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About Inquiry-based Learning

Inquiry-based Learning for the 21st Century

> "Inquiry into authentic questions generated from student experiences is the central strategy for teaching science."
>
> —National Science Education Standards

In its official position statement on inquiry-based learning in science, the National Science Teachers Association (NSTA) encourages every teacher to make inquiry science a part of the daily curriculum, noting that it is important to help younger learners become problem-solving learners.

NSTA defines scientific inquiry as "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world."

According to the NSTA, students learn science best when:

- they are involved in firsthand exploration and investigation and inquiry/process skills are nurtured;
- instruction builds directly on the students' conceptual framework;
- content is organized on the basis of broad conceptual themes common to all science disciplines;
- mathematics and communication skills are integral parts of science instruction.

This position is supported by The National Science Education Standards (1996), which views inquiry as "central to science learning." As the standards explain, "when engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations."

It is important for educators today to prepare students for the lives they will lead outside of the classroom. The world has changed drastically over the past 75 years, and the education provided to students must reflect those changes. According to research from the Partnership for 21st Century Skills (2002), "workers need the learning capacity to become lifelong learners, updating their knowledge and skills continually and independently." Inquiry-based learning pushes students to ask questions, think critically to answer those questions, synthesize their ideas, and draw conclusions. This type of learning prepares students to become learners outside of the classroom and provides them with tools that they can apply to other questions or problems they encounter.

Despite widespread agreement on the importance of inquiry-based learning, some teachers are still hesitant to adopt this pedagogical approach in their science classrooms for a variety of reasons. Some feel it is only appropriate for advanced learners; others feel inadequately prepared for this type of instruction; still others are concerned about "managing" an inquiry-based classroom in which students have a greater opportunity, some would say, to be disruptive, pay less attention, socialize, or simply not participate. Yet, research proves these concerns are unfounded.

About Inquiry-based Learning *(cont.)*

Qualities of an Inquiry-based Classroom *(cont.)*

The inquiry-based classroom is in stark contrast to rote learning, memorization (merely for the sake of memorization), or fact-based learning. In an inquiry-based classroom, the teacher does not impart knowledge as much as create an environment in which students learn for themselves through their own inquisitiveness and experiences.

Making the Transition to Inquiry-based Instruction

Inquiry-based science lessons can take one of three approaches or range of practices: structured inquiry, guided inquiry, and open inquiry (Colburn 2000). Teachers can incorporate these approaches based on the needs of the students or the objectives of the lesson. In some lessons, it is important for students to have a more structured or guided activity, while other lessons may be more suited for "free-ranging explorations of unexplained phenomena" (Huziak 2003).

It is important to understand that these stages of inquiry are not independent of each other; rather, they exist along a continuum. Therefore, teachers do not need to make the transition to open inquiry-based instruction all at once. "Both students and teachers alike need time to gradually make a transition from the more classical confirmation-type activities and lectures to open-ended activities characteristic of inquiry-based instruction" (Colburn 2000).

An inquiry-based science classroom offers both teachers and students a wonderful opportunity to explore science in an exciting way. While there is a learning curve in the adoption of this approach for both teachers and students, research confirms that inquiry-based methods of teaching not only improve student achievement in science (across all ability groups), but also increase student interest and excitement about science (Walker 2007). As Alan Colburn, professor in the Department of Science Education at California State University, Long Beach, concludes, "It's up to you to find the right mix of inquiry and non-inquiry methods that engages your students in the learning of science" (2000).

Structured Inquiry

In this process, teachers give students a problem to solve, the materials with which to solve the problem, and the steps to follow in conducting an experiment. The teacher does not provide the students with the expected outcome.

Guided Inquiry

The teacher suggests possible problems to investigate and provides some materials that might be used in the investigation (students may add others). However, the teacher does not provide the actual steps to follow in the investigation. Students devise their own experimental design and draw their own conclusions.

Open Inquiry

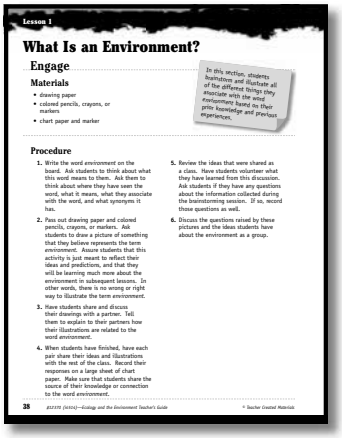
In this approach, students develop their own questions for investigation based on previous knowledge or discussion. They create hypotheses and design their own methods of investigation.

About Inquiry-based Learning *(cont.)*

Using the 5 Es in a Science Classroom

One method for structuring an inquiry-based instructional approach is based on a model developed by Biological Science Curriculum Study (BSCS 2006). This model employs the 5 Es—engage, explore, explain, elaborate, and evaluate—and is based on a constructivist philosophy of learning. In this philosophy of learning, students build or construct their own understanding of new ideas based on what they already know.

Each "E" represents part of a sequential instructional process or learning cycle designed to help students construct their own learning experiences and ultimate understanding of the topic or concept. The general goal and activities at each stage in the 5E model are listed below and on the following page.


Lesson 1

What Is an Environment?

Engage

Materials

- drawing paper
- colored pencils, crayons, or markers
- chart paper and marker

In this section, students brainstorm and illustrate all of the different things they associate with the word *environment* based on their prior knowledge and previous experiences.

Procedure

1. Write the word *environment* on the board. Ask students to think about what this word means to them. Ask them to think about where they have seen the word, what it means, what they associate with the word, and what synonyms it has.
2. Pass out drawing paper and colored pencils, crayons, or markers. Ask students to draw a picture of something that they believe represents the term *environment*. Assure students that this activity is just meant to reflect their ideas and predictions, and that they will be learning much more about the environment in subsequent lessons. In other words, there is no wrong or right way to illustrate the term *environment*.
3. Have students share and discuss their drawings with a partner. Tell them to explain to their partners how their illustrations are related to the word *environment*.
4. When students have finished, have each pair share their ideas and illustrations with the rest of the class. Record their responses on a large sheet of chart paper. Make sure that students share the source of their knowledge or connection to the word *environment*.
5. Review the ideas that were shared as a class. Have students volunteer what they have learned from this discussion. Ask students if they have any questions about the information collected during the brainstorming session. If so, record those questions as well.
6. Discuss the questions raised by these pictures and the ideas students have about the environment as a group.

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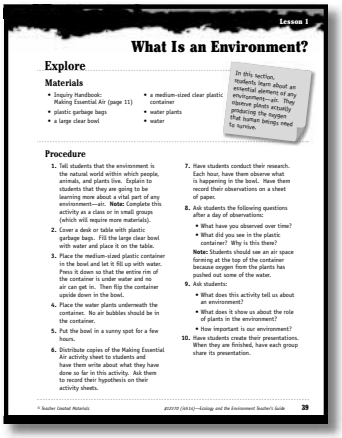
Engage

At this stage, teachers introduce a topic or concept with an intriguing, fascinating, or challenging question or demonstration designed to capture students' interest, curiosity, and attention. At this stage, teachers do not seek a "right answer"; rather, they prompt students to talk about what they already know about the topic (or think they may know), and discuss what else students would like to know.


Lesson 1

What Is an Environment?

Explore

Materials

- Inquiry Handbook: Making Essential Air (page 11)
- plastic garbage bags
- a large clear bowl
- a medium-sized clear plastic container
- water plants
- water

In this section, students learn about an essential element of any environment—air. They observe plants actually producing the oxygen that human beings need to survive.

Procedure

1. Tell students that the environment is the natural world within which people, animals, and plants live. Explain to students that they are going to be learning more about a vital part of any environment—air. **Note:** Complete this activity as a class or in small groups (which will require more materials).
2. Cover a desk or table with plastic garbage bags. Fill the large clear bowl with water and place it on the table.
3. Place the medium-sized plastic container in the bowl and let it fill up with water. Press it down so that the entire rim of the container is under water and no air can get in. Then flip the container upside down in the bowl.
4. Place the water plants underneath the container. No air bubbles should be in the container.
5. Put the bowl in a sunny spot for a few hours.
6. Distribute copies of the Making Essential Air activity sheet to students and have them write about what they have done so far in this activity. Ask them to record their hypothesis on their activity sheets.
7. Have students conduct their research. Each hour, have them observe what is happening in the bowl. Have them record their observations on a sheet of paper.
8. Ask students the following questions after a day of observations:
   - What have you observed over time?
   - What did you see in the plastic container? Why is this there?

   Note: Students should see an air space forming at the top of the container because oxygen from the plants has pushed out some of the water.
9. Ask students:
   - What does this activity tell us about an environment?
   - What does it show us about the role of plants in the environment?
   - How important is our environment?
10. Have students create their presentations. When they are finished, have each group share its presentation.

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Explore

During exploration, students conduct various hands-on or problem-solving activities and experiments designed to help them explore the topic and make connections to related concepts, often within groups or teams. During this stage, students share common experiences while the teacher acts as a facilitator, providing materials as needed and guiding the students' focus.

Renewable Resources

Standards

Content Standard

Understands the origins and environmental impacts of renewable and nonrenewable resources, including energy sources like fossil fuels

Process Standard

Uses appropriate tools and simple equipment to gather scientific data and extend the senses

Vocabulary

energy: a supply or source of electrical, mechanical, or other form of power

renewable: capable of being replaced by natural ecological cycles

replenish: to make full or complete once more

water: a clear, odorless, and tasteless liquid that is a major part of all living organisms

Essential Question

What are renewable resources and in what ways do they contribute to a healthier ecosystem?

Overview

Engage

In this section, students look at a diagram of the water cycle to make predictions about what renewable means, and use their prior knowledge to list other resources found in nature that are renewable.

Explore

In this section, students learn about renewable resources by designing a solar water heater and considering the benefits and drawbacks of solar power.

Explain

In this section, students read about different renewable resources and how they can be used as energy sources.

Elaborate

In this section, students learn ways in which renewable resources are able to naturally sustain themselves, and consider why we need to protect these valuable natural resources.

Evaluate

In this section, students examine the Essential Question of the lesson, reflect on their learning, and take the Renewable Resources Assessment.

Renewable Resources

Background Information for the Teacher

A natural resource is any substance found in nature that people use. There are thousands of natural resources. Some natural resources are renewable. This means they are constantly being replenished through natural processes, such as the energy made from the sun or water from the water cycle. Renewable resources will be around for a long time to come, especially if they are taken care of properly.

Other natural resources are considered to be nonrenewable. This means that they are being used faster than they can be replenished naturally. There is great concern over the possibility of running out of certain nonrenewable resources, especially fossil fuels. Fossil fuels are the prehistoric remains of plants and animals that lived over 300 million years ago. These remnants collected energy from the sun, and the energy they have stored for millions of years is released when fossil fuels are burned. Fossil fuels include natural gas, oil, and coal. These fuels provide energy in the form of electricity and petroleum to power a variety of things in our modern world.

Many renewable resources are vital to sustaining life on Earth. Water is a natural resource that keeps all living organisms alive and well. Almost 75 percent of Earth's surface is covered with water. Out of that water, less than 1 percent of it is available for drinking. Additionally, water is an important resource that helps factories to run, and helps grow crops on farms. Some water is even used to create energy. Dams at hydroelectric power plants use the force of rushing water to make electricity.

Water recycles and renews itself over and over through the water cycle. But having access to safe and clean water for all who need it is still an issue in some places. Water found underground is being used very quickly and may soon become a nonrenewable resource. Water pollution is another related issue because it is making some of our water unusable.

Air is a second renewable natural resource that is essential for life. Through the process of photosynthesis, plants use carbon dioxide to make food. Then plants release oxygen. Oxygen is the gas that people and animals need to breathe. We breathe in oxygen and breathe out carbon dioxide. Air will never run out, but air pollution does make air harmful for living organisms.

Finally, sunlight is perhaps the most important natural resource of all. It is the source of all the energy on Earth. Energy from the sun is used to make energy in the form of food, wind, and even coal and oil. For example, plants use sunlight to make food. Plants become food for animals. Then plants and animals are food for human beings.

Renewable natural resources are critically important for all life on Earth. If not overused, these resources will be around for many, many years to come.

Renewable Resources

Explore

In this section, students learn about renewable resources by designing a solar water heater and considering the benefits and drawbacks of solar power.

Materials

- Inquiry Handbook: Solar Water Heater *(*page 59)
- scissors and masking tape
- black plastic garbage bags
- aluminum foil cake pans
- aluminum foil
- wax paper
- measuring cup
- plastic wrap
- thermometers
- small plates or saucers
- water

Procedure

Note: Choose a sunny day to do this lesson. If possible, start mid-morning when the sun is overhead.

1. Begin a discussion about renewable resources by asking students to think about something that is renewable. Explain that *renewable* means sustainable because of limitless supply or because of an ability to create or grow more of something.
2. Tell students that some natural resources are renewable. These resources found in nature are practically limitless. They include wind, air, and water. Tell students that the sun is a renewable resource as well.
3. Explain to students that many people already use the sun as a way to provide renewable energy. Tell them that solar energy can provide heating among other things, without the pollution that is associated with other sources of energy, such as fossil fuels.
4. Inform students that they are going to work in groups to design a solar water heater. Distribute copies of the Solar Water Heater activity sheet to students.
5. Display the materials that students will use in the experiment. Discuss as a class what each material is and how it could be used. Tell students that as they design their experiments, any additional materials needed should be discussed with you.
6. Divide the class into groups and provide each group with a set of materials to conduct the experiment.
7. Have students formulate their hypotheses and conduct their experiments.
8. Allow students to use thermometers periodically to check the water temperatures in their water heaters.
9. At the end of the experimental period, have each group share its hypothesis, its experimental design, and its conclusion. Discuss the benefits and drawbacks of solar power.

Renewable Resources

Explain

In this section, students read about different renewable resources and how they can be used as energy sources.

Materials

- Inquiry Handbook:
  Protecting Renewable Resources (page 60)
  How Do We Use Them? (page 61)
  Renewable Resources Vocabulary (page 62)

Procedure

1. Distribute copies of the Protecting Renewable Resources background page to students. Ask someone to read the title of the text aloud.
2. Explain to students that the information presented in this text will describe different renewable resources. Tell students to pay close attention to the ways in which the renewable resources can be used as energy sources.
3. Have students read the text independently, in pairs, or in small groups.
4. Distribute copies of the How Do We Use Them? activity sheet to students. Allow time for students to complete the activity sheet in pairs. Students should use the Protecting Renewable Resources background page to complete the activity.
5. Discuss the Protecting Renewable Resources background page and the How Do We Use Them? activity sheet by asking students the following questions:
   - What different examples of renewable resources did you read about?
   - What are the different uses for each of the renewable resources included in the reading?
   - Do you think renewable or nonrenewable energy sources should be used to create energy? Why or why not?
   - What is an important distinction between renewable and nonrenewable resources?
   - Do you think most people around the world think about their own personal use of renewable or nonrenewable resources? Why or why not?
6. Distribute copies of the Renewable Resources Vocabulary activity sheet to students and allow them time to complete it. Encourage them to discuss possible answers with their peers.

Name_____

Renewable Resources

Solar Water Heater

Directions: Read the question below and formulate a hypothesis. Then, design an experiment to test your hypothesis. Use the materials your teacher has provided. Make your observations and draw your conclusions. Create a record of your experiment on a separate sheet of paper.

Question

What is the best material for conducting solar energy?

Hypothesis

Formulate a hypothesis. (What is the answer to the question?) Record your hypothesis.

Experimental Design

Design and conduct your experiment. Write the steps to your experiment. One suggestion for your experiment is outlined below.

1. Design different pans made from different materials.
2. Use a measuring cup to fill each of the pans with the same amount of water.
3. Place the pans in the sun.
4. Compare the temperatures of the water in the different pans after they sit in the sun for a chosen amount of time.

Observation

What happened during your experiment? Record your observations.

Conclusion

What is the answer to the question? Write your conclusion. Do your findings support your hypothesis? What did you learn during this experiment?

Renewable Resources

Protecting Renewable Resources

A natural resource is something found in nature that people use. Natural resources can be put in different groups. One group is *nonrenewable*. Another group is *renewable*.

Renewable resources are made in nature. They are made over and over again. They will be around for a long time to come. Sunlight is one example. Water is one. Air is also an example.

Renewable resources are very important. They support all life on Earth. For example, water keeps all living organisms alive. Water is used to help factories run. It is also used to make crops grow.

Another renewable resource is air. All living organisms need air. Plants need carbon dioxide from the air. Animals need oxygen from the air. Humans also need oxygen from the air. Air will never run out. But pollution can make air dirty. This is harmful for living organisms. Humans need to take good care of the air so that it is safe to breathe.

The sun is the most important resource. It is the source of all the energy on Earth. Best of all, it is renewable. Nothing could live on our planet without the sun. Sunlight helps plants grow. Animals get energy when they eat plants. Humans do, too. This energy keeps them all alive.

People often use renewable resources for energy. The energy made from them is renewable, too. That means we can keep making more and more energy. It will not run out. Sunlight is used to make energy. Water is used to make energy. Wind is also used. Energy from the sun, water, and wind is also better for our planet. It does not make pollution. Pollution makes air and water harmful for living organisms. It is not healthy for our planet.

Scientists are trying to find better ways to use sunlight, water, and wind to make energy. This will help us right now. It will also help us in the future. It will help us use energy without making pollution.

Energy from renewable resources is important. Natural resources are very important for all life on Earth. Fortunately, renewable resources are made over and over again. We need to take care of these important resources. We need them for many years to come.

Name_____

Renewable Resources

How Do We Use Them?

Directions: Think about the information you read. Fill out the chart below by describing different ways that humans use each renewable resource. Include ideas about how the resources are used as sources of energy.

Renewable Resources

water
air
sun

Name_____

Renewable Resources

Renewable Resources Vocabulary

Directions: Write words, phrases, or examples that are connected to each vocabulary word.

energy: _____

_____

_____

renewable: _____

_____

_____

replenish: _____

_____

_____

water: _____

_____

_____

Directions: Write a paragraph that includes each of the vocabulary words.

_____

_____

_____

_____

_____

_____

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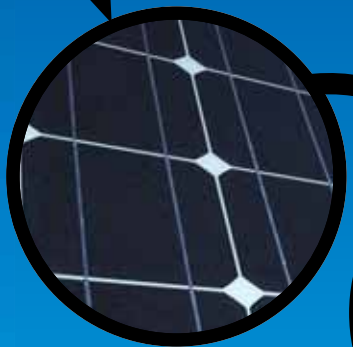
POWERED BY SOLAR ENERGY

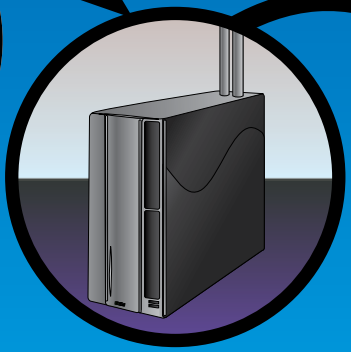
sunlight travels to solar panels

power delivered to city

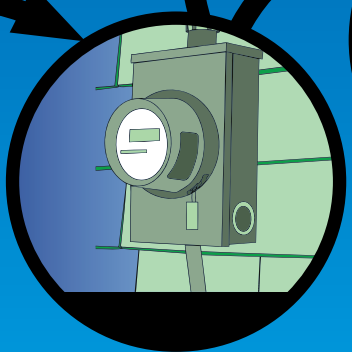
output to utility grid



solar cells absorb sunlight



inverter converts electricity



utility meter delivers electricity

output to home

SHUTTERSTOCK

Renewable Solar Energy

Background Information

Renewable resources will not run out. They can be made over again in nature. They can be used to make energy. One example is sunlight.

Solar panels are used to make energy from sunlight. They can be put on top of houses. They can also be put on top of buildings. They can even stand alone in the ground. Here are the steps it takes to make solar energy:

1. Light from the sun hits the solar panel.
2. There are *solar cells* inside the panel. They turn light into *direct current* (DC) electricity.
3. This electricity goes through wires. It goes into a *converter*. Then in is changed from DC electricity into *alternating current* (AC) electricity. This is the type that light bulbs use. Household items, like toasters, use this, too. Even TVs use this.
4. This electricity goes through wires. It goes to the *utility meter*.
5. The meter sends electricity to the home first. The things in the home get all that they need. Leftover electricity goes to the *utility grid*. It gets sent to other homes. It also gets sent to other businesses.

Analyzing Science

- ● What are some things that solar energy is used for?
- ■ Why is sunlight used to make energy?
- ▲ Is using renewable resources to make energy a good idea? Why or why not?

Nonfiction Writing Prompt

Some countries in the world have more homes with solar panels than others. Write a letter to your state official. Explain the benefits of using solar energy. Persuade the official to put solar panels on the roofs of all the houses in your neighborhood. Include facts and details in your letter.

Fiction Writing Prompt

Write an acrostic poem using the word *renewable*. Include ideas about renewable resources and energy in your poem.

Scientific Challenge

Research how a different renewable resource is used to make energy. You can find information on the Internet or at the library. Create a presentation with the information you find. Include pictures and diagrams in your presentation.