Nuclear Energy
and the
Three Mile Island Unit Two Accident
Lesson Plans and Resource Guide

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Background Information

Introduction

The accident at the Three Mile Island nuclear power plant in 1979 made newspaper headlines around the globe. Issues surrounding the causes and effects of this accident have been investigated, analyzed and debated. They continue to be a source of controversy.

The following lesson plans will introduce the basics of nuclear energy and educate students about the accident that began at the nuclear power plant in Middletown, Pennsylvania, on March 28, 1979. The information, aligned with National Science Education Content Standards and Pennsylvania Academic Standards, will be presented in a hands-on, engaging manner. It will be balanced, coming from a variety of sources. This balance will allow students to analyze and interpret their findings. Teachers are encouraged to be neutral facilitators, allowing students to formulate their own conclusions and opinions.

In order to put nuclear power and the accident into perspective, a basic understanding of energy resources first will be addressed.

Energy Resources

The necessities and luxuries in our everyday lives create the increasing demand for energy resources. The total world consumption of primary energy is approximately 460 quadrillion (one quadrillion = 1,000,000,000,000,000) Btu's annually. Btu's are British thermal units, which are a measure of heat energy. The heat produced by burning one wooden kitchen match is equal to about one Btu. The United States consumes over 100 quadrillion Btu's per year. Projections indicate that by the year 2025, the world will use 640 quadrillion Btu's annually.

Most of the energy consumed by the world comes from nonrenewable resources, which are limited in quantities and can be depleted. These resources are primarily fossil fuels: petroleum, coal and natural gas. Petroleum accounts for approximately 37% of the world's energy consumption. Coal and natural gas together supply approximately 48%. Uranium is another nonrenewable energy resource used in nuclear power plants. It is used for approximately 7% of the world's energy.

Renewable energy resources, of endless supply, account for approximately 8% of the world's energy consumption. Hydroelectric power, derived from running water, is the most widely used form of renewable energy. These resources also include biomass (from plants, garbage and agricultural waste), solar, geothermal (heat energy within the earth) and wind. Researchers continue to study other sources of energy, among them nuclear fusion and a variety of hydrogen-based technologies.

Nuclear Energy

Nuclear energy is sometimes called atomic energy because it involves the atom, the basic unit of all matter. Great amounts of energy are released either when an atom is split apart or fused with other atoms. The splitting of the nuclei of atoms is called nuclear fission. This process is conducted in nuclear power plants. "Nuclear power" is defined as nuclear energy that has been processed to generate electricity. Nuclear fusion, the same reaction that powers the sun, takes place when nuclei of atoms are forced together. Fusion technology is still in the experimental stages.

The nucleus, or central part, of an atom contains protons (positively charged) and neutrons (neutrally charged). Electrons (negatively charged) orbit the nucleus. The nucleus of unstable elements, such as uranium and plutonium, can be split apart as neutrons from one atom bombard the nucleus of other atoms. This causes a chain reaction, creating vast amounts of radiant heat energy. In a nuclear power plant, the chain reaction is controlled and adjusted at a fixed rate.

The TMI Nuclear Reactors

Most nuclear reactors in power plants use uranium as their fuel. Uranium in its natural form (99.3% uranium-238 and .7% uranium-235) is collected from underground mines. It is processed and enriched to contain more uranium-235, usable as a fuel for fission. In typical reactors uranium is formed into ceramic pellets and placed into metal fuel rods. A nuclear reactor's core contains fuel rods and control rods in an enclosed unit. The control rods are used to slow down or stop the fission process. This is accomplished when control rods are lowered to absorb neutrons and prevent them from splitting other neutrons. The Three Mile Island Unit 2 reactor (TMI- 2) contained 69 control rods and 36,816 fuel rods (208 rods, each 12 feet in length, housed in 177 assemblies).

TMI-2 was a pressurized water reactor (PWR). In such reactors, there is a primary water loop, a closed system that serves a dual purpose: it cools the fuel rods so the core does not overheat, and it transfers heat from the fission process. The water in this loop is pressurized and does not boil when contacting the fuel rods, although the average temperature is 580^{o}F (304.4^{o}C). This water becomes radioactive as it flows around the fuel rods. The heated water exits the core to a steam generator tank. Here, the heat is transferred to a separate supply of water, the secondary water loop. The water in this system is not radioactive. In this loop, the water boils to produce steam. The steam turns the blades of a turbine, which drive a generator to produce electricity.

Nuclear Waste and Environmental Impacts

The splitting of unstable atoms in the fission process produces radioactive particles. Therefore, the waste products from nuclear power plants are radioactive. Large amounts of radiation can be hazardous to living things. The biological effects of radiation are measured in millirems. An adult residing in the United States receives an average of 360 millirems of radiation per year: 300 from natural sources (e.g., the human body, the sun and soil) and 60 from other sources (e.g., televisions, microwaves and coal-fired power plants). According to Nuclear Regulatory Commission (NRC) standards, nuclear power plant workers are permitted to receive up to 5,000 millirems of radiation per year. Commonly used monitoring systems include dosimeters and Geiger counters. Dosimeters measure accumulated radiation doses over a specific period of time. Geiger counters measure radiation levels at the actual time of use.

Small amounts of radioactive particles are vented into the atmosphere during nuclear power production. Low-level radioactive waste are sealed in steel containers and buried at several federally-licensed sites. High-level radioactive waste, such as spent nuclear fuel, can be hazardous for thousands of years. At this time, there is no permanent disposal site for high-level nuclear waste. On June 2, 2008 the U.S. Department of Energy filed its application with the Nuclear Regulatory Commission for a license to move ahead with building the nation a nuclear waste repository at the Yucca Mountain in Nevada. The site is 90 miles outside of Las Vegas, near fault lines only 8 miles from the site of the 1992 earthquake. The DOE is asking for permission to build this repository without a standard yet established for how much radiation may be “safely” released from the site over the long centuries ahead. Commercial reprocessing of nuclear waste in America has been hampered by costs and concerns over nuclear proliferation.

Nuclear power plants have an adverse impact on aquatic ecosystems. Water consumption, fish kills, chemical leaks, thermal inversion and effluent discharges are under reported consequences of nuclear power plants.

The TMI Unit Two Accident

Websites:
Report of the President's Commission on the Accident at Three Mile Island

Three Mile Island Alert: www.tmia.com
National Academy of Engineering/Online Ethics Center: onlineethics.org

The accident began on Wednesday, March 28, 1979, at approximately 4:00 A.M. EST. Sources agree that the secondary water supply to the steam generators shut down during routine maintenance in the non-nuclear section of the plant. The turbines and electric generators automatically stopped. Emergency feedwater pumps, which were backups used to cool the steam generators, started to run; however, valves were mistakenly closed on each of the water lines so that no water reached the generators. Eight minutes into the accident, an operator discovered that the backup feedwater valves were closed. He immediately opened them, allowing much needed water to flow to the steam generators through the secondary water loop.

Meanwhile, secondary problems caused heat and pressure in the primary water loop to increase. The pilot-operated relief valve (PORV) automatically opened as the pressure rose. Steam and water began to flow out of the primary water loop to a drain tank on the floor. Also, the control rods automatically dropped in the reactor's core to stop the fission process. Although the fission process was halted, heat continued to be produced by the reactor due to the spontaneous disintegration of radioactive fission products, known as decay heat.

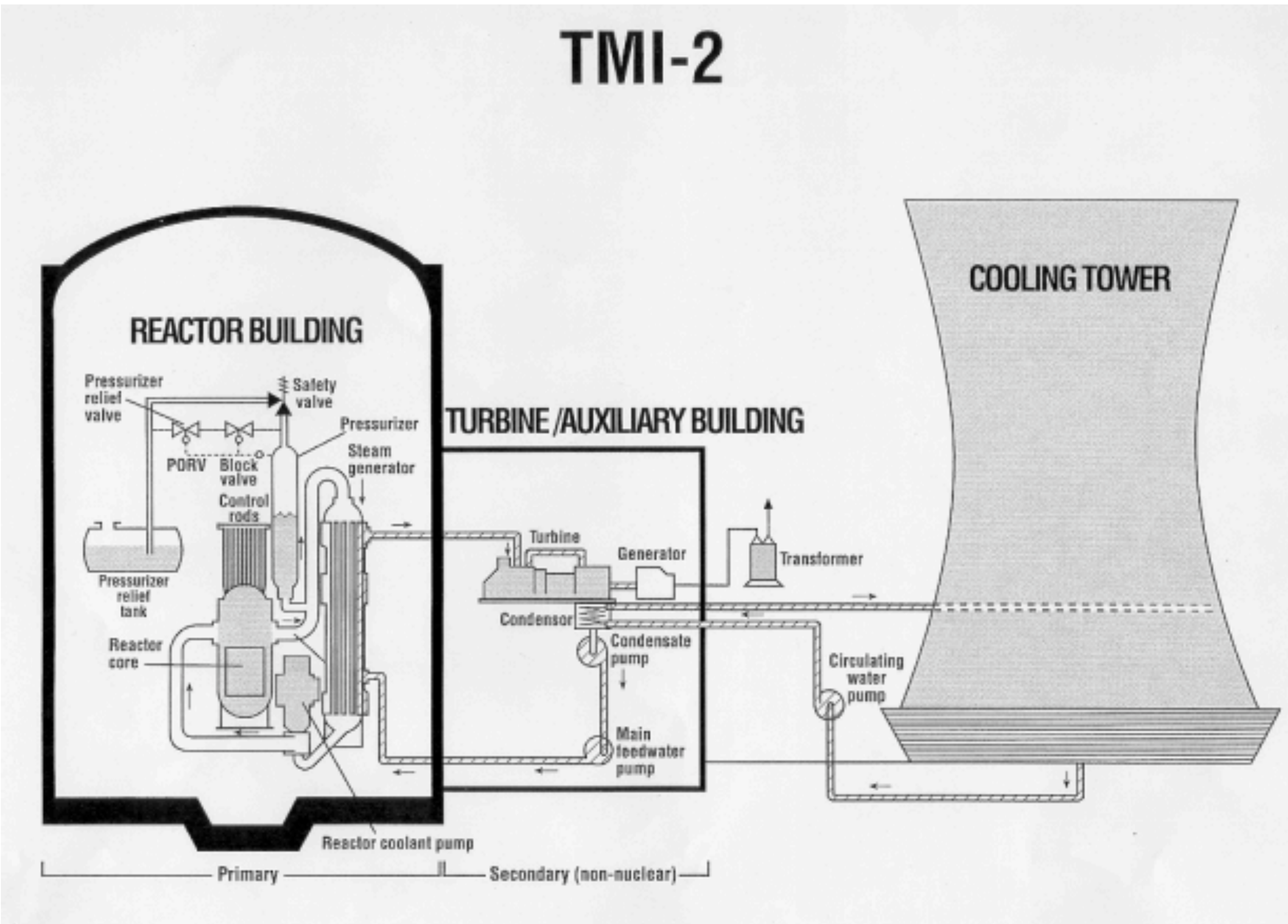
The PORV was supposed to close as pressure dropped, but it failed to do so. Backup emergency pumps started due to the low pressure and began refilling the primary water loop, but the operators turned these pumps off because a gauge indicated that the primary water loop had too much water. Thousands of gallons of water left the primary system through the PORV. Sources agree that a combination of human error and equipment failure caused the accident.

Due to the intense heat and lack of sufficient cooling, the nuclear core was not covered with water. Known as a Loss of Coolant Accident (LOCA), the exposed core reached temperatures over 5,100^{0}F (2,815.6 ^{o}C), water turned to steam in the reactor, nuclear fuel melted, and radiation levels increased. Radioactive gases were vented into the atmosphere. On March 30th, Governor Thornburgh recommended that people living within ten miles of the plant remain indoors. He also advised that pregnant women and young children within a five-mile radius be evacuated.

The heat caused the metal fuel rods, containing zirconium, to react with steam, producing hydrogen gases that burned in the containment structure. Several days after the initial incident, hydrogen was still present. A “hydrogen bubble” caused concern because some believed it could create a major explosion, if the hydrogen content was high enough. Others believed there was no danger of an explosion.

After several days, the hydrogen bubble subsided. As a result of the accident, in which a partial core meltdown occurred, issues of recovery and clean up needed to be addressed. Radioactive gases were vented into the atmosphere and radioactive water was discharged into the Susquehanna River. There was no consensus regarding the amount of radiation released into the environment.

The accident at TMI-2 was the most serious in U.S. commercial nuclear power history. As a result of this accident, changes were made in the nuclear power industry.



Courtesy of U.S. Nuclear Regulatory Commission:
www.nrc.gov

Elementary Lesson Plans

National Science Education Content Standards: F
PA Academic Standards: 4.2
Subject areas: Science, Social Studies, Language Arts

Unit Objectives

Students will:

1. Define “energy” and identify various energy resources.
2 Explain and demonstrate the basic processes in nuclear power plants.
3. Describe and illustrate the TMI-2 accident.
4. Organize information gathered about the accident and its effects.
5. Classify information as fact or opinion.

Activity 1: Introduction to Energy

Objective

Students will define "energy" and identify different energy resources.

Materials

“Background Information”, encyclopedias or Internet access, magazine pictures, poster board or large construction paper, glue, scissors

Procedure

Direct students to use resources available (encyclopedia or Internet) to define “energy," in simple terms. (Energy is the ability to do work.)
Review: Work is done when something moves or changes. Potential energy is stored energy or the energy an object contains. Kinetic energy is energy in motion or at work.

Discuss the forms of energy: heat, mechanical, electrical, chemical, light and nuclear. Have students list where these kinds of energy are used. Heating homes, running cars and electrical appliances require energy to work.

Introduce the fuels or resources needed to produce energy. Relate how our bodies use food as fuel to help us function or give us energy. As a class, list types of energy resources or fuels used to produce energy: coal, petroleum, natural gas, wind, water, solar, wood, etc. Have students classify and group the list of energy resources as renewable or nonrenewable. (See “Background Information.”)

Evaluation

Assignment: Instruct children to make a collage, with magazine pictures or illustrations, depicting the use of different energy resources. Have students label the fuel used to produce energy in each picture.

Activity 2: A Chain Reaction in Nuclear Energy

Objective

Students will recognize and demonstrate a chain reaction and compare it to nuclear fission.

Materials

"Background Information", dominoes, small block or box, writing/drawing paper

Procedure

See "Background Information." Explain that nuclear energy involves the central part of an atom (nucleus) being split apart. This type of reaction is called nuclear fission, and it produces great amounts of energy. Uranium atoms are widely used to conduct the fission process. A small baseball-size amount of uranium produces more energy than a ton of coal.

Demonstrate the chain reaction of nuclear fission: Have student volunteers set up track of dominoes spaced so each will hit the next. Explain that each domino represents an atom (or nucleus of an atom). Ask students to tip over the first domino and describe a chain reaction. Have students explain what would happen if they had an endless supply of dominoes.

Demonstrate control of a chain reaction: Have students set up another path of dominoes. Have student place a block or obstacle along the path. Ask students what will happen when a domino hits that spot. Relate the stopping block to a control rod in a nuclear reactor. Set dominoes in motion. After the chain reaction stops, raise the block straight up so that the domino resting on it strikes the next domino. Facilitate a discussion on the importance of being able to control a chain reaction in a power plant.

Evaluation

Students complete a diagram with explanation of nuclear fission as a chain reaction. (Students may draw atoms bombarding other atoms and splitting them apart.)

Enrichment

Assign students to create another way to explain and demonstrate the fission process.

Activity 3: Steam Turns Turbines

Objective

Students will relate a simulation of a turbine to a turbine in a nuclear power plant and explain the process.

Materials

"Background Information", kettle with spout or small vaporizer, hotplate, approximately 1 liter of water, lightweight pinwheel, large glass jug with wide mouth, diagram or picture of turbine, Internet access

Procedure

Review the process of fission: atoms split apart causing great amounts of energy. The chain reaction causes intense heat, which is carried by pressurized water to a second water system where the water turns to steam. This steam turns the blades of a turbine, which drive a generator to produce electricity.

Set up heating kettle or vaporizer next to the dominoes. (Children need to recognize the activities are related.) Pour water into kettle or vaporizer and allow several minutes for the water to boil and produce steam. Place an inverted jug directly above the escaping steam. A cloud of steam will form in the jug to verify that much steam is escaping. Set down glass jug. (Water droplets will drip on inside – condensation.)

Have students predict what will happen when a pinwheel is placed above the venting steam. Place pinwheel directly above the steam and have students observe the spinning wheel. Have students relate and compare the steam turning the pinwheel to the steam in a nuclear power plant turning the blades of a turbine.

Review: The turbine is connected to a generator that produces electricity. The electricity travels to homes and businesses by way of power lines.

Evaluation

Students will research the role that a turbine and generator play in creating electricity. Then, they will either create a diagram or find one on the Internet that shows this process. They will share, explain and display their results.

Activity 4: Reviewing Fission and Introducing the TMI Unit 2 Accident

Objectives

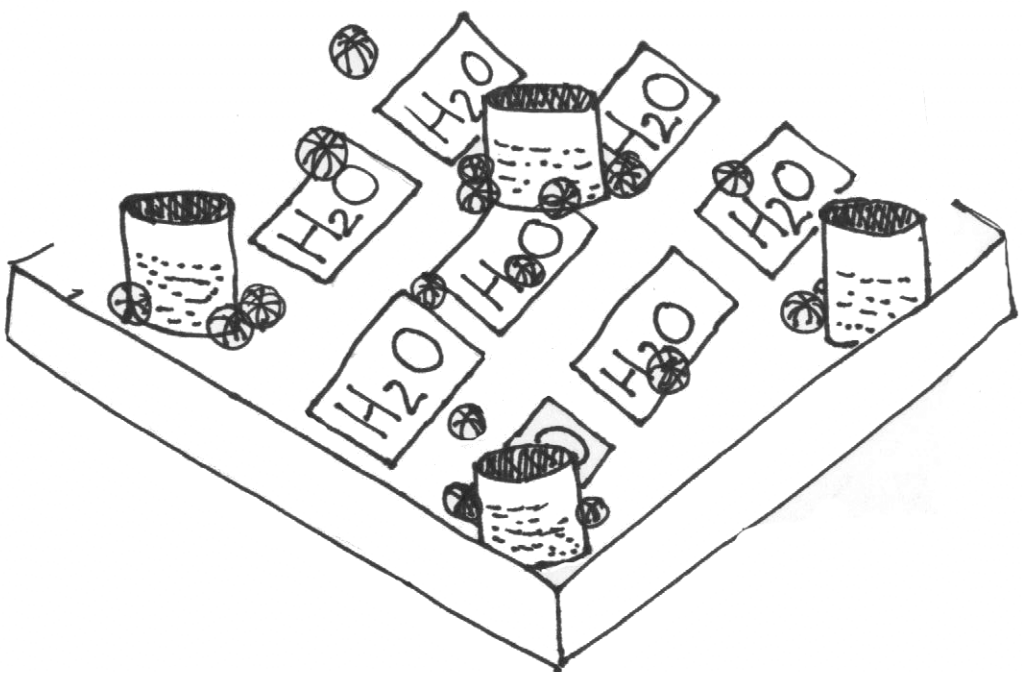
Students will explain and demonstrate the basic process in nuclear power plants.
Students will recognize a loss of coolant problem in TMI-2.

Materials

"Background Information", marbles, heavy construction paper, empty film canisters (4 or 5), duct tape or extra sticky double-sided tape, small note cards with the symbol H2O written on them, note cards with heat symbols drawn on them, Internet access and/or additional resources (see "Background Information")

Procedure I

Review "Background Information." Place a short ridge around a table by taping construction paper on sides. Place H2O cards on all areas of the table. Set 30 or more marbles on table. Have volunteer flick a marble into the other marbles to create a type of chain reaction. Discuss how each marble represents an atom, and one atom can bombard another. Explain: This demonstration shows the fission process, a chain reaction that causes intense heat. Water (coolant) must be present to keep the reactor from overheating and causing damage or melting down.



Add several inverted and taped film canisters to the tabletop to represent control rods. Wrap duct tape loosely (so marbles stick more easily) around film canister with the sticky side out. (Extra sticky double-sided tape may be used.) Have students predict what will happen when the marbles are set into motion again. Select volunteer to flick marbles. Some of the marbles should stick to the canisters. Compare and contrast this to the action of control rods in a nuclear reactor: when the rods are dropped into the reactor; they absorb all the neutrons, causing the fission process to stop.

Review and quiz students on basic concepts:
The chain reaction of fission generates heat.
Water absorbs the heat.
Water changes to steam.
Steam turns the blades of turbines.
Turbines drive generators to produce electricity.

Have volunteers explain and demonstrate the basic processes in nuclear power plants.

Evaluation

Divide students into groups to research and describe the fission process in a nuclear reactor, including the coolant system.

Procedure II

Set up table as in last activity. Ask a student to demonstrate how the fission process stops when the control rods absorb the neutrons. Remind students that, due to decay heat, a great deal of heat remains in the reactor even after the fission stops. Remove several H2O cards at a time and ask what this demonstrates. (The heat is not being removed.) Ask students to place symbols on table to indicate heat rising in the reactor. These heat symbols can be added as more H2O cards are removed. Facilitate class discussion concerning the loss of water in the accident.

Evaluation

Students participate in class discussion and draw a picture with notes describing the activity.

Activity 5: Loss of Coolant in the TMI-2 Accident

Objective

Students will describe and illustrate the TMI-2 accident.

Materials

"Background Information", hotplate (double burner preferred), 2 similar candles (votive style works well), 2 similar steel pans, aluminum foil, water

Procedure

Review the process of nuclear fission and the need to keep a reactor from overheating.

Line the inside of each pan snuggly with aluminum foil. Pour small amount of water in one pan. (Use enough water to cover ¼ of the candle. The candle should not float.) Have students predict what will happen when the pans are heated. Heat only the pan containing water and wait until water comes to a rapid boil. Then start heating empty pan. After 30 seconds, place a candle in each pan. Have students observe changes in candles. Discuss observations and compare to the lack of coolant in the TMI-2 accident. Even though the water is boiling rapidly at 212°F (100°C), the empty pan melts the candle more quickly.

Evaluation

Instruct students to divide a drawing paper in half to illustrate candle activity. Have students include annotated drawings and a paragraph explaining how this experiment relates to the loss of coolant (water) in the TMI-2 accident.

Enrichment

Do Middle School Activity #3.

Activity 6: The Effects of the TMI Accident: Facts and Opinions

Objective

Students will research, organize and report on the TMI-2 accident, including the effects of the accident.

Materials

"Background Information", internet access, periodicals, and personal accounts

Procedure

Define the terms *fact* and *opinion*. Give statements concerning the effects of the TMI-2 accident and have students classify each statement as fact, opinion or not known. Examples: Some people evacuated due to the accident. (fact)
The accident proved that nuclear power cannot be made safe. (opinion)

Homework: Instruct students to gather information and several statements regarding the effects of the TMI accident. Sources should be cited. As a class, students share their statements to be listed on board. Facilitate discussion about whether statements are facts or opinions. Some information may be believed to be factual, but later disproven. Allow for different responses.

Evaluation

The students gather information and participate in discussion. Students complete listings of facts and opinions related to the effects of the TMI accident.

Enrichment I

Pass out index cards to students labeled *Fact*, *Opinion* and *Not Known*. State ideas concerning the accident and the resources they were taken from. Have students hold up the appropriate card after each statement. Allow for conflicting answers.

Enrichment II

Do Middle School Activity #4.

Middle School Lesson Plans

National Education Content Standards: F
PA Academic Standards: 3.4, 3.8, 4.2

Unit Objectives

Students will:

1. Recognize the increasing need for energy resources and compare various energy resources.
2. Identify the parts of a nuclear reactor.
3. Research and explain the processes in nuclear power plants.
4. Describe and illustrate the TMI-2 accident.
5. Use a variety of sources to research and report on the effects of the accident: emotional and physical health issues, economic ramifications, and changes in the nuclear power industry.
6. Compare the TMI-2 accident to the Chernobyl accident.

Activity 1: Comparing Energy Resources

Objective

Students will recognize the increasing need for energy resources and compare various energy resources.

Materials

"Background Information", internet access, encyclopedias, additional resource books, library

Procedure

Review Energy Resources in "Background Information." List energy sources: petroleum, coal, natural gas, propane, uranium, wind, solar, water, geothermal and biomass. Have students categorize resources as renewable or nonrenewable.

Divide students into small groups and assign each group an energy resource to research and present to class. Student groups are to note what each member's responsibility is: researching and note-taking, report writing, revising or class presentation. Each group should include information relating to the safety, the efficiency, the environmental impact and the cost of its resource.

Evaluation

The students present their research to the class with a list of each participant's contribution.

Enrichment

Have students imagine they are frontiersmen in a new land where rapid population growth is expected and all the modern day technologies are available. Have them assume that every energy resource is accessible and they must decide which energy source they should pursue first. Students may share in a creative writing assignment.

Activity 2: Nuclear Reactor Model Demonstration

Objective

Students will identify parts of a nuclear reactor and compare to a model. They will research and describe the basic processes that take place in nuclear power plants.

Materials

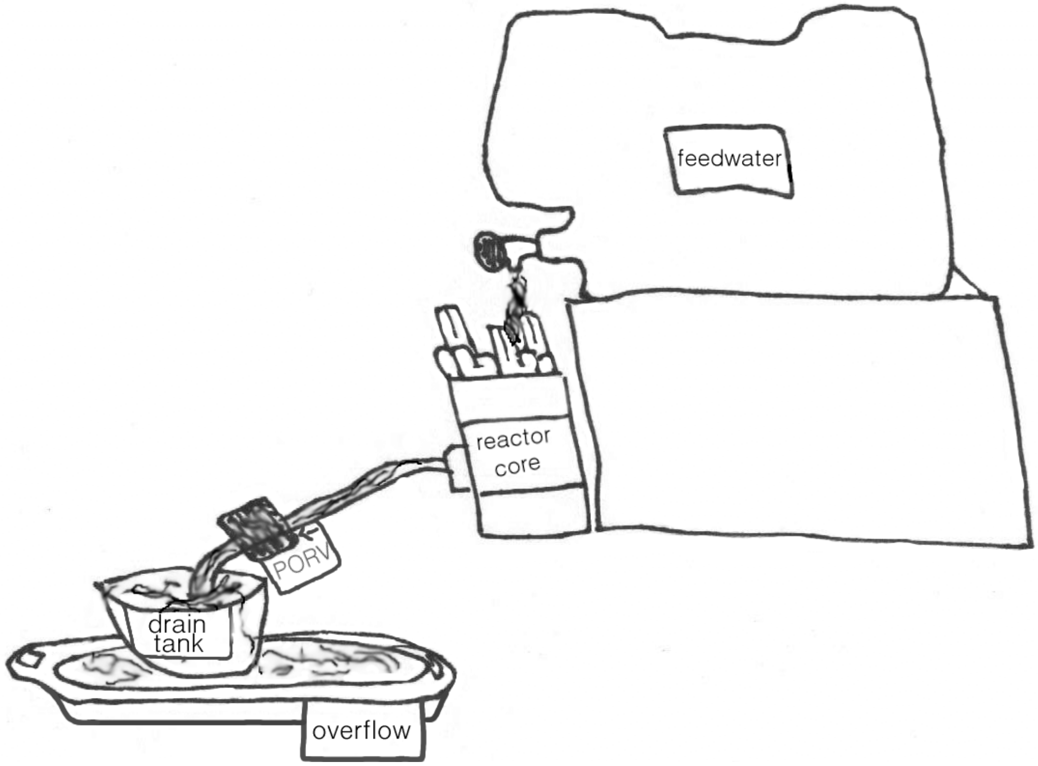
diagram of TMI-2, empty milk carton with top removed, straws (2 different colors), plastic aquarium tubing, scissors, glass bowl, thermos or container with valve at bottom, small cork or stopper (optional), duct tape, water, internet access, resource books

Procedure

Review: In a nuclear reactor, fission generates intense heat. The heat is transferred to a secondary water system, where the water turns to steam and moves the blades of a turbine. The turbine drives a generator to produce electricity. (See elementary lessons, if needed.)

Note: The following model will represent the reactor core with fuel rods and control rods, feedwater leading to the reactor, and a pressure release system in a reactor. (It will not demonstrate water leading to the steam generators.)

If pressure becomes too high in the reactor, the PORV opens and excess pressure is released. Water and steam may also be released. Water exits through a pipe leading to a drain tank on the floor of the containment building.



Set up model of nuclear reactor: Poke hole on side of cut milk carton, approximately 5 cm. from bottom. Push plastic tubing slightly into the hole and secure with duct tape**.** Place other end of tubing into empty bowl. Set thermos with water, or water container with valve, above the milk carton. Fill milk carton with 2 different colored straws to simulate fuel rods and control rods.

Have students identify the parts of the model by comparing to a diagram of TMI-2: reactor building (milk carton), fuel rods (straws), control rods (different colored straws), feedwater (thermos with water), PORV (stopper or pinched area) and drain tank.

Turn valve on thermos to release water into carton (reactor). Water should flow around straws (rods) and empty through tubing (pipe with PORV) to bowl (drain tank). Demonstrate and explain how the model relates to a nuclear reactor. Have volunteers demonstrate and describe the water or coolant passing through a nuclear reactor.

Evaluation

Students research the basic processes that take place in nuclear power plants, using the following resources: Internet access, resource books, encyclopedias, periodicals, etc. Instruct students to illustrate and explain their findings.

Enrichment I

Have students research and create a classroom mural with a timeline of nuclear technology. (They may begin in 1942, when Dr. Enrico Fermi succeeded in controlling a nuclear chain reaction.)
See US Department of Energy,"DOE Timeline."
www.energy.gov/about/history.htm

Enrichment II

Do High School Activity #3.

Activity 3: Simulating the TMI-2 Accident

Objective

Students will describe and illustrate the TMI-2 accident.

Materials

Same as Activity #2; plus, "Background Information", high range thermometer capable of reading at least 392°F (200°C), double hotplate (single burner may be substituted), two similar steel pans with insulated handles, water

Procedure I

Demonstrate the loss of coolant in reactor simulation:

Set up reactor model as in last lesson. Begin by clogging the tube in the bowl either by inserting the cork or stopper, or by pinching the tube. Fill milk carton with water. Have student demonstrate and describe the accident by opening the PORV (unclog tubing in bowl), but keeping the feedwater lines (thermos valve) closed. As the water drains from the milk carton (reactor), have students explain why this is a concern.

Review the event and discuss the problem: operators mistakenly believed the feedwater valves were turned on and water was entering the reactor. After discussion, turn on valve of thermos (feedwater) to demonstrate that the error was noticed and resolved.

Procedure II

Demonstrate the intense heat that occurs with a loss of coolant problem:

Place two pans on a double burner hotplate. Pour water in one pan, approximately ½ full. Allow the pan with water to boil. Then turn on the burner with the empty pan. Leave both burners on for one minute and record temperatures on bottom of each pan. Compare temperatures. The pan containing the boiling water remains at 212°F (100°C). The other pan will exceed 392°F (200°C). Discuss findings.

Evaluation

Have students research the accident and write an outline of events. (See websites in “Background Information.")

Enrichment

After writing the daily events of the TMI-2 accident in first person, diary form, each student can present a monologue to the class. Cultural aspects of the 1970’s can be incorporated into each presentation, including clothing, music, etc.

Activity 4: The Effects of the Accident

Objective

Students will use a variety of sources to research and report on the effects of the accident: emotional and physical health issues, economic ramifications, and changes in the nuclear power industry.

Materials

See “Background Information”, “Resources”, periodicals, internet access, personal interviews, map of Middletown, PA, and surrounding counties, population data, protractor and compass

Procedure

View map of area surrounding the TMI Nuclear Power Plant. Have students use a protractor and compass to measure and list counties, cities, etc., within a 5, 10 and 20 mile radius.

Review population within perimeters at the time of the accident:
5 miles = 28,800
10 miles = 166,300
20 miles = 743,600
50 miles = 2,166,000

Discuss effects of the accident: emotional and physical health issues, economic ramifications, and changes in the nuclear power industry.

Brainstorm possible resources about the effects of the TMI-2 accident: periodicals, Internet, personal interviews, etc. Assign research data to be collected from a variety of sources about the effects of the accident (listed above).

Review data in class, citing the resources. Discuss which sources may be biased or neutral. Compare the positive and negative impacts.

Evaluation

Students use data collected in class and independently to create a poster which shows the immediate and long term effects of the TMI-2 accident: pictures, summaries of interviews (two opposite view points are suggested), changes in the industry, possible health effects, etc. Sources should be cited.

Students compile their research and create a web outline of the effects of the accident on poster board. (Place the accident in center and have arrows extending outward to summaries of interviews, pictures, and statements.)

Activity 5: Comparing the TMI-2 Accident to the Chernobyl Accident

Objective

Students will research and compare the TMI-2 accident to the Chernobyl accident.

Materials

research materials, internet access, See "Resources."
http://lcweb.loc.gov/exhibits/archives/cher.html

Procedure

Introduce accident at Chernobyl. The worst industrial accident in world history occurred in 1986 at the Chernobyl nuclear power plant, located in the Ukraine (formally the USSR). An explosion occurred in the number 4 reactor, which blew the lid off the reactor. Thirty-one people lost their lives immediately, and millions were exposed to high levels of radiation. Thousands have died due to radiation fallout and many future deaths and birth defects have been attributed to this accident.

Instruct students to use a variety of sources to compare the TMI-2 accident to the Chernobyl accident. Students should compile information on index cards comparing construction of the nuclear reactors, causes for the accidents and the effects of the accidents. Facilitate class discussion on findings.

Evaluation

Divide students into three groups. Instruct each group to create a Venn diagram comparing the TMI-2 accident to the Chernobyl accident. Each group will be assigned one of three Venn diagrams to complete using their research data: reactor construction and operations, causes of the accidents, and the effects of the accident.

(A Venn diagram is a symbolic drawing of overlapping circles, which shows the relationship between ideas or sets. The overlapping section would be the characteristics that are in common.)

High School Lesson Plans

National Science Education Content Standards: E, F
PA Academic Standards: 3.4, 4.2
Subject areas: Science, Social Studies, Language Arts

Unit Objectives

Students will:

1. Review and define basic energy concepts, primarily nuclear energy.
2. Research and report on the advantages and disadvantages of the nuclear power industry.
3. Create and demonstrate a model of the Three Mile Island Unit 2 reactor.
4. Describe and illustrate the TMI-2 accident.
5. Use a variety of sources to determine the short and long term effects of the accident.
6. Debate the use of the nuclear power as an industry.

Activity 1: Reviewing Energy Concepts

Objective

Students will review and define basic energy concepts, primarily nuclear energy.

Material

"Background Information", internet access, resource books

Procedure

Facilitate a class discussion to determine students' knowledge of energy, and in particular, nuclear energy.

Review concepts if needed:

Energy cannot be created or destroyed ("Conservation of Energy"). It can change form. Electrical, heat, mechanical, chemical, light and nuclear energy are the six basic forms of energy. An example of energy changing form is solar heat energy being transformed into electricity.

Matter can be transformed into energy: $E=MC^2$.

Energy sources can be classified as renewable or nonrenewable. (See "Background Information.")

Uranium ore is enriched to contain more uranium-235 to be useable as a fission fuel for nuclear power plants.

Review the fission process involved with nuclear energy. (See "Background Information.") Demonstrate Middle School activities, if needed.

Evaluation

Give short quiz on basic energy concepts.
Review with activities from Middle School if needed.

Activity 2: The Pros and Cons of the Nuclear Power Industry

Objective

Students will research and report on the advantages and disadvantages of the nuclear power industry.

Materials

"Background Information", internet access, resource books, periodicals, personal interviews

Procedure

Facilitate a class discussion about the advantages and disadvantages of nuclear power. Allow students to formulate their own ideas.

Instruct students to write a research paper about the advantages and disadvantages of nuclear power, using a balanced variety of sources: pro-nuclear power, anti-nuclear, and as unbiased as possible.
Research data may include: potential energy supplies for the future and the environmental effects on air and water.

Have students share ideas with the whole class and/or in small groups.

Evaluation

Students research and report on the pros and cons of nuclear power, including a bibliography from a balanced variety of sources.

Enrichment

Have students role play as if they are members of a city council and need to decide whether or not to allow a nuclear power plant to be built within the city limits.

Activity 3: Creating a Model of the TMI-2 Reactor

Objective

Students will create and demonstrate a model of the TMI Unit 2 reactor.

Materials

"Background Information", diagram of TMI-2 reactor, internet access, computer graphics program (optional), Middle School Activity #2

Procedure

Set up model as in Middle School Activity #2. Pass out diagram of TMI-2 and have students compare to model.

Assign students to work in small groups or independently to design their own model of the Unit 2 reactor. Instruct students to draw blueprints of their reactor model with labels: reactor containment building, reactor core, fuel rods, control rods, water systems, steam generator, pressure relief valve (PORV), safety valve, block valve, pressurizer, reactor coolant pump and drain tank. Students may include turbines and generator. Have students list the materials needed for their model and describe their design ideas.

Evaluation

Students use their designs to construct a model of the Three Mile Island Unit 2 reactor with major parts labeled. (Parts may be color coded with a reference key.) A written report describing the model and an explanation of the fission process should be included. Have students present and share their models in class.

Enrichment

Encourage students to ask their own questions concerning nuclear power plants. Then instruct students to research and answer their own questions.

Activity 4: Simulating the TMI-2 Accident

Objective

Students will describe and illustrate the TMI-2 accident

Material

"Background Information", websites listed in "Resources", students' models constructed in last lesson, Internet access, resource books, periodicals, computer room, library

Procedure

Review the websites listed in "Resources." Have students access them to research the TMI-2 accident and print out a timeline of the event from the "Report of the President's Commission on the Accident at Three Mile Island":

National Academy of Engineering: Online Ethics Center
onlineethics.org

Three Mile Island Alert
www.tmia.com

Students may summarize and write a simplified timeline, which includes details of the loss of coolant problem and the hydrogen bubble concern. Set up small groups for students to discuss their findings.

Students demonstrate the accident with their models and plan a presentation to the class.

Evaluation

Students present their explanation of the accident with a demonstration, using their selected models.

Enrichment

Teachers use discretion in having students view *The China Syndrome*. Facilitate a class discussion comparing and contrasting the movie to the accident at TMI-2. (See Resource Guide.)

Activity 5: The Effects of the Three Mile Island Unit 2 Accident

Objective

Students will use a variety of sources to determine and report on the short-term and long-term effects of the accident.

Materials

Internet access, websites listed in “Resources”, periodicals, personal interviews

Procedure

Have students use a variety of balanced resources to investigate the short-term and long-term effects of the TMI-2 accident. Encourage students to go beyond the resource books and Internet. Personal accounts and newspaper articles (on Microfiche) may add a different perspective. The effects should include emotional and physical health issues, economic ramifications, and changes in the nuclear power industry.

Students may work independently or in small groups to research the different effects of the accident.

Evaluation

Students complete research and report in written form or as a presentation.

Enrichment

The definitions and biological health effects of different forms of radiation may be assigned for clarification: alpha radiation, beta radiation and gamma radiation.

The use of potassium iodide pills may be researched as a method to block radiation effects in the thyroid.

Nuclear decay including the half-life (time period it takes for half of the element to decay into other elements) of Uranium-235 may be researched.

Activity 6: Debate Nuclear Power as an Industry

Materials

Students' cumulative research data

Objective

Students will debate the use of nuclear power as an industry.

Procedure

Inform students that they will be conducting a debate on the use of commercial nuclear power for a growing population of energy resource needs. Pass out slips of paper. Have students write their names on the paper and vote “yes” in support of or “no” against the continuing use of nuclear power. After votes are tallied, divide students into their supporting groups. Students meet in two groups to select four or five debaters. The remaining group members will analyze their research and write notes for speakers to include in their debate. Allow sufficient time for groups to meet and corroborate.

Evaluation

Students assess relevant research data and either fill the roles of debaters or team supporters for the nuclear power debate.

Enrichment

As an ongoing project, have students collect current news items related to nuclear energy listed on state, federal and action groups’ websites. Articles may be summarized and displayed on poster or bulletin board.

Motivated students may choose to voice their opinions related to the nuclear power industry by contacting state representatives and state and federal agencies.

Academic Standards

PA Academic Standards for Science and Technology:

Physical Science, Chemistry and Physics	3.4
Science, Technology and Human Endeavors	3.8

PA Academic Standards for Environment and Ecology:

Renewable and Nonrenewable Resources	4.2

www.pde.state.pa.us

National Science Education Content Standards:

Physics	B
Science and Technology	E
Science in Personal and Social Perspectives	F

www.nsta.org/publications/nses.aspx

Resources

Archives and Websites

Alliance to Save Energy: Lesson plans for grades 4-6.
www.ase.org/educators

Dickinson College, Carlisle, PA
Library: Archives and Special Collections
www.dickinson.edu

Energy Quest: Energy News
www.energyquest.com

Energy Information Administration: Official Statistics
www.eia.doe.gov

EFMR Monitoring Group, Inc.: Resource and Monitoring Center
www.EFMR.org

The Federal Emergency Management Agency (FEMA)
www.fema.org

George Mason University- ECHO (Exploring and Collecting History On-line Program)
echo.gmu.edu

History Channel: videos and articles
www.historychannel.com

How Stuff Works: Nuclear Power
www.howstuffworks.com

Inside TMI: Minute by Minute:
http://kd4dcy.net/tmi/

International Atomic Energy Agency (IAEA)
www.iaea.org

Library of Congress: Revelations from the Russian Archives
Chernobyl' Information:
http://lcweb.loc.gov/exhibits/archives/cher.html

National Academy of Engineering: Online Ethics Center
onlineethics.org

National Science Education Standards
www.nap.edu/html/nses

NEED Project: Energy Education
www.need.org

Pennsylvania Department of Education: Academic Standards
www.pde.state.pa.us

Pennsylvania Department of Environmental Protection (DEP)
www.dep.state.pa.us

Pennsylvania Emergency Management Agency (PEMA)
www.pema.state.pa.us

Public Broadcasting Station (PBS): <u>Meltdown at Three Mile Island</u>.
www.pbs.org

Report of the President's Commission on the Accident at Three Mile Island:
This document that was presented to President Jimmy Carter in 1979:

onlineethics.org	National Academy of Engineering
www.tmia.com	Three Mile Island Alert

Three Mile Island Alert: Website hosted by a non-profit citizens' group dedicated to promoting safe energy alternatives while monitoring the safety of TMI.
www.tmia.com

Union of Concerned Scientist: Energy Solutions
www.ucsusa.org
Contact Person: Mr. David Lochbaum, Nuclear Safety Engineer

U.S. Nuclear Regulatory Commission:
www.nrc.gov

U.S. Nuclear Regulatory Commission: TMI Accident
www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html

Virtual Nuclear Tourist: Joseph Gonyeau's introduction to nuclear power for all age levels.
www.nucleartourist.com

Books

Brennan, Kristine. *The Chernobyl Nuclear Disaster*. Philadelphia, PA: Chelsea House, 2002. (age 12+)

Cole, Michael D. *Three Mile Island Nuclear Disaster*. Berkeley Heights, NJ: Enslow Publishers, Inc., 2002. (age 10+)

DeAngelis, Therese. *Three Mile Island: Great Disasters: Reforms and Ramifications.* Philadelphia, PA: Chelsea House, 2002. (age 12+)

Goldstein, Natalie. *How Do We Know: The Nature of the Atom*. New York: The Rosen Publishing Group, Inc., 2001. (age 9+)

Hampton, Wilborn. *Meltdown: A Race Against Nuclear Disaster at Three Mile Island: A Reporter's Story.* Cambridge, MA: Candlewick Press, 2001. (age 12+)

Henderson, Harry. *Nuclear Physics*. New York: Facts of File Inc., 1998. (age 12+)

Milne, Lorus J. and Milne, Margery. *Understanding Radioactivity*. New York: Atheneum, 1989. (age 9+)

Pringle, Laurence. *Nuclear Energy: Troubled Past, Uncertain Future*. New York: MacMillan Publishing Co., 1989. (age 12+)

Multimedia

Meltdown at Three Mile Island. Gazit, Chana, Steward/Gazit Productions, Inc., Film for The American Experience, WGBH Educational Foundation, 1999. Documentary; includes a comprehensive lesson plan.
www.pbs.org

Modern Marvels: Inviting Disaster. Chiles, James, The History Channel, 2003. Documentary; explores causes and effects of accidents related to modern technology, including TMI.
www.historychannel.com

The China Syndrome. Columbia Tristar, 1979. Rated PG. (This PG rating precedes the MPAA's PG-13 classification system. It is recommended that teachers preview this film.) Starring Jack Lemmon, Jane Fonda and Michael Douglas, *The China Syndrome* dramatizes a fictional nuclear accident. This film-- considered by many people to have a strong anti-nuclear bias-- was released 12 days prior to the TMI accident. During the chaotic days as the accident unfolded, many news reporters watched the film in order to help them understand how nuclear power plants work.

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