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About Inquiry-based Learning

Inquiry-based Learning

> "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 at every grade level, 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 first-hand exploration and investigation and inquiry/process skills are nurtured;
- instruction builds directly on the student's 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."

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.

Concern #1: Inquiry-based learning is only appropriate for advanced learners.

Research suggests that students in an inquiry-based classroom perform equally as well among all "...diversity groupings (based on ethnicity, socioeconomic status, gender, and ELL status)" as compared with students in a traditional classroom (Lynch et al. 2005). Other studies have shown that the inquiry-based curriculum is "more effective than traditional instruction in increasing certain aspects of motivation and engagement, particularly among historically disadvantaged student groups" (Hmelo-Silver et al. 2007).

About Inquiry-based Learning *(cont.)*

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 both for teachers and for 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).

Below are brief descriptions of the three approaches to inquiry-based instruction.

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). But the teacher does not provide the actual steps to follow in the investigation. Students devise their own experimental design and make their own conclusions.

Open Inquiry

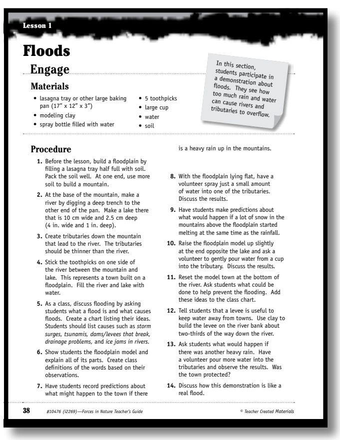
In this approach, students develop their own questions for investigation based on previous knowledge or discussion. They create hypotheses and design their own methods of investigation.

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 5 E model are listed below and on the following page.


Lesson 1

Floods

Engage

In this section, students participate in a demonstration about floods. They see how too much rain and water can cause rivers and tributaries to overflow.

Materials

- lasagna tray or other large baking pan (17" x 12" x 3")
- modeling clay
- spray bottle filled with water
- 5 toothpicks
- large cup
- water
- soil

Procedure

1. Before the lesson, build a floodplain by filling a lasagna tray half full with soil. Pack the soil well. At one end, use more soil to build a mountain.
2. At the base of the mountain, make a river by digging a deep trench to the other end of the pan. Make a lake there that is 10 cm wide and 2.5 cm deep (4 in. wide and 1 in. deep).
3. Create tributaries down the mountain that lead to the river. The tributaries should be thinner than the river.
4. Stick the toothpicks on one side of the river between the mountain and lake. This represents a town built on a floodplain. Fill the river and lake with water.
5. As a class, discuss flooding by asking students what a flood is and what causes floods. Create a chart listing their ideas. Students should list causes such as *storm surges, tsunamis, dams/levees that break, drainage problems,* and *ice jams in rivers.*
6. Show students the floodplain model and explain all of its parts. Create class definitions of the words based on their observations.
7. Have students record predictions about what might happen to the town if there is a heavy rain up in the mountains.
8. With the floodplain lying flat, have a volunteer spray just a small amount of water into one of the tributaries. Discuss the results.
9. Have students make predictions about what would happen if a lot of snow in the mountains above the floodplain started melting at the same time as the rainfall.
10. Raise the floodplain model up slightly at the end opposite the lake and ask a volunteer to gently pour water from a cup into the tributary. Discuss the results.
11. Reset the model town at the bottom of the river. Ask students what could be done to help prevent the flooding. Add these ideas to the class chart.
12. Tell students that a levee is useful to keep water away from towns. Use clay to build the levee on the river bank about two-thirds of the way down the river.
13. Ask students what would happen if there was another heavy rain. Have a volunteer pour more water into the tributaries and observe the results. Was the town protected?
14. Discuss how this demonstration is like a real flood.

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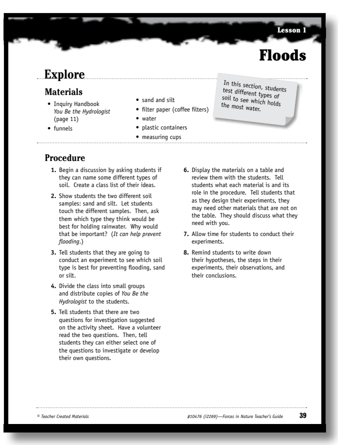
Engage

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

Floods

Explore

In this section, students test different types of soil to see which holds the most water.

Materials

- Inquiry Handbook *You Be the Hydrologist* (page 11)
- funnels
- sand and silt
- filter paper (coffee filters)
- water
- plastic containers
- measuring cups

Procedure

1. Begin a discussion by asking students if they can name some different types of soil. Create a class list of their ideas.
2. Show students the two different soil samples: sand and silt. Let students touch the different samples. Then, ask them which type they think would be best for holding rainwater. Why would that be important? (*It can help prevent flooding*.)
3. Tell students that they are going to conduct an experiment to see which soil type is best for preventing flooding, sand or silt.
4. Divide the class into small groups and distribute copies of *You Be the Hydrologist* to the students.
5. Tell students that there are two questions for investigation suggested on the activity sheet. Have a volunteer read the two questions. Then, tell students they can either select one of the questions to investigate or develop their own questions.
6. Display the materials on a table and review them with the students. Tell students what each material is and its role in the procedure. Tell students that as they design their experiments, they may need other materials that are not on the table. They should discuss what they need with you.
7. Allow time for students to conduct their experiments.
8. Remind students to write down their hypotheses, the steps in their experiments, their observations, and their conclusions.

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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.

Floods

Standards

Content Standard

Knows how features on Earth's surface are constantly changed by water

Process Standard

Plans and conducts simple investigations, makes systematic observations, and develops logical conclusions

Vocabulary

flood level: the amount of water a river can hold before flooding

floodplain: flat area, usually on either side of a river, which has the potential to easily flood

levee: a natural or artificial embankment or slope designed to prevent the flooding of the land behind it

watershed: an area of land that water flows across as it moves toward a stream, river, or lake

Essential Question

What role does the hydrologic cycle play in flooding?

Overview

Engage

In this section, students participate in a demonstration about floods. They see how too much rain and water cause rivers and tributaries to overflow.

Explore

In this section, students test different types of soil to see which holds the most water.

Explain

In this section, students learn about the causes of floods as they relate to a real-world example.

Elaborate

In this section, students learn about the relationship between the hydrologic (water) cycle and floods.

Evaluate

In this section, students examine the Essential Question of the lesson and reflect on their learning. Students also take the *Floods Assessment*.

Floods

Background Information for the Teacher

Floods are the most common of all natural hazards. They happen all over the world, killing more people than any other single natural hazard, including hurricanes and tornadoes. They can also cause more damage than any other severe weather-related event. The one good thing about floods is that, unlike earthquakes and some other natural hazards, floods can often be predicted.

River floods are caused by heavy rains or melting snow that cause rivers and streams to slowly rise and overflow, generally over a period of several days. Debris jams also cause rivers or streams to overflow and flood surrounding areas.

Coastal floods occur when strong winds or hurricanes push huge waves to come ashore, flooding coastal areas.

Flash floods happen suddenly with little warning, usually within six hours after torrential rains or after a dam or levee failure. They catch people off guard, and produce a devastating, fast-moving flow of water and debris.

Several factors contribute to flooding, including topography of the land, soil conditions, river flow and tidal surges, building and development of land, and ground cover. But the two main elements are the intensity of the rainfall in an area and its duration.

What may come as a surprise is the fact that the amount of water on Earth has essentially never changed. There is the same amount of water on Earth today as there was millions of years ago. The explanation for that has to do with the hydrologic cycle (or water cycle). Water is continuously being recycled from the atmosphere to land surface to under the ground. Even in times of floods or droughts in certain areas of the world, the total amount of water worldwide remains the same.

Another important concept to understand is a river's watershed. A watershed is any area of land that water falls on and drains off to the same place—a stream, river, lake, or ocean. There are small watersheds, consisting of a creek or stream, and large watersheds, such as the Amazon, Congo, and Mississippi basins. The boundary of a watershed is defined by the path a drop of rainwater follows to its outlet.

There are many reasons why it is important to understand watersheds. For example, many communities use rivers and streams as their source of drinking water. The quality of our water is directly related to the watershed it originates from. Floods are also a major event in a watershed. When rivers, streams, and lakes overflow, they threaten human lives and damage or destroy property. Watersheds can also become dry, causing water shortages for those who depend on their lakes and rivers for drinking water. Finally, many ecosystems are dependent on the watersheds.

While floods cannot be completely controlled, people can take steps to protect themselves from this force in nature.

Floods

Explore

Materials

- Inquiry Handbook: *You Be the Hydrologist* (page 11)
- funnels
- sand and silt
- filter paper (coffee filters)
- water
- plastic containers
- measuring cups

In this section, students test different types of soil to see which holds the most water.

Procedure

1. Begin a discussion by asking students if they can name some different types of soil. Create a class list of their ideas.
2. Show students the two different soil samples: sand and silt. Let students touch the different samples. Then, ask them which type they think would be best for holding rainwater. Why would that be important? (*It can help prevent flooding*.)
3. Tell students that they are going to conduct an experiment to see which soil type is best for preventing flooding: sand or silt.
4. Divide the class into small groups and distribute copies of *You Be the Hydrologist* to the students.
5. Tell students that there are two questions for investigation suggested on the activity sheet. Have a volunteer read the two questions. Then, tell students they can either select one of the questions to investigate or develop their own questions.
6. Display the materials on a table and review them with the students. Tell students what each material is and its role in the procedure. Tell students that as they design their experiments, they may need other materials that are not on the table. They should discuss what they need with you.
7. Allow time for students to conduct their experiments.
8. Remind students to write down their hypotheses, the steps in their experiments, their observations, and their conclusions.

Floods

Explain

In this section, students learn about the causes of floods as they relate to a real-world example.

Materials

- Inquiry Handbook:
  A Terrible Flood (page 12)
  The Causes and Effects of Floods (page 13)
  Floods Vocabulary (page 14)

Procedure

1. Tell students that each year floods kill more people than any other natural disaster. One of the worst flood disasters occurred more than 100 years ago in Johnstown, Pennsylvania.
2. Distribute copies of *A Terrible Flood* to students. Tell them that the story tells about this terrible disaster. It also explains some of the reasons for this disaster.
3. Have students read the background information in pairs. As they read, they should look for four different causes of this natural disaster.
4. After the students finish reading, create a cause-and-effect chart and list the causes of this flood. As a class, discuss whether any of these causes could have been prevented in the Johnstown Flood.
5. Distribute copies of *The Causes and Effects of Floods* to the students. Have them record the four causes of floods from the class chart onto the causes section of the graphic organizer.
6. Discuss each cause and its effect(s). Record the information on the class chart and have students record the same information on their activity sheets.
7. Now ask students what happens when rain falls. *(Possible Answers: It soaks into the ground or evaporates.)*
8. Tell students that while some water soaks down into the soil and becomes groundwater, much of the precipitation runs across the surface of the land toward a specific stream, river, or lake. The area of land which water flows across is called a *watershed*. When too much rainwater is in a watershed, this also causes flooding. Add this cause and effect to the class chart and have students do the same.
9. Have students think back to the other activities completed in the lesson (Engage and Explore activities) to see if they can list additional causes and effects of floods. Allow them to complete this in pairs.
10. Have students share their ideas and add them to the class chart.
11. Now distribute copies of *Floods Vocabulary* to students and have them use their understanding from the activities to complete the sheet. Students may work independently or in pairs.

Name____

Floods

You Be the Hydrologist

Directions: Choose one of the Questions for Investigation below. Use the question you chose to formulate a hypothesis. Then design an experiment to test your hypothesis. Make observations and draw a conclusion. Create a record of your experiment on a separate sheet of paper.

Questions for Investigation

- Will water infiltrate sand or silt faster?
  Hint: As you test soil samples, be sure to measure the exact same amount of soil into the funnel and pour in the exact same amount of water.
- Will water infiltrate saturated or dry soil faster?
  Hint: Test a moist sample of soil (sand or silt). Then, test a dry sample of the exact same amount of soil.

Question

Select one of the Questions for Investigation. Write the question you chose.

Hypothesis

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

Experimental Design

Design and conduct your experiment. Write down the steps to your experiment.

Observation

What happened during your experiment? Record your observations.

Conclusion

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

Floods

A Terrible Flood

At about 3:00 P.M. on May 31, 1889, the South Fork Dam suddenly gave way. More than 18 billion kilograms (20 million tons) of water rushed down the narrow valley to the town of Johnstown, 22 kilometers (14 miles) below.

The massive wall of water was like a huge tidal wave. It reached speeds of 64 kilometers (40 miles) per hour. It picked up houses. It also picked up trees and trains. It tossed them aside. It had the force of Niagara Falls.

By the time it reached the town, the flood did not even look like water anymore. People who saw it coming said it looked like a black mountain of junk.

In minutes, most of the town was destroyed. That included about 1,600 homes. More than 2,200 people had also been killed.

What caused this natural disaster? As with most floods, there are many answers.

First, it had been raining heavily for two days. Two rivers in the area had already overflowed their banks. Much of the town was already under half to two meters (two to seven feet) of water. In addition, much of the ground above the town had become heavily soaked. It could not absorb any more water. That created a dangerous runoff.

Secondly, Johnstown had been built on a floodplain. The floodplain was at the bottom of a long narrow valley. Narrow, deep valleys do not allow water to spread out.

A third reason for the terrible disaster was that there was very little warning. People did not have time to escape. No one knew what to do.

Fourth, over the years, there had been a lot of new development above the town. Trees and other plants had been removed from the hillside. Trees soak up a lot of rain. Their roots help keep the soil from eroding.

Finally, the dam failed. It had first been built over 30 years earlier. But there had been problems with the dam before. It had not been properly taken care of and repaired. All those facts combined into one terrible flood. It was one of the worst floods the world had ever known.

Name____________________________________

Floods

The Causes and Effects of Floods

Directions: Think about the information you read on the previous page. The causes and effects of the Johnstown flood can be similar to other floods. Write the causes and effects of the Johnstown flood in the graphic organizer below.

Causes	**Effects**

Name ___________________________

Floods

Floods Vocabulary

Word Box

levee   watershed   floodplain   flood level

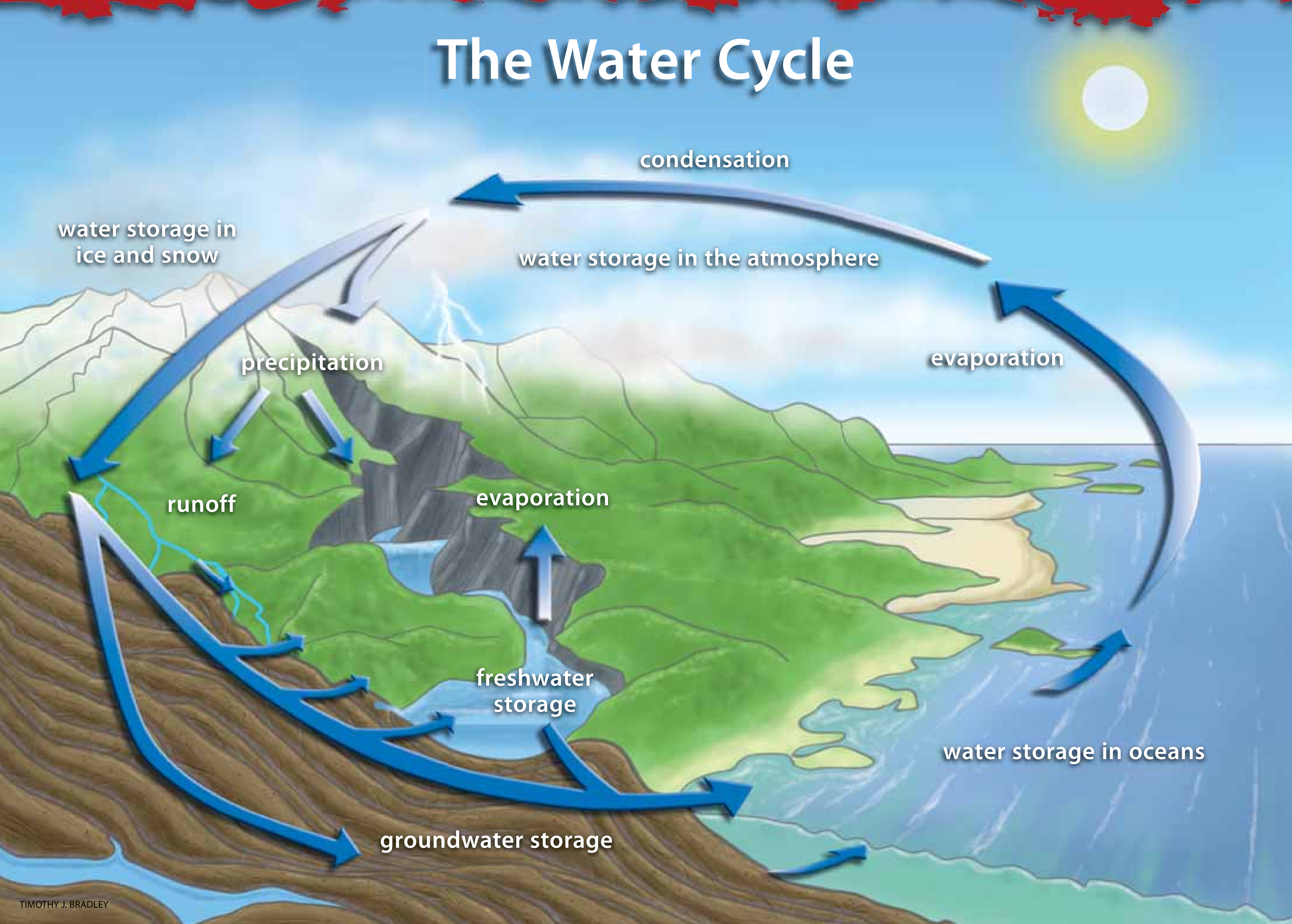
Directions: Write the vocabulary word or phrase next to its definition. Choose words from the word box above.

Definition	Vocabulary Word
1. The amount of water a river can hold before flooding.	
2. An area of land that water flows across as it moves towards a stream, river, or lake.	
3. A natural or artificial embankment or slope designed to prevent the flooding of the land behind it.	
4. Flat area, usually on either side of a river, which has the potential to easily flood.	

Directions: Illustrate each vocabulary word in the space provided below.

flood level	floodplain	levee	watershed

The Water Cycle



TIMOTHY J. BRADLEY

Floods

Background Information

The water cycle (also called the *hydrologic cycle*) is the process of how water flows from the atmosphere to Earth and back to the atmosphere again. Even though it does not have any beginning or end, there are five general parts to the water cycle. In the water cycle:

1. rain falls (precipitation)
2. precipitation that is not absorbed by the soil flows to a larger body of water (runoff and collection)
3. water in the larger bodies of water vaporizes and rises into the sky (evaporation)
4. clouds form (condensation)
5. the process starts all over again

If the water cycle did not exist, groundwater would continue to rise, rivers would flood their banks, and oceans would rise above the shoreline. This would cause major flooding in towns and cities all over the world. That is why the water cycle is very important for all living things on Earth.

Analyzing Science

- ● What is the third step in the water cycle? Why is it important?
- ■ What would happen if the third step in the water cycle did not exist?
- ▲ Name another cycle that exists on Earth. Compare and contrast it with the water cycle.

Nonfiction Writing Prompt

Pretend you are a newspaper reporter in Johnstown, Pennsylvania, in 1889. Write a feature article for the newspaper about the Johnstown flood. Include the essential facts in the lead of your story (who, what, where, and when). Then add additional details (why and how).

Fiction Writing Prompt

The year is 2050. Scientists are very worried. There has been a worldwide drought. How can the scientists help solve this problem? Base your story on scientific facts about the water cycle.

Scientific Challenge

What role does the water cycle play in helping to purify the water we drink and use? Research this question on the Internet or at the library. Create a poster detailing your answer. Use pictures, diagrams, and words on your poster.