process (Jonassen, 1994), and ensuring cognitive flexibility of learning, knowledge representation, and knowledge transfer (Spiro & Jehng, 1990). The classroom teacher keeps the group grounded in the fidelity of implementation realities of the classroom. During an iterative development process, the teacher helps the group to address many implementation issues including curriculum time and scheduling constraints (such as classroom time required state testing), designing instructional materials for students with special needs and below average reading abilities, and computer and network issues that commonly occur in school settings.

In this chapter, we first present an overview of two instructional middle school modules, the 4-week *Environmental Issues: Land Use Change* (http://www.ei.lehigh.edu/eli/luc/) unit and the 8-week *Energy* (http://www.ei.lehigh.edu/eli/energy/) unit. Both curricular units use Google Earth as an instructional learning tool and were developed as part of our partner NASA Explorer School's 8th grade science curriculum. Next, we describe a series of design principles that we use as a guide in the development of instructional activities to promote earth and environmental science learning. We include examples from *Land Use Change* and *Energy* to discuss how we incorporate our design principles into our learning activities. In our presentation of the design principles, we include recommendations for other curriculum developers interested in using Google Earth as a learning tool. We conclude the chapter with implications for the professional development of teachers who implement curriculum materials that use Google Earth as a learning tool.

2 Environmental Issues: Land Use Change

Urban area expansion and population growth through commercial, industrial, and residential development results in a loss of natural vegetation, agricultural lands, and open space (Alberti, 2005). For the first time in human history a majority of the world's population now resides in cities. 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 4-week *Land Use Change* module is designed to assist students in understanding land use change concepts including environmental issues that are typically associated with sprawl and development such as urban heat island effects, and to promote the learning of essential skills used in interpreting remotely sensed images. Urban heat islands occur as a result of increased heat production and diminished heat dissipation due to city structure. More solar energy is absorbed and retained creating a "hot spot" as compared to nearby suburban and rural areas that have more vegetation. To understand concepts involved in the formation of urban heat islands, students use Google Earth to investigate how shopping malls change natural environments. The module begins with a student investigation of the spatial and environmental aspects of a shopping mall in Huntsville, Alabama. Students learn to use basic elements of aerial photo interpretation (including tone, size, texture, pattern, shadow, site, and association) to aid in identifying objects in aerial photographs, enhancing their three dimensional visualization skills. Next, students use Google Earth to complete a geographical case study of Atlanta's urban heat island effects and the consequences of urban deforestation in the greater Atlanta area. In the instructional activities, students learn how communities can use certain heat island reduction strategies to reduce the impact of an urban heat island effect. They also interpret land use maps of the greater Atlanta area to understand environmental issues that are typically associated with sprawl and land development.

Student investigations continue with a case study of the Lehigh Valley area in Pennsylvania using Google Earth to identify various man-made and natural land features (Figure 1). Next, they compare the land-use types around five different shopping mall areas using Google Earth as they examine the significance of mall locations. Shopping malls use a lot of land and stand out on the landscape. They are large enough to appear on aerial photos and satellite images and contribute to heat island effects in an area. Malls affect other places in a community and encourage dependence on automobiles. Wherever malls are built, there are environmental consequences as vegetation and wildlife habitat is fragmented and lost. Shopping malls are found in large and small communities and are a part of everyday life for most middle school students in the United States. Studying mall locations helps learners examine changes in ecosystems that are associated with sprawl and development.

In the next learning activity, students use remotely sensed images to recognize land use patterns of diverse areas in our world. They examine and interpret time-sequenced satellite data and aerial photographs of urban areas to interpret geographic growth patterns. In addition, they examine landscape changes over time through analysis and interpretation of satellite data images and aerial photographs. By studying diverse areas, they learn about the nature and consequences of human–environment interactions.

Figure 1. Image from Google Earth displaying locations of an active limestone quarry (left pushpin) and an abandoned flooded quarry (right pushpin). The lake level in the abandoned quarry is the local groundwater table, pumping has lowered the groundwater table in the active quarry.

In the culminating activity, students recommend a plan for locating a new Wal-Mart Supercenter in the greater metropolitan Lehigh Valley area to have minimal impact on the environment. Students use Google Earth to analyze and evaluate features of different land areas for proposed development sites. Lastly, they develop a proposal to apply “smart growth” principles to their planning decisions and communicate their plan in a simulated planning commission meeting.

3 Energy

The 8-week *Energy* module takes advantage of geospatial learning tools including Google Earth and GIS to promote student understandings that there are many sources of energy to power society and they each have impacts on the environment. In the learning activities, students investigate the underlying physical science concepts pertaining to the production of energy from different sources, learn how energy is used for electricity production, and enhance their geography knowledge by investigating the spatial relationships of energy sources among our planet. Students also examine energy use and inefficient practices and consider ways to sustain the future of our environment with alternative energy sources. The learning activities address common student misconceptions and knowledge deficits about energy concepts. This section describes the learning activities that incorporate Google Earth to investigate renewable energy sources.

In the first renewable energy activity that uses Google Earth, students are presented with the driving question: *Where is the best place to locate a new solar power plant*? First, students locate and tour existing solar power plants around the world. They examine the ground cover area and measure perimeters of each solar power plant with the Google Earth measuring tool, thus become introduced to quantitative geospatial analysis. The investigation continues as students analyze newly planned solar power plant locations and a 30-year average world insolation dataset with MyWorld GIS to evaluate the suitability of the locations for construction.

Students learn about harnessing wind energy as they use Google Earth to investigate *Where is the best place to locate a new wind farm?* They view seven different wind farms around the world to examine land cover, topography, perimeter, and wind power classes at each location. In this activity, students determine the optimal characteristics of a location to develop a new wind farm. The activity continues by examining sixteen proposed wind farm locations in Pennsylvania using MyWorld GIS.

Students learn about tidal power as they explore locations with high tidal ranges with Google Earth. In the learning activity, they examine the funnel shapes of the Bay of Fundy (Figure 2), Severn Bay, and the Baltic Sea – areas with very large tidal ranges that make these locations advantageous for the placement of tidal power plants. Students then compare the water body shapes of these areas to those with low tidal ranges such as the Gulf of Mexico.

Figure 2. The Bay of Fundy. Image from Google Earth.

The next Google Earth activity has students examine and compare the characteristics of five different hydroelectric dams and their surrounding areas. Students examine the location of each dam, the height, and the dam capacity, then measure the width of the dam and distances from each dam to nearby population centers. The shape and size of each dam's reservoir is compared to the shape and size of the river on the downstream side of the dam (Figure 3). The activity continues as students use MyWorld GIS to query and examine features of the 1,184 most productive hydroelectric dams in the United States. The activity concludes as students use Google Earth to investigate specific features of five major Pennsylvania hydroelectric facilities on the Allegheny and Susquehanna Rivers, including a pumped storage generating station facility.

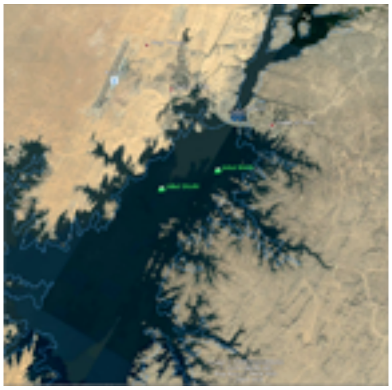

Figure 3. The upstream Nile reservoir and downstream Nile River separated by the Aswan Dam. Image from Google Earth.

The final renewable energy resource activity, *Where is the best place to locate a geothermal power plant?* has students use Google Earth to explore "hot Earth" areas in Iceland and in the United States. Students use Google Earth to identify Earth features that are evident of geothermal activity. These include locations of geysers, fumaroles, natural hot spring areas such as the Blue Lagoon in Iceland (Figure 4), lava fields, volcanic mountain features, and a chain of volcanic islands that marks the boundary between the Pacific and North American tectonic plates. Students 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.

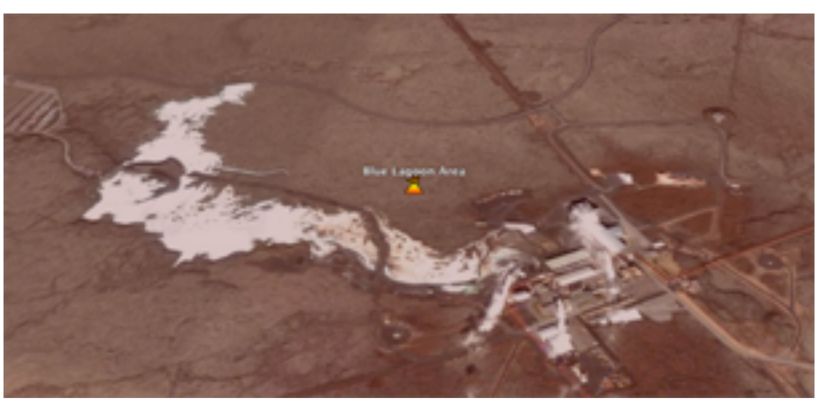

Figure 4. The Blue Lagoon area and Svartsengi geothermal power plant in Iceland. Image taken from Google Earth.

4 Design Principles

Design principles speak to the pragmatic aspects of practice while also informing theories of learning (Bell, Hoadley, & Linn, 2004). Like other design principles used in education (Kali, 2006), our principles are designed to focus not only on local classroom implementation, but also for more generalized classroom learning environments. These design principles are a product of a series of design-based research studies conducted in diverse educational settings over the past six years whose primary aim has been to promote innovation in earth and environmental science learning. It is our intent that the ideas presented in this section will serve as recommendations to curriculum developers who intend to use Google Earth in their design and development work.

1. Design curriculum materials to align with the demand of classroom contexts. Schools across the USA have made significant investments in technology such as high-bandwidth wireless networks and widely available laptop computers in classroom instructional settings. 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 educator-developers 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 other classroom learners. In addition, such curricula may not take into consideration teacher time constraints on curriculum implementation and mandated academic year content coverage. We develop our learning activities in ways that teachers may customize the instructional sequence and still meet the learning goals of the units. We incorporate design features in instructional materials so that low-level readers and low-ability students can understand scientific concepts and processes in addition to learners whose cognitive abilities are at or above the intended grade level. For example, we provide animations and images on many content Web pages to help learners visualize scientific concepts that occur over time such as the formation of fossil fuels. In addition, we design activities to promote active learning with Google Earth to promote high learner engagement with this learning tool.

2. 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 be of sufficient detail that by completing them, the students will make connections to larger and more complex environmental problems. Portability means the problems addressed in the activities should involve concepts and practices that are applicable to diverse locations and situations, allowing learners to extrapolate their derived understandings to problems other than those to which they were exposed (Bodzin & Anastasio, 2006). We structure learning experiences in ways that allow students to see connections from local to global, and between the specific cases and generalized settings in order to maximize educational value (Bednarz, 2004). For example, in *Land Use Change*, a case study of a shopping mall area in Huntsville is used to introduce students to urban heat island effects. The concepts learned are then later applied to examining the land uses and infrastructures of shopping mall areas in the greater Lehigh Valley area. The understandings gained from these activities are then later applied to finding a location for a new Wal-Mart Supercenter that will have minimal impact on the environment.

3. 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 & Shive, 2004). Such motivating contexts, such as examining a shopping mall environment – a location where middle school age students often spend their free time - provide students with reasons to want to learn more about a particular environmental issue such as how new development impacts land use change.

4. Provide personally relevant and meaningful examples. To make earth and environmental science learning accessible, we seek out and include examples that are personally relevant to students. By including issues pertaining to students' everyday experiences, we make science learning meaningful and relevant. In our implementation studies, we have found that students become more motivated to understand environmental issues when they recognize that the issues involved are directly connected to their daily lives. In *Land Use Change*, we have students use Google Earth to examine land features in their community and consider the environmental impacts of a new building construction project in their area. In *Energy*, the use of Google Earth to analyze nearby area locations for placing renewable energy power plants provides learners with a meaningful context for considering the environmental impacts of these new facilities.

5. Promote spatial thinking skills with easy to use geospatial learning technologies.

Instructional activities should include easy to use tools to support spatial thinking and reasoning activities. We identify readily available remotely sensed aerial and satellite images from 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 & Nyitrai, 1998; Klagges *et al*., 2002). We compose screen placemark images at specific sizes and scales to help learners understand the scale and spatial distribution of Earth features and guide learner attention by automatically delivering sequential image examples that reinforce the educational concepts. For example, in a MyWorld GIS investigation of hydroelectric power dams, we start nationally then zoom to Pennsylvania, and finally the Susquehanna River. Then we sequence a Google Earth exploration of energy generating hydro and nuclear power plants on the same river, bringing the students to their home region and recognizable geography. Our materials instruct students and teachers to display certain layers, such as the *Terrain* layer to emphasize natural geographic features such as mountain ranges and canyons. In addition, we develop files using Google Earth tools such as polygons and image overlays to assist students with understanding the spatial relationship among different features. For example, in *Energy*, we created colored polygons to enable learners to see greater metropolitan areas in the northwest USA.

6. Design image representations that illustrate visual aspects of scientific knowledge. Earth scientists have years of training and experience with recognizing salient information in visual material. For example, a geologist is more likely to identify prominent information in a satellite image of a volcanic mountain area than a non-scientist. Yet, visualizations can distract learners rather than encourage understanding. We use Google Earth to take advantage of a scientist's craft by designing Google Earth images that clearly display aspects of scientific understanding. For example, when one uses the Google Earth search feature to observe Mt. Fuji, the resulting image display does not prominently illustrate key features that identify Mt. Fuji as a volcanic mountain (Figure 5, left image). When we design our placemark images, we take advantage of the ability to resize, rotate, and adjust the angle of the image to provide learners with an initial image display that highlights prominent physical features. This helps novice learners to better understand the connection between Earth and environmental processes and the landscape. For example, we created the right image on Figure 5 to enhance the prominence of the features that allow a trained eye to conclude the image is of a volcano. The salient observations include that this is a cone shaped mountain rising above a surrounding plain. The radiating gullies confirm the cone shape. The snow line on the flanks support the conclusion that the feature has a high altitude and the numerous switchbacks in the flanking roads suggest the feature is steep. The tilted image better shows the crater depression on the crest. When taken together the crater-topped, steep, high, conical mountain is correctly interpreted to be a volcano, a characteristic of empirical science inquiry.

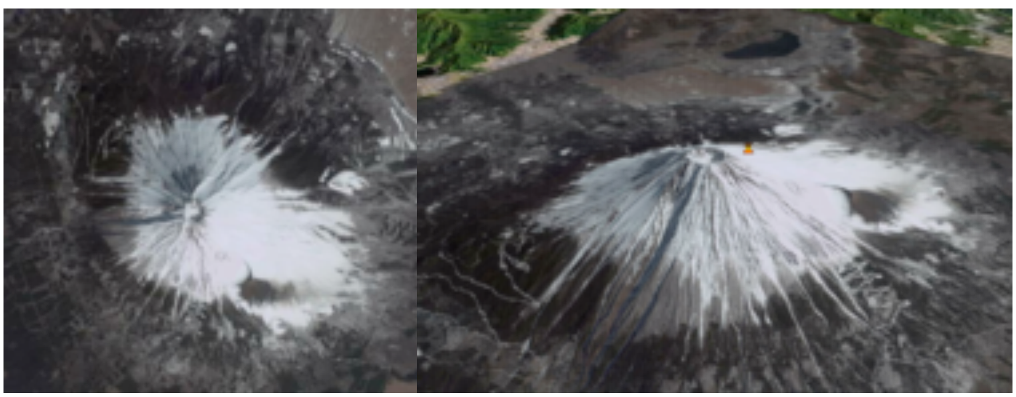

Figure 5. The left image shows Mt. Fuji as displayed with the Google Earth search feature. The right image is created to display prominent volcanic features by tilting the viewer's perspective.

7. Develop curriculum materials to better accommodate the learning needs of diverse students. Today's classrooms are quite diverse with learners of varied cognitive abilities, language skills, and special learning needs. We incorporate design features in our instructional materials to accommodate varied learning needs. We reduce the complexity of examples and visualizations by eliminating details that may distract learners from understanding the main concepts. In our instructional materials, we keep language simple and use graphical features in the instructional materials to help learners understand content as well as procedures for using geospatial learning tools. For example, Figure 6 shows how large numbered red arrows are added to a screen capture of the *layers* window of Google Earth to help students understand image display procedures. Bold and italicized text fonts are used to draw learners' attention to key words in the procedure.

Step 2: Turn on the Populated Places and Terrain layers.

a. In the ***Layers*** window (lower left panel), click the arrow to the left of ***Borders and Labels*** (see arrow #1 below).
b. Click the box to the left of ***Populated Places*** to **place a checkmark** in the box. (see arrow #2 below).
c. Click the box to the left of ***Terrain*** to **place a checkmark** in the box (see arrow #3 below).

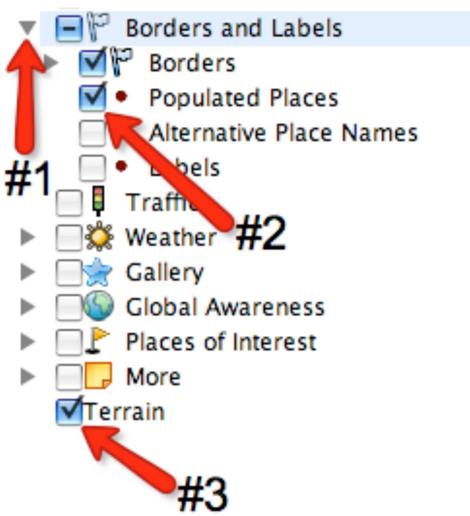

Figure 6. Google Earth procedure from the *Exploring Hydroelectric Dams with Google Earth* activity that provides graphical features and specialized text font.

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8. Scaffold students to explain their ideas.

Many students have problems being successful with open-ended investigations and complex activities where data are analyzed and evidence is carefully considered to formulate conclusions. We design materials with embedded prompts in the learning activities to help students focus their observations. Such prompts help learners articulate their thoughts, and think critically about observed phenomena. Table 1 includes some examples of prompts used in the *Exploring Hydroelectric Dams with Google Earth* activity designed to help learners examine and think about features of hydroelectric power dams. The prompts in Table 1 are designed to help students focus on key features of dams and the area surrounding them such as reservoir shape and size and proximity to populated areas.

Table 1.

Select prompts used in the *Exploring Hydroelectric Dams with Google Earth* activity.

- Do all dams have the same **shape**? Do all dams have the same **length**? Do all the dams have the same **height?** What do they look like?
- Is the **area surrounding** each dam similar or different? What does the area around each dam look like?
- Why do you think dams are built on rivers?
- What are the **advantages** of building a dam near a **large population area**?
- Which dams were built **furthest away** from large population areas? Why do you think these dams were built in these locations?
- What does the river look like on each side of the dam? How are the **shape** and **size** of the reservoir different from the shape and size of the river on the downstream side of the dam? Is the water area larger and wider on one side of the dam? By looking at which side of the dam has a larger body of water, can you tell which way the river flows? Remember the reservoir is located on the upstream side of the dam. Water flows downstream.
- What are some **advantages** of having one side of the dam contain a **much larger volume of water** than the other side?

9. Use icons that portray the real-world concept. Google Earth provides different icons that can be used as placemarks, and it also allows for using custom icons. Instead of using the default pushpin, we use icons (images) that depict the concepts being learned. This might help the learners to form an association between the icon and the concept it represents which may enhance recall. In Figure 7, for example, we used the sun icon to put placemarks at locations of solar power plants and the water icon to put placemarks at locations of hydroelectric dams. This may help learners recall that solar energy comes from the sun and hydroelectricity comes from the force of moving water. According to Paivio (1971), images act as mediators in learning and memory tasks, and can be amazingly effective as memory aids.

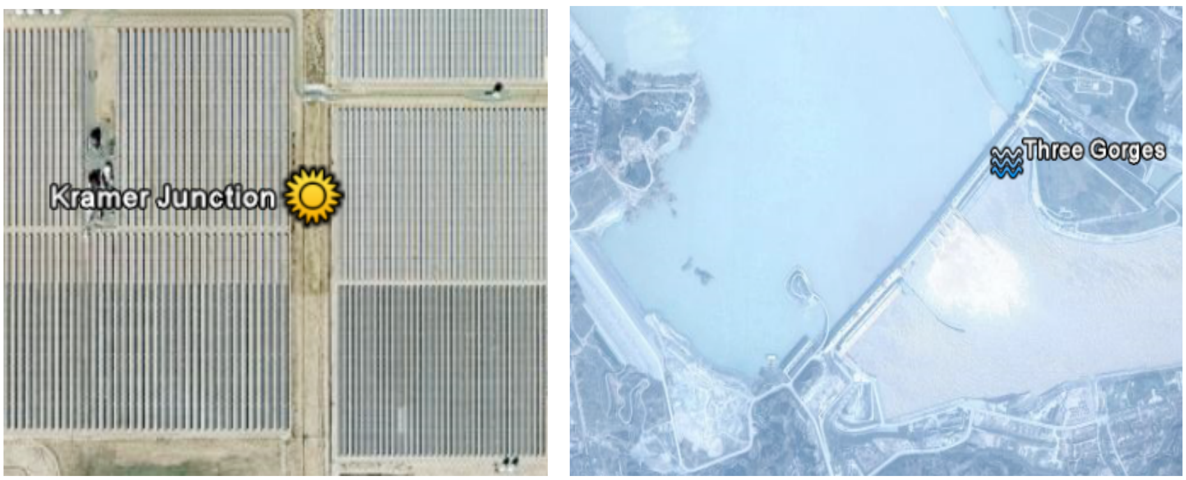

Figure 7. The sun icon was used as a placemark at the Kramer Junction solar power plant in the left image. The water icon was used as a placemark at the Three Gorges hydroelectric dam in the right image. Images from Google Earth.

5 Educative Curriculum Materials as a Form of Professional Development

As discussed in Chapter 14, teacher professional development is highly effective when designed to accompany particular curriculum materials. We contend that the use of educative curriculum materials in and of themselves provide a form of professional development since they include designs to promote teacher learning and support teacher decision-making for implementing curriculum materials. These materials may be used independently or with other forums for teacher learning such as face-to-face or Web-based professional development experiences. Remillard (2000) describes using curricular materials to "speak to" teachers about rationales behind instructional decisions. Since the classroom teacher is the agent who ultimately decides and structures what is to be taught educative curriculum materials should help teachers to understand how Google Earth fits contextually within the instructional design of the curriculum. For example, in both the *Land Use Change* and *Energy* curricula, Google Earth is used to explore concepts through geospatial-supported investigations. Consequently, our instructional materials are designed to help teachers learn how image displays in Google Earth, when used with overlay features such as terrain, roads, and 3-D buildings in urban areas, provide support for students to identify and interpret land-cover features.

Educative curricular materials can be used to help teachers promote spatial thinking skills. When using Google Earth 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. Much structure is needed to guide students to observe spatial patterns in land use, especially in areas that are unfamiliar to them. Furthermore, unlike adults who have developed better locational skills as automobile drivers, middle school student typically have a myopic view of their world, so spatial locations are more difficult for them to comprehend. Our Google Earth activities allow learners to view their world close up as they normally encounter it and to pan back to see relationships between things they only know previously in isolation. In our curriculum materials, we provide instructional recommendations encouraging teachers to model the processes of analyzing and interpreting such relationships to their students. In addition, we design educative curricular materials to help teachers provide appropriate scaffolds to students when they examine images with different land use types, especially in areas that include environmental contexts that are unfamiliar to students.

6 Final Thoughts

Google Earth, when accompanied with appropriately designed learning and support materials, can be used as an effective tool for learning about the Earth and the environment. In educational learning environments, Google Earth can be used to foster certain spatial thinking skills with diverse learners. Google Earth is a freely available, powerful, user-friendly tool that can be used to examine and investigate natural and man-made features on the Earth's surface, helping learners to visualize and understand processes that occur on our planet. Working together, science educators, scientists, designers, and classroom practitioners can design and develop instructional materials that present earth and environmental content and concepts in appropriate and engaging ways for learners.

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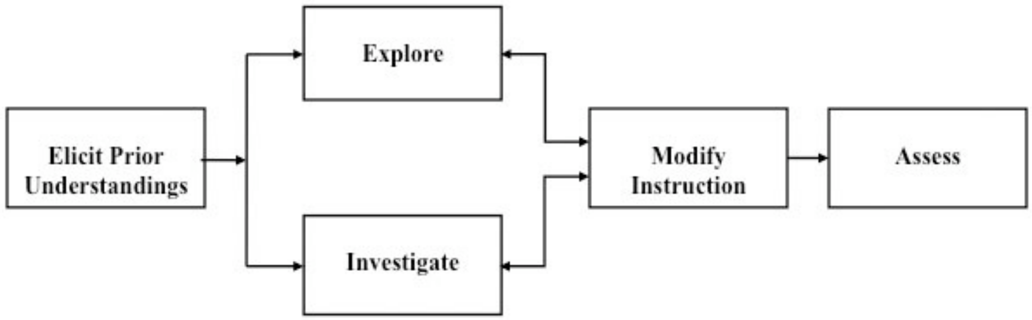
Appendix A. Energy Unit Instructional Design Model



Elicit Prior Understandings.
At the beginning of the unit, the teacher evaluates what students know through a concept map, content knowledge, and attitude and behavior pretests.

Explore and Investigate.
Students explore and investigate concepts through geospatial-supported investigations, laboratory experiments, and other curricular materials to help them acquire desired knowledge, skills, and attitudes.

Modify Instruction.
The teacher adjusts instruction as needed based on students' responses to the learning activities (formative assessment).

Assess.
At the end of the unit, the teacher evaluates students through their completed artifacts and summative assessment. These include energy policy presentations, concept maps, and content knowledge, attitude, and behavior posttests.