

Designing for Geospatial Information Technologies  
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Geospatial information technologies such as geographic information systems (GIS), global positioning systems (GPS), and global visualization tools (for example, Google Earth, and WorldWind) are increasingly being incorporated in the classrooms to promote student problem solving, data analysis, and critical thinking. These tools allow for visualizing, mapping, organizing, and analyzing multiple layers of geographically referenced information (Broda & Baxter, 2002; DeMers, 2005; ESRI, 1993). Baker and Case (2000) suggested GIS may be a promising educational technology for developing contextually rich student learning and Kerski (2008) noted the use of GIS in education is increasingly viewed as facilitating active learning to engage students in critical thinking (see also Bull & Mason, 1998; Ramirez, 1995; Sanders, Kajs & Crawford, 2002). Bednarz and Audet (1999) agreed, suggesting a GIS may provide an authentic, inquiry-based learning environment for the K-12 classroom. In fact, K-12 educators are harnessing the power of GIS technology to support standards-based math, science, geography, and social studies curricula (Holzberg, 2006). There is, however, a paucity of research on implementing GIS in science classrooms.

Keiper (1998) identified as barriers to implementing a GIS in the classroom lack of a specific relevant curriculum that includes a GIS, student frustration with the technology, and teachers' lack of a pedagogical style conducive to using a GIS (see also Sanders et al., 2002). According to Baker and Case (2000), many teachers find time a limiting factor in using a GIS because they need time on their own to learn and practice using the GIS and then need quite a bit of time to teach students to use the software. It appears using a GIS in the classroom may make some unusual cognitive demands on the learners and demands on teachers' limited instructional time.

### Purpose of the Study

Given the paucity of research on implementing GIS in science classrooms and the promising nature of GIS to foster science inquiry, our goal was to determine how a Web-based module might best be designed and developed to enhance science inquiry supported by GIS with classes of eighth-grade students.

### Design Conditions and Limitations

There were five conditions and limitations that shaped how we designed our materials and what instructional approaches we are able to employ.

1. The students in our study were of diverse ethnic backgrounds with 19% of them being non-native English speakers. Eighty-three students (41%) received lower scores on the 2008 state standardized reading skills test. Thus, a large portion of our sample would be classified as low-level readers.
2. One hundred and ninety-eight students (78%) received lower scores on the 2008 state standardized test of science knowledge. Thus, more than three quarters of these students would be classified as low-level science learners.

3. The school had adopted the Understanding by Design instructional development process model for its new science curriculum. We needed, therefore, to make sure that whatever we designed also conformed to the requirements of this model.
4. The science content was developed by science education experts and earth and environmental science experts who were part of the larger design team. As with all design projects, the instructional designer's role was to organize, sequence, and design science instruction, not the content. The instruction was to be completed in eight weeks and all developed materials had to be reviewed and approved by the design team.
5. The instructional unit was to be supported by My World GIS. The students and the teacher did not have experience using this particular GIS software. They were going to use My World GIS for the first time.

### Selected Instructional Design Theories

The theories that guided us in the design process include behaviorism, constructivism, and inquiry teaching. We chose the behaviorist theory because the population of students with which the study was to be conducted is one that research suggests is likely to benefit from direct instruction and extensive practice, two behaviorist approaches (Gersten, Keating, & Becker, 1988). In addition, behaviorists tend to emphasize correct responses and we were concerned that the students in our study would be measured against state standardized tests that employ behaviorist assessment techniques almost exclusively. We employed many instructional practices classified as behaviorist (for syntheses of such practices, see Bugelski, 1971 and Snelbecker, 1974). We chose the constructivist theory because we wanted students to modify and refine what they already know and collaborate on performing tasks as they learned from one another. We used many instructional practices deriving from constructivism (for syntheses, see Bednar, Cunningham, Duffy & Perry, 1992; Duffy & Jonassen, 1992; Honebein, 1996; Knuth & Cunningham, 1993; and Savery & Duffy, 1996). We chose Collins and Stevens' (1983) expression of the theory of inquiry teaching because we wanted students to engage with hands-on activities and use evidence to justify their explanations just like scientists do. Further, scientific inquiry is the central tenet of science education reform.

### Selected Instructional Models

We used four instructional development process models and three instructional design models to design instruction. Instructional development process models describe the phases/stages of designing and developing instruction, while instructional design models provide steps to guide designers organize, structure, and sequence instruction. Designers use instructional design models to make decisions about how content should be sequenced, how to use overviews and examples, how to practice, and how to assess learning.

#### Instructional Development Process Models

The first instructional development model we chose was the generic ADDIE model. ADDIE is an acronym for Analyze, Design, Develop, Implement, and Evaluate (Learning

Theories Knowledgebase, 2008). We classified the other three models according to how they mapped to the ADDIE model. The second model was the Dick, Carey, and Carey (2005) model which breaks ADDIE's basic five phases into nine stages. A phase may contain one or more stages and stages break down phases into more specific actions and provide more guidance on how to design. Further, the Dick, Carey and Carey model makes clear that the process is iterative; that is, a designer goes back to any of the stages of design or development to make revisions. Although the model specifies sequenced stages, it recognizes explicitly that many design processes are complementary and may occur near simultaneously. The third model we used was Wiggins and McTighe's (1998) Understanding by Design model that focuses on a topic's enduring understandings. Enduring understandings refer to the big and important ideas that the teacher wants the students to comprehend and retain. The authors contended that "by having students encounter big ideas in ways that provoke and connect to students' interests, we increase the likelihood of student engagement and sustained inquiry" (p. 11). Our fourth model was Keller's (1983) ARCS motivation model that focuses on enhancing student motivation. ARCS is an acronym for Attention, Relevance, Confidence, and Satisfaction. Given that the learners were low-level science learners, sustaining their motivation was crucial for their success in this unit.

### Instructional Design Models

We chose three instructional design models to match the theories that we used. For the behaviorist instructional model, we selected Gagné's (1977) Nine Significant Events model because it represents a sequence many effective teachers use in direct instruction. A constructivist model seemed well suited to this project because of the open-ended nature of the learning tasks and activities. We chose two constructivist design models: Jonassen's (1999) model for designing constructivist learning environments and Black and McClintock's (1996) interpretation construction (ICON) model. These two models appeared well matched to the content and target audience. Under inquiry teaching, we used three inquiry models: Bybee et al's (1989) 5E model that has been used over the years to design instruction; Eisenkraft's (2003) 7E model that adds two steps to the 5E model; and the National Research Council's ([NRC], 2000) Five Essential Features model that specifically applies to science.

### Derived Instructional Model

As a result of our analyses of the various design models, we derived an instructional model and three sub-models for teachers to follow and we developed materials that fit our derived model and its sub-models. The larger instructional model has four major steps, the second of which represents presentation of all types of instructional content and incorporates our three sub-models. The three sub-models are unified under the larger model and they present models for the presentation of content, for computer-supported activities, and for laboratory activities. The steps of our instructional model (and sub-models) are listed below and explained in the paragraphs that follow.

1. Confirm learners have necessary background.
  - 1.1 Administer content knowledge pretest.
  - 1.2 Administer attitude towards science and technology pretest.
  - 1.3 Elicit and discuss prior understandings of unit concepts aloud.
  - 1.4 Elicit additions to the concept map independently.
  - 1.5 Identify misconceptions from student responses.
2. Present instruction using the appropriate model.
  - 2.1 Instructional model for content presentation
    - 2.1.1 Elicit prior understandings of lesson concepts.
    - 2.1.2 Gain and sustain learners' attention.
    - 2.1.3 Tell learners the objectives.
    - 2.1.4 Stimulate recall of prerequisite learning.
    - 2.1.5 Explain content.
    - 2.1.6 Illustrate content.
    - 2.1.7 Elicit answers to specific questions on students' worksheets.
    - 2.1.8 Solicit some responses from students' worksheets and provide feedback aloud.
    - 2.1.9 Review content.
  - 2.2 Instructional model for computer-supported activities
    - 2.2.1 Elicit prior understandings of lesson concepts.
    - 2.2.2 Present authentic task.
    - 2.2.3 Model task.
    - 2.2.4 Provide worked example.
    - 2.2.5 Ask learners to perform task.
    - 2.2.6 Scaffold task.
    - 2.2.7 Ask learners additional questions to elaborate task.
    - 2.2.8 Review activity concepts.
  - 2.3 Instructional model for laboratory activities
    - 2.3.1 Elicit prior understandings of lesson concepts.
    - 2.3.2 Present authentic task.
    - 2.3.3 Form student groups.
    - 2.3.4 Model task.
    - 2.3.5 Ask students to make predictions.
    - 2.3.6 Ask group members to collaborate on task.
    - 2.3.7 Have students make observations.
    - 2.3.8 Have students use evidence to form explanations.
    - 2.3.9 Have students evaluate explanations and draw conclusions.
    - 2.3.10 Have students share and justify results.
    - 2.3.11 Address misconceptions.
    - 2.3.12 Ask learners to perform extension tasks.
    - 2.3.13 Review activity concepts.
3. Confirm instruction is meeting goals and objectives.
  - 3.1 Ask questions aloud and respond to student answers.
  - 3.2 Solicit and respond to student questions.

- 3.3 Check students' worksheet responses aloud.
  - 3.4 Provide feedback aloud.
  - 3.5 Have students add new ideas to their concept maps.
  - 3.6 Adjust instruction to meet learners' needs.
4. Confirm learners have acquired desired knowledge, skills, and attitudes.
    - 4.1 Assess culminating activity.
    - 4.2 Assess concept map.
    - 4.3 Administer and analyze content knowledge posttest.
    - 4.4 Administer and analyze attitude towards science and technology posttest.

Step 1 is based on Dick, Carey and Carey's "identifying and analyzing entry behaviors and learner characteristics," Eisenkraft's first E, elicit, and Jonassen's constructivist step of providing knowledge representation tools.

In Steps 1.1 and 1.2, the teacher administers a content knowledge and attitude and behavior pretests to determine what knowledge, skills, and behaviors students bring to the learning task.

In Step 1.3, the teacher uses oral questions to identify what students know about energy (for example, "What is energy?" or "Where does energy come from?"). The teacher then discusses learners' responses.

In Step 1.4, the teacher asks students to brainstorm on their own, listing everything they know about energy and then to add to their individual concept maps. Students add ideas to their concept maps periodically as they complete the unit. The goal is for learners to construct their own relationships among concepts as they learn them.

In Step 1.5, the teacher addresses misconceptions learners may have about unit concepts. It is likely the teacher will examine student responses to the pretests outside of class to check for students' misconceptions and decide which areas to address and clarify when teaching.

As noted earlier, Step 2 encompasses three sub-models; the first for presenting content, the second for doing computer-supported activities, and the third for doing laboratory activities. The instructional sub-model for content presentation comes first because students need to acquire and understand science content before they can practice. The instructional sub-model for the computer-supported activities is presented second because the unit is primarily based on using GIS to support science teaching and learning. Computer-supported activities include using the GIS software, Google Earth, and spreadsheets to perform tasks. The content and activities are organized around Wiggins and McTighe's (2005) framework of focusing on big ideas. Laboratory activities augment GIS activities. Teachers employ the appropriate sub-model—or a combination of sub-models—depending on the nature of the activity for a class. The three instructional sub-models are discussed below.

#### Instructional model for presenting content

Step 2.1.1 matches Dick, Carey and Carey's "identifying and analyzing entry behaviors and learner characteristics," and Eisenkraft's first E, elicit. The teacher asks students questions about the specific lesson concepts and, in this way, identifies what

knowledge and skills learners bring to the learning task. For example, a teacher might ask, “What is solar energy?” when introducing students to solar energy.

Step 2.1.2 combines Bybee et al.’s first E, engage, Gagné’s gain attention, and Keller’s attention. In the unit, we use brief videos, animations, demonstrations, oral stories, and objects to capture attention. For example, the teacher begins the lesson on geothermal energy by showing students a brief video of geothermal areas in Iceland. Throughout lessons, this sub-model uses such ARCS (Keller, 1983) attention-sustaining strategies as posing questions, engaging learners with tasks, and balancing content presentation with interactive sessions.

Step 2.1.3 matches Gagné’s “inform the learner of objectives” with Keller’s relevance by presenting objectives in a way that conveys the usefulness of the instruction (for example, by telling teachers such things as, “Inform students that they will investigate ways of conserving energy.”)

Step 2.1.4 is drawn verbatim from Gagné’s Nine Significant Events model. The teacher reminds students of important prerequisite knowledge or skills they have learned previously. This also helps prepare learners for the new content.

Step 2.1.5: Using direct instruction, demonstrations, and videos, the teacher explains the new content or students access new content on the unit’s student resources Web page. This step integrates Bybee et al.’s third E (explain) and Gagné’s “present stimuli.” The teacher uses small cycles of events to present the content and images are used in the materials to reduce the reading load and provide some content redundancy.

Step 2.1.6 interweaves Collins and Stevens’ inquiry teaching strategies, Gagné’s “provide guidance,” and Keller’s relevance. Examples, illustrations, and answers to student questions are used to help learners understand new content. The teacher relates examples to the learner’s experience and values and uses positive and negative examples and counterexamples as well. For example, students receive teacher guidance on how to complete the personal energy audit in which they note their daily and weekly energy consumption.

Step 2.1.7 is an adaptation of Gagné’s “elicit performance” event. Teachers ask learners to respond on their worksheets to specific questions as the content is presented.

Step 2.1.8: This is Gagné’s event seven, “provide feedback,” although we have the teacher provide such feedback aloud. The teacher asks students to share their worksheet responses with the class and he or she then discusses some of those responses with the class. In this way, the teacher reinforces correct responses, clarifies misunderstandings, and summarizes the content. This step also addresses Keller’s satisfaction. Teacher-provided feedback should help to sustain desired behavior.

In Step 2.1.9, lesson concepts are reviewed by the teacher in order to reinforce student learning and to clarify any concepts students did not understand. This is a variation of Gagné’s “enhance retention and transfer.”

### Instructional model for computer-supported activities

Step 2.2.1 combines Eisenkraft's first E, elicit and Dick, Carey and Carey's "identifying and analyzing entry behaviors and learner characteristics." The teacher asks questions about lesson concepts to determine what knowledge and skills students bring to the learning task.

In Step 2.2.2, the students become aware of their authentic task when the teacher presents it. This is a modification of Jonassen's "select an appropriate task for learners to do." Instructional materials present tasks in different ways. In some tasks, students analyze regional or worldwide cases first and then move to local cases. In other tasks, students analyze in the opposite direction. Regardless, this step obeys Collins and Stevens' strategy to vary cases systematically.

Step 2.2.3: Teachers model for learners how to do the task, for example, how to obtain data about solar power plants using the My World GIS Get Information tool. This is an instance of both Jonassen's and Black and McClintock's steps in which the teacher models the task.

Step 2.2.4 implements Jonassen's "provide worked examples." Either the teacher or the materials (or both) provides a worked example to help guide students in performing the task. For example, in our energy unit, the materials provide a worked example of how students should complete the solar power plants data chart. As noted earlier, the materials also provide positive and negative examples, and counterexamples (Collins & Stevens, 1983) to highlight important things that should help learners complete the task. For instance, the materials provide screenshots of what students would see when they perform a task either correctly or incorrectly.

Step 2.2.5: Learners perform the task. This step integrates the NRC's first essential feature ("learners engage with a scientifically oriented question"), Keller's satisfaction, and Bybee et al.'s second E, explore. Learners construct their own understandings by engaging actively with the task. To address Keller's satisfaction, teachers have learners use their newly acquired knowledge and skills to manipulate data in a simulated setting. For instance, the culminating task has students apply the unit's knowledge and skills to recommend the best combination of energy sources for a fictional island.

In Step 2.2.6, the materials and the teacher provide guidance to the learners as they complete GIS tasks. This honors Jonassen's steps where the teacher coaches the learners and provides cognitive tools to support the learners' performance. In our instructional unit, learners only use the GIS when they need it to accomplish a learning task. An orientation to the GIS is given by the teacher and he or she models how to use it to visualize, manipulate, and analyze data. Students learn to use the GIS through completion of a series of authentic tasks. We have scaffolded the handouts for using GIS heavily: They use screenshots, hints, and a consistent sequence to help enable students to use them to complete tasks independently outside the classroom. GIS activities are integrated with non-GIS activities that learners already know how to do so that students

do not become overwhelmed as they begin working with the GIS software with which they have no prior experience.

Step 2.2.7 addresses Bybee et al.'s fourth E, elaborate. The teacher and materials ask students to answer higher-order questions, draw conclusions, and reflect on how concepts relate to each other. All this is done in hopes of fostering greater student understanding.

Step 2.2.8 is a variation on Gagné's "enhance retention and transfer." To reinforce student learning, the teacher reviews the concepts learned in the activity. This review should also allow the teacher to clarify any concepts students did not understand.

### Instructional model for laboratory activities

Step 2.3.1 combines Eisenkraft's first E, elicit and Dick, Carey and Carey's "identifying and analyzing entry behaviors and learner characteristics." Just before beginning the activity, students are asked questions about lesson concepts in order to identify what knowledge and skills they bring to the learning task.

Step 2.3.2: The teacher presents the task to the learners. This is a modification of Jonassen's "select an appropriate task for learners to do."

In Step 2.3.3, the teacher assigns students to groups in which they will perform laboratory experiments.

Step 2.3.4: The teacher demonstrates the task. This represents both Jonassen's and Black and McClintock's teacher modeling of the task.

Step 2.3.5 implements Collins and Stevens' "make predictions" by having the teacher ask students to make predictions before they begin the laboratory experiment.

Learners conduct laboratory experiments in Step 2.3.6. This step integrates the NRC's first essential feature ("learners engage with a scientifically oriented question") with Bybee et al.'s second E, explore, and having students work collaboratively on tasks (Black & McClintock, 1996; Jonassen, 1999).

In Step 2.3.7, learners make observations of their laboratory experiments, thus implementing Black and McClintock's student observations of authentic artifacts.

Step 2.3.8: Obeying the NRC's third essential feature ("learners to give priority to evidence") and Collins and Stevens' "consider alternative predictions," students focus on evidence, think about alternative predictions, and formulate explanations from evidence. In keeping with Bybee et al.'s third E, explain, students discuss explanations and alternatives and expand their understanding of concepts.

In Step 2.3.9 learners evaluate their explanations in light of alternative explanations, and think their way towards solutions. This step integrates Bybee et al.'s fifth E, evaluate, the NRC's fourth essential feature ("ask learners to evaluate their explanations in light of alternative explanations"), particularly those reflecting scientific understanding, and Collins and Stevens' "question authority" (modified here to "draw own conclusions").

Step 2.3.10 is based on the NRC's fifth essential feature ("learners communicate and justify their proposed explanations") and Black and McClintock's steps. Learners share results and present and defend their explanations. We anticipate that this should enhance their motivation to be well prepared and may help to give them a sense of ownership of the content. This step is also designed to address Keller's confidence. In formulating an energy policy for a fictional island, students are provided with performance requirements and evaluative criteria to support them as they complete the task.

Step 2.3.11 represents Collins and Stevens' "trace consequences to a contradiction" and in this step the teacher corrects student misconceptions evinced in students' explanations.

Step 2.3.12 is based on Eisenkraft's seventh E, extend. Teachers ask learners to use the skills they have acquired to perform additional tasks. The intent is to enhance the transfer of student learning.

Step 2.3.13 reflects Gagné's ninth event ("enhance retention and transfer"). To reinforce student learning and clarify any concepts about which students seem confused, the teacher reviews the concepts covered.

This brings us to step 3 of the larger instructional model. This step is a variation of Dick, Carey and Carey's formative evaluation and also addresses Jonassen's constructivist model in which teachers adjust task difficulty or redesign the task to accommodate learners who are experiencing difficulties in completing it. The teacher asks questions and responds to student answers in Step 3.1, while in Steps 3.2, 3.3, and 3.4, the teacher reverses the process, soliciting student questions and responding to them and then providing feedback on students' worksheet responses. The goal here is to determine if the instruction was effective, to identify any weaknesses, and to determine where and how instruction should be revised and improved. Formative evaluation occurs while the instruction is in progress, so the teacher can adjust upcoming instruction to meet better the needs of students. Students add new ideas to their individual concept maps at various times during the unit in Step 3.5, while in Step 3.6 the teacher considers how best to improve classroom instruction and student performance.

Lastly, Step 4 is summative evaluation (Dick, Cary & Carey, 2005). In Steps 4.1 and 4.2, the teacher examines the culminating activity and concept maps to identify how well students learned in the unit. In Steps 4.3 and 4.4, learners complete content knowledge and attitude and behaviors posttests. The teacher considers student responses to these assessments as part of evaluating the effectiveness of the unit and deciding what revisions should be made for future.

### Meta-Design Principles

We also derived five meta-principles that apply to the design of the unit as a whole. These meta-principles tell us when to apply a rule and how to apply it.

Meta-principle 1: Use multiple ways of learning to address learner differences.

The brain processes information in different ways; learners may see different connections between concepts if information is presented in multiple ways. Gardner (1993) proposed seven intelligences initially and argued that everyone is born with potential in all seven. He contended, however, that cultural and personal contacts determine which intelligences develop. The seven intelligences include linguistic, logical-mathematical, bodily-kinesthetic, spatial, musical, interpersonal, and intrapersonal. Gardner later added naturalistic intelligence. We applied this meta-principle by conveying the core concepts of the unit using as many modalities as possible to reach the various students. Examples include having students investigate optimal areas for building different energy-generating facilities (logical-mathematical intelligence); having students read about different energy sources (linguistic intelligence); having students manipulate GIS data and recognize patterns (spatial intelligence); and having students collaborate on group activities (interpersonal intelligence). We used different entry points, such as telling a story (linguistic intelligence); asking questions (logical-mathematical intelligence), displaying real objects in class (bodily-kinesthetic intelligence), and doing hands-on activities (bodily-kinesthetic intelligence) to help engage learners with the topic.

Meta-principle 2: Facilitate the process of modifying instructional materials to meet the needs of different learners.

According to Kinnaman (1993), teachers play a major role in effective implementations because they can identify how to modify materials to address the needs of the students in their classes. Cates and Kulo (2009) argued that designers should provide adequate scaffolds for teachers to help them become more effective in supporting their students. In this way, a good design for teaching and learning is also a professional development program. We developed two sets of handouts, a simplified one for the students that includes scaffolds for the task, and a detailed one for the teacher that not only includes scaffolds for the task but also scaffolds for what students are supposed to learn and the thought processes involved. We provided handouts in both PDF and Word format. The teacher can choose to modify the activity and/or materials based on how learners perform the task, including adjusting task difficulty. The teacher can also enrich the student handout by adding detailed explanations of the activity copied from the teacher's handout.

Meta-principle 3: Use icons consistently to enhance and reinforce student learning and use illustrations to reduce learner dependence on text.

According to Paivio (1971) images act as mediators in learning and memory tasks and can serve as highly effective memory aids. To take advantage of the power of images, we used icons throughout, in materials for both teachers and students and we illustrated all materials extensively. Our use of icons and images was not simply to make the materials more attractive but also clearer. The image on the left in Figure 1 shows the student resources Web page. Since learners use this page almost every day, we used images that depict each energy source to facilitate navigation and also to enhance and reinforce student learning. For example, we used an image of a volcano for geothermal energy and an image of a water wheel with flowing water for hydroelectric energy. We also used illustrations with arrows to connect the text with the task and to illustrate the task (see image on the right).

Figure 1. Examples showing the use of icons and illustrations


**ELI Environmental Literacy & Inquiry**

**Energy - Student Resources**

[Energy Story](#)


[Energy Audit](#)


Energy Basics ([PDF](#))  
 Energy Uses ([PDF](#))  
 Renewable Energy ([PDF](#))  
 Nonrenewable Energy ([PDF](#))  
 Energy Timeline ([PDF](#))  
 Energy Efficiency ([PDF](#))  
 Famous People in Energy ([PDF](#))


 [Understanding Electricity](#)


Electricity ([PDF](#))


[Energy Concept Map](#)

 **Solar Energy**  
[Exploring Solar Power Plants with Google Earth](#)  
[Where is the Best Place to Locate a New Solar Power Plant?](#)  
 Solar Energy ([PDF](#))


 **Wind Energy**  
[About Wind Energy](#)  
[Exploring Wind Farms with Google Earth](#)  
[Where is the Best Place to Locate a New Wind Farm?](#)  
 Wind Energy ([PDF](#))

 **Tidal Energy**  
[About Tidal Energy](#)  
[Exploring Water Bodies with Google Earth](#)  
 Tidal Energy ([PDF](#))


 **Hydroelectric Energy**  
[About Hydroelectric Energy](#)  
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[Investigating Hydroelectric Dams with My World GIS](#)  
[Exploring Pennsylvania Energy on the River with Google Earth](#)


 **Geothermal Energy**  
[Where is the Best Place to Locate a Geothermal Power Plant? Metropolitan Areas in the Northwest U.S.A.](#)  
 Geothermal Energy ([PDF](#))


**US Energy**  
[US Energy Production and Consumption](#)

 **Biofuels/Biomass**  
[About Biofuels/Biomass](#)  
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**Fossil Fuels**  
[About Fossil Fuels](#)

 **Oil**  
[Investigating Oil Production and Consumption with My World GIS](#)  
 Petroleum ([PDF](#))

 **Natural Gas**  
[Investigating Natural Gas Production and Consumption with My World GIS](#)  
 Natural Gas ([PDF](#))

 **Coal**  
[Investigating Coal Production and Consumption with My World GIS](#)  
 Coal ([PDF](#))

[Impacts of Energy Sources](#)

 **Isle of Navitas**  
[Investigating Energy Resources for Isle of Navitas with My World GIS](#)

**Energy Policy Presentation PowerPoint Template**  
[Energy\\_policy\\_template.ppt](#)

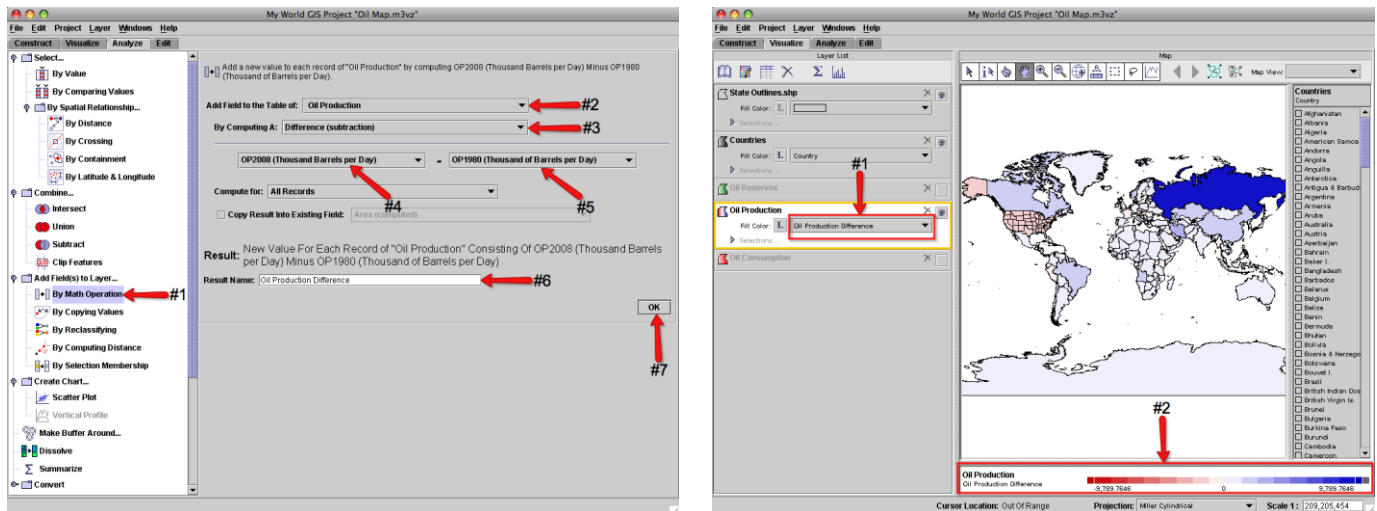
Click the eye to turn the **Navitas Provinces.shp** layer off.



Meta-principle 4: Use procedural facilitators to guide learners' responses.

Scardamalia and Bereiter (1986) defined procedural facilitators as questions, prompts, and simple outlines of important learning elements that teachers use to scaffold learning. According to Rosenshine and Meister (1992), such scaffolds provide the support students need to do higher-level thinking. Tasks in the energy unit have steps that must be done in sequence to get the desired results. Our procedural facilitators are designed to increase learner comprehension and ensure students do not skip steps. For example, the image on the left in Figure 2 outlines the steps for doing a task, while the image on the right shows results students should get when they follow those steps.

Figure 2. Illustrations of the use of procedural facilitators



Meta-principle 5: Use Contrast, Repetition, Alignment, and Proximity (CRAP) design.

According to Williams and Tollett (2000) there are four basic design principles one should apply in designing both print materials and Web pages. These are contrast, repetition, alignment, and proximity. Figure 3 illustrates how we applied these principles. We employed contrast in the form of larger sans serif font in bold to emphasize key words and by using a background color that contrasts well with the text and images. We employed repetition by using the same shades of green and white colors, consistent fonts, the Environmental Literacy and Inquiry (ELI) logo at the top, and light bulb navigation buttons. We used a larger sans serif font for the rest of the body text and used left alignment for items on the Web pages. We employed proximity by placing headings and subheadings closer to their related text or graphic than to the text or graphics above them. The Web pages also have lots of white space to help reduce cognitive load on the learners. Our intent throughout was to enhance readability.

Figure 3. Illustration of CRAP design

ELI Environmental Literacy & Inquiry

Nuclear Energy

**Nuclear Fission**


In nuclear fission, atoms split apart to form smaller atoms, releasing energy. Nuclear power plants convert this released energy into electricity.

**How does a nuclear power plant work?**

↑

Left alignment

↓

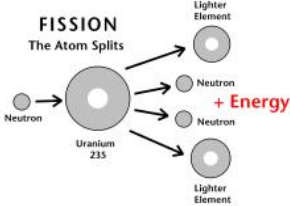


Proximity - title is closer to the image than to the text above.

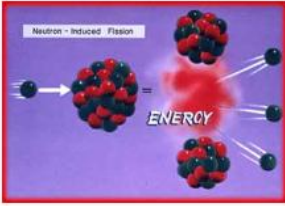
Contrast - key words stand out.

The fuel most widely used by nuclear power plants is **uranium**. Uranium is non-renewable. It is found in trace (tiny) amounts in many rocks. Nuclear plants use a certain kind of uranium, uranium-235, as fuel because its atoms are easily split apart. When Uranium-235 absorb a neutron, a **fission** (or splitting) of the atom often results. Fission splits the atom into two or more smaller elements and also releases energy and **neutrons**. Some of the neutrons produced can be absorbed by other Uranium atoms. These split and release more neutrons sustaining a **chain reaction**.


**FISSION**  
The Atom Splits



Neutron-Induced Fission




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