RADON LESSON PLAN

Introduction

Radon is a cancer-causing, naturally occurring radioactive gas that you cannot see, smell, or taste. Radon emanates from soil and bedrock, including granite, and can seep into homes primarily through cracks and seams in foundation floors and walls. It may also enter through well water.

Communities in southeastern and eastern New Hampshire have the highest percentage of homes with elevated radon levels. Rockingham, Carroll, and Stafford counties have several communities in which more than half of the homes tested had elevated radon. Exposure to radon gas is the second leading cause of lung cancer in the United States, with more than 21,000 deaths attributed annually to radon-related lung cancer. Radon is associated with approximately 100 lung cancer and related deaths in New Hampshire residents each year.

The mission of the New Hampshire Radon Program is to help all people in New Hampshire understand the health impacts of radon. To reach the younger population, the New Hampshire Division of Public Health Services and the New Hampshire Radon Program have developed curriculum with a primary focus on raising awareness among youth on the health effects and mitigation of radon.

This lesson plan is adapted from the Colorado Seventh Grade Science Radon Lesson Plan. Efforts have been made to adapt this lesson plan to fit within New Hampshire's Common Core State Standards and the Next Generation Science Standards performance expectations. Please see the following page for the specific academic standards met by this lesson plan.

CONTACT INFORMATION

Lynne Clement
NH Radon Program
Division of Public Health Services
NH Department of Health and Human Services
Phone: 603-271-1708
Email: lynne.m.clement@dhhs.nh.gov

STANDARDS MET

Common Core State Standards for ENGLISH

Reading Standards for Literacy in Science and Technical Subjects

1. Cite specific textual evidence to support analysis of science and technical texts.
2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

Common Core State Standards for MATHEMATICS - 7th Grade

The Number System

- Apply and extend previous understandings of operations with fractions to add, subtract, multiply, and divide rational numbers.

Next Generation Science Standards

MS-LS1-1. Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.
MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.
MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
MS-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

Health Education Curriculum Guidelines - Middle School Curriculum

Community and Environmental Health

1. Community and Environmental Health Services
    - 1.1 Identify home, school and community resources to promote health
    - 1.2 Identify how to access health agencies
    - 1.3 Identify Public Service Community Health Activities
2. Environmental Health and Resource Conservation
    - 2.1. Recognize environmental health risks
    - 2.2 Analyze the community for health problems

LESSON PLAN OBJECTIVES

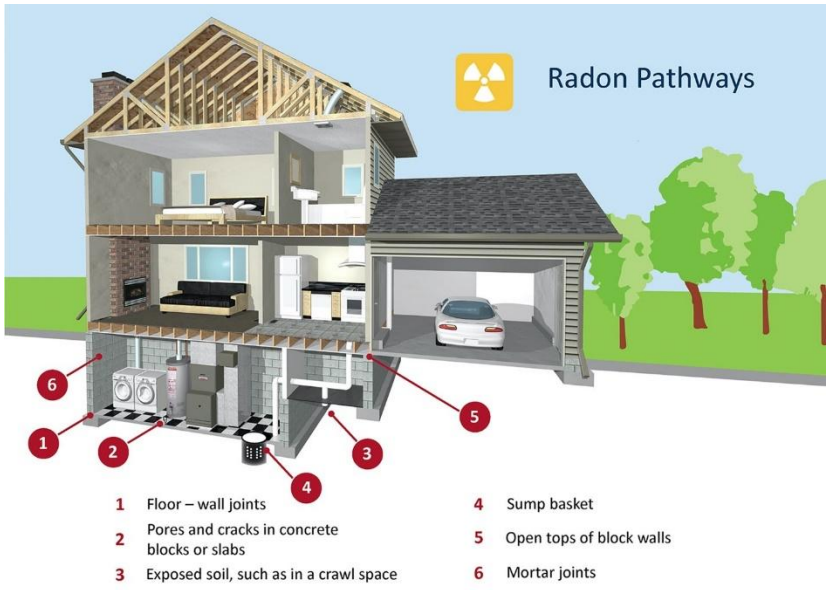
Students will be able to:

- Recall properties of radon
- Explain how radon is formed
- Distinguish between the types of ionizing radiation and compare their ability to damage DNA
- Identify what events may occur if a cell is damaged
- Describe how radon impacts health
- Describe how radon enters homes
- Identify forces and processes that result in increased or decreased radon levels
- Create original messaging to advocate for radon testing

LESSON ASSETS:

Lesson Plan
Experiment
Activities & Demonstrations
PowerPoint
Student Booklet
Teacher Booklet

A minimum of four 60 minute class periods recommended to facilitate all lesson portions. The lesson plan does not require all parts to be completed.



Note: In advance of implementation, ensure to coordinate collection and/or delivery of FREE radon test kits for the number of students applicable to the implementation of this lesson, from your local public health agency. NH residents can order free radon test kits through this order form.

For questions or more information, contact the New Hampshire Radon Program at (603) 271-1708 and radon@dhhs.nh.gov.

PART 1A: RADON & RADIATION — RECOMMENDED TIME: 60 MINUTES

QUESTIONS:

What is radon and how is it formed?
What is ionizing radiation and what are the differences between the different types?

Materials: Projection/Smartboard, Radon PowerPoint, Student Radon Booklets (printed for each student), 10 dominoes per group, and 3 balls per group (1 small Styrofoam ball, 1 small plastic ball and 1 tennis ball)

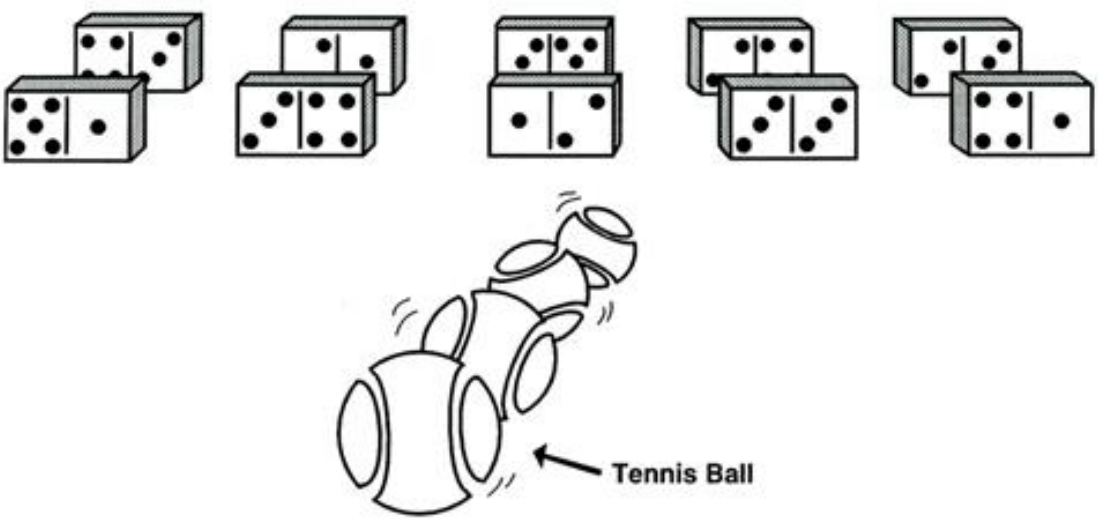
Slides 1-15: Introduce radon through presentation and student engagement with content of Radon PowerPoint and Student Radon Booklets.

Activity 1: "Domino DNA with Alpha, Beta, and Gamma"
(Recommended that students work in small groups)

Procedures:

1. Group representative should gather the activity materials and place them on the desk.
2. Set each domino on its long edge and spread them out leaving a four-centimeter space between each (about the length of one domino).
3. Arrange the dominoes in two parallel rows of five dominoes each. Space the rows about eight centimeters apart (about two domino lengths). Now, you should have two straight and parallel rows of evenly spaced and upright dominoes.

4. **FLICK (not roll)** the tennis ball toward the dominoes. How many dominoes were displaced or knocked down? Record the "damage" on your activity sheet.



5. Repeat steps three and four two more times to complete 3 trials.
6. Repeat steps three, four, and five using the small plastic ball, and then the Styrofoam ball.
7. Calculate the average values for each ball, and identify which type of ionizing radiation each ball represents.

PART 1B: RADON & DNA DAMAGE

RECOMMENDED TIME: 60 MINUTES

QUESTIONS:

What events may occur if a cell is damaged? How does radon impact health?

Advance Preparation:

1. Duplicate a set of puzzle pieces (Figure 3-D) for each student. You may wish to use a different color of paper for each set to help keep the sets separate. In addition, you may wish to laminate the puzzle pieces before cutting them apart.
2. For each page:
    a. Cut out the nine squares along the dashed lines.
    b. Randomly remove one of the nine pieces. (Do not remove the same piece for each puzzle.) Place eight of the nine pieces in an envelope.
    c. To provide some accommodations in this activity you may choose not to cut apart all nine puzzle pieces; leaving two or more pieces still attached to make putting the puzzle together easier.

Materials: Projection/Smartboard, Radon PowerPoint, Student Radon Booklets (blank grids on page), One per student - envelope containing puzzle pieces (eight of the nine pieces only)

Slides 16-25: Continue radon instruction through presentation and student engagement with content of Radon PowerPoint and Student Radon Booklets. Note: Answer Key to Puzzle on Slide 27

Activity 1: "Life Goes On!"

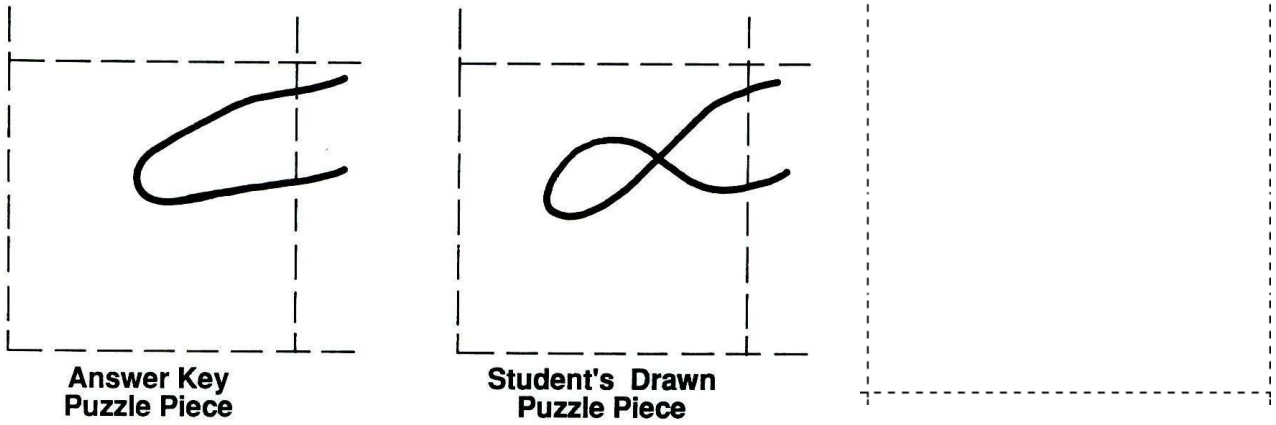
Teacher Instructions:

a. Remind the class that *this activity will simulate what happens to a cell after it is damaged by ionizing radiation*. Explain that each student will be given an envelope which contains eight pieces out of a nine-piece puzzle and a nine-square grid. The puzzle represents a damaged cell. The completed puzzle is one continuously drawn line (i.e., all lines are connected and do not go off the grid).
b. Don't tell the class that each student has the same puzzle, but with different missing pieces. Students should work individually and not peek at their neighbor's puzzle pieces. It will destroy the point of the activity to look for the missing piece that a neighboring student may have.
c. Give students from three to ten minutes to put the puzzle together on the blank grid. The amount of time to assemble the puzzles will vary each time depending on the class. Judge the amount of time to allow in each class based on the number of students that put the puzzle together. Have students stop when only a few students have not assembled the puzzle so that only a few "cells" die. Most students should be able to assemble the eight pieces.
d. Once the pieces are assembled on the grid (the grid is in their student booklet), they should attempt to draw the missing piece in the blank grid space. Explain to students that putting together the puzzle pieces and drawing the missing piece represents the cell's attempt to repair itself.
e. Emphasize that there is no wrong answer. Students have not failed if they are not able to assemble their puzzle within the time limit. The level of difficulty for each student will depend on which puzzle piece is missing. The length of time given to assemble the puzzle and draw the missing piece is designed to be short so that some puzzles are not completed in time, and thus the cell was unable to make the needed repairs.

1. Start the activity by giving each student an envelope. Students should not open the envelope until you give the signal.
2. After the time has elapsed, students should stop working on the puzzle. Have the students complete Part 1B of their student booklet.
3. Show the class the Answer Key in the PowerPoint presentation, while they answer questions in the student booklet.
4. As a summary, tally the number of "cells" that died (puzzles were not assembled), the number of "cells" which successfully repaired themselves (puzzles were assembled correctly), and the number of "cells"

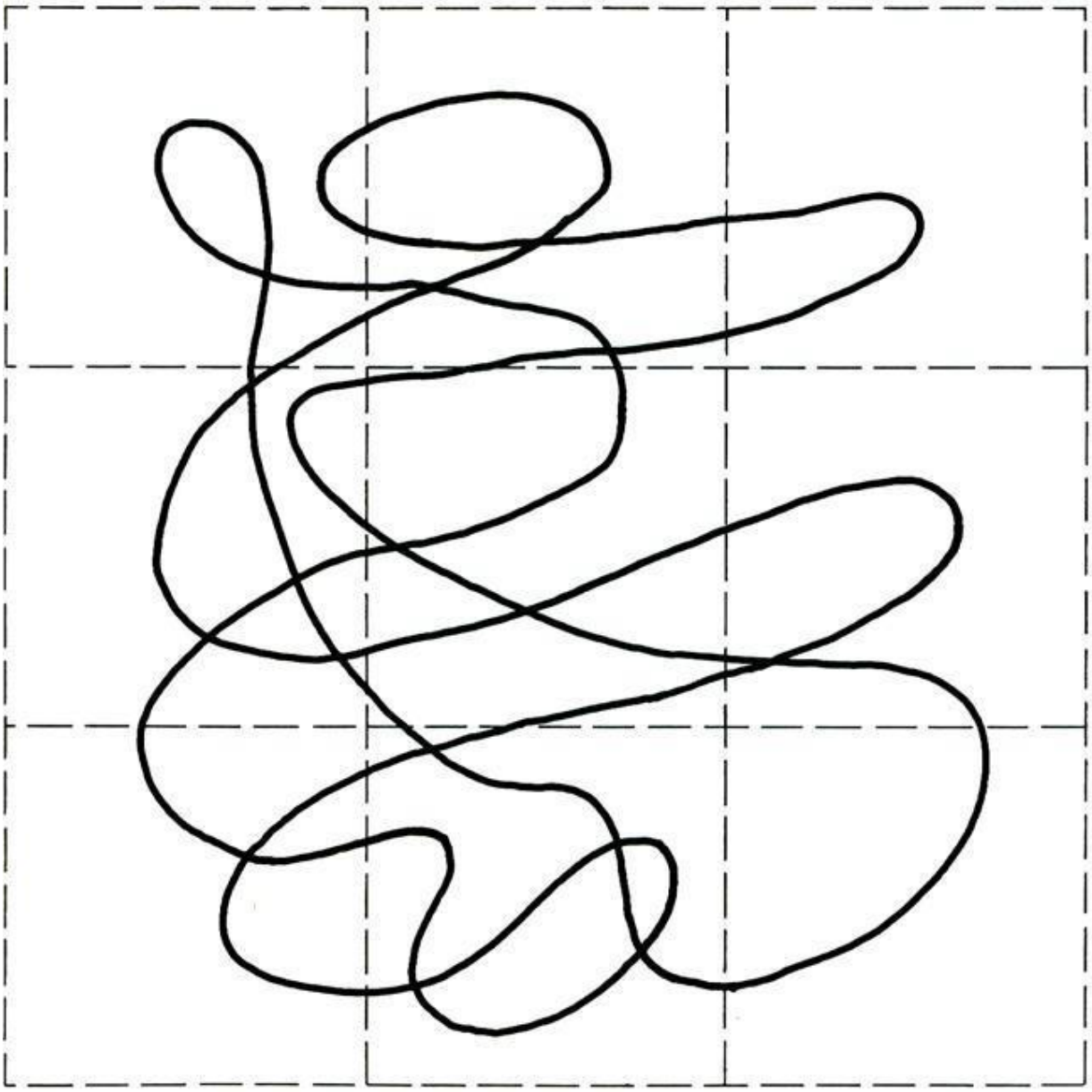
which mis-repaired themselves (puzzles were assembled, but the missing piece was dissimilar to the Puzzle Answer Key.) Consider a puzzle correctly assembled if the appropriate connections of the lines were made. The actual shape within the grid square may differ from the Puzzle Answer Key, but the appropriate lines are properly connected (see slide 26)

Example of Puzzle Correctly Completed



Note:

- Print this page to create your puzzle piece sets.
- Ensure to cut out the blank square
  (for the hand-drawn piece that will replace one of the pieces that is removed)
- The blank puzzle grids are in the student and teacher booklets.



TEACHER'S NOTES AND DEBRIEFING:

Radon is an invisible, tasteless, odorless, and radioactive gas. Radioactive is a term to describe unstable atoms that spontaneously change into different atoms which results in radiation. Half-life is related to radioactivity intensity; the shorter the half-life, the greater the radioactive intensity. Radon has a half-life of 3.8 days. Because of a relatively short half-life, radon and its decay products give off a lot of radiation in a short period of time. Radiation where atoms are physically changed by making them electrically charged is known as ionizing radiation. All forms of ionizing radiation (Alpha, Beta, Gamma and X-ray) can result in cancer, but some are more damaging than others. Alpha particles are not very penetrating but are extremely hazardous once inside the body. Radon gives off alpha particles which damage tissue more easily than beta or gamma radiation. The "Domino DNA with Alpha, Beta, and Gamma" activity simulates the interactions between alpha, beta, and gamma radiation and DNA in lung cells. Radon gas and its decay products account for over half of our ionizing radiation exposure, and that exposure to ionizing radiation can cause cancer.

Radon is present in soils and rocks because it is a decay product from uranium and radium. It is also in ground water because it can be dissolved, and in air because it is a gas. Since radon is a gas, it enters and exits the lungs easily during breathing. The real danger to our lungs is not the radon gas itself, but the radon decay products which are solid materials. The radioactive radon decay solids stick to dust particles in the air. Radon decay products and dust are attracted to each other because they are oppositely charged.

Normal breathing brings the dust with the decay products attached into the lungs where they are trapped by the sticky, mucous-covered tissues that line the trachea, bronchial tubes and lungs. Once they have been trapped on the lung lining, they are in close proximity to the sensitive cells of the lung and can damage the tissue when the next radioactive decay takes place.

The body has some natural protection processes. Small hair-like structures called cilia will move the mucus and the decay products up through the larynx and out of the body. White blood cells will patrol the lungs and search out and capture intruding particles. Despite this protection, radon can still hurt you, especially when the amount of radon is large. Radon is second only to cigarette smoking in causing lung cancer.

When radiation strikes a cell, it may pass through the cell doing no damage. If damage does occur to the cell, one of the following three events may occur:

1. the cell dies either because the radiation kills it or the body's immune system identifies a problem with the cell and destroys it;
2. the cell repairs itself and is restored to its pre-damaged state; or

3. the cell repairs itself but mistakes are created within the cell.

Only the last possibility, which may ultimately result in cancer, is of major concern. (Even killing cells is not a problem as long as the number of cells killed is not too high. For example, radiation therapy is used by doctors to kill cancer cells.) When ionizing radiation strikes cells, it may break apart important molecules such as DNA (deoxyribonucleic acid). DNA (found in every cell in the body) consists of large molecules which encode the special characteristics for that cell and control all cellular functions. If radiation damages the cell's DNA and the cell mis-repairs itself, this may result in genetic defects. When cells divide, they generate new cells identical to themselves; therefore, such genetic defects are passed on to succeeding generations of new cells. Keep in mind that the changes in the genetic code will be passed on not only to the next generation of cells, but also to any cells that they reproduce and every successive generation of cells.

Luckily, one genetic defect within a cell does not generally result in cancer. The body contains many cells which have been genetically altered due to spontaneous errors in DNA replication or interactions with various forms of radiation or chemicals. Millions of alterations within cells occur each day and these genetic alterations do not necessarily produce cancerous cells. While scientists are still studying and identifying the necessary steps and mechanisms for the development of various forms of cancer, it is clear that multiple genetic mis-repairs must occur over many generations of cell growth.

Since most radiation-induced cancers have a latency period of ten to twenty years, an exposure today may not result in symptoms of cancer for a decade or more.

The "Life Goes On!" activity simulates the possible fates to a cell after it is damaged by ionizing radiation.

PART 2: RADON IN THE HOME

RECOMMENDED TIME: 30 MINUTES

QUESTIONS:

How does radon enter homes?
What processes and forces impact radon levels?

Materials: Projection/Smartboard, Radon PowerPoint, Student Radon Booklets

Slides 28-37: Continue radon instruction through presentation and student engagement with content of Radon PowerPoint and Student Radon Booklets.

TEACHER'S NOTES AND DEBRIEFING:

Bernoulli's Principle states that when airflow speed is lower, there is higher pressure, and when airflow speed is higher, there is lower pressure. The faster that air moves across the top surface of the penny, the lower the air pressure. Higher pressure under the penny from slower moving air, causes lift. With the Bernoulli Effect, air flows from a higher pressure to a lower pressure. This explains the lift of airplanes, shower curtains attacking bathers, and radon gas being pulled out of rocks and soil by simply heating the house.

Radon travels in small spaces in soil and rock under our homes. Then it gets drawn into a home through dirt floors, crawl spaces, cracks and pores in floors and walls. As pressure differences are created around a house, any radon present in the soil moves along the path of least resistance from high to low pressure. A number of different factors influence the rate and amount of radon which enters buildings:

High winds cause more radon to escape from the soil, both underneath and around buildings.

Rain or melting snow can fill the spaces in the soil and acts as a cap in water-saturated soil, preventing radon from escaping from the underlying rock. However, the radon will move through dry spaces and into the house

Heating systems raise indoor air temperatures causing warm air to rise through the various floors of the building and reducing air pressure at the lower levels of the home resulting in the "stack effect"

Building design factors that affect air flow (such as vents and chimneys) can also cause lower pressure in basements that will draw more radon into the home

Activities within a building such as use of stove, water heater and dryer leads to lower pressure inside. Bathroom exhaust fans pull air out of the house leading to lower pressure inside.

In addition to radon escaping from soils and rocks, radon can also enter a house through the water system. Radon can escape from the water any time water is exposed to air. Radon levels of air in your home do not indicate the levels of radon in water; these must be tested separately.

Blowing between two cans produces faster moving air which creates a low pressure area between the cans. The higher pressure on the opposite side of the cans pushes them together.

PART 3A: RADON TESTING

RECOMMENDED TIME: 30 MINUTES

QUESTION:

How can we determine the radon levels in our homes?

Materials: Projection/Smartboard, Radon PowerPoint, Student Radon Booklets, radon test kit for each student

Slides 38-46: Continue radon instruction through presentation and student engagement with content of Radon PowerPoint and Student Radon Booklets.

Review at-home activity instructions. Consider using one test kit in the classroom and demonstrating the setup of the draft shield and hanger.

At-Home Activity: "The Only Way to Know"
"Begin Test" Procedures for Students: (Starting on a Monday evening)

1. Record the serial number of the test kit on the table below. (See page 6 in student booklet)
    a. Your Test Kit Serial # is required to access your test results.
    b. The Test Kit Serial # is on the plastic side of the Sampler
    c. Write your Test Kit Serial # on the front of this Instruction Sheet and keep it for future reference
2. Register your test kit at aelabs.com/register
3. Open the test kit instructions and carefully follow the instructions below for beginning the radon test.
    a. Follow Closed House Conditions:
        i. All exterior doors and windows are closed for 12 hours before starting your test, except for normal entry & exit.
        ii. Keep all exterior doors and windows closed for the entire testing period, except for normal entry and exit.
        iii. Use dehumidifiers, heating, & cooling systems normally.
        iv. Avoid using vent or exhaust fans during your test.

Note: It is recommended to *start the test on a Monday night, and* then end the test on a Thursday night, and hand in to teacher on a Friday (or start on a Thursday/Friday and end on a Monday/Tuesday. Review the test kit instructions in advance and decide which portion will be labelled by the teacher afterwards and which portion you wish students to complete. It is recommended that the teacher determines one central email for the test results to be submitted. It is essential that students record their serial number or that the teacher keeps a reference sheet so that the test results can be matched to the right student. **It may be useful to start Part 4 during wait time between parts 3A-3C.**

b. Avoid Testing During Severe Weather:
    i. Severe or unusual weather can temporarily change the building's radon levels. If unusual weather occurs during testing, visit aelabs.com/weather for guidance.
c. Where to Place the Radon Sampler
    i. Place the Radon Sampler in a central room on the **lowest level of the building suitable for occupancy**, whether finished or unfinished.
    ii. Visit aelabs.com/strategy to learn more.
    iii. Place the Sampler paper side up on a flat surface.
    iv. Place the Sampler 2-7 feet above the floor.
    v. Place the Sampler at least 3 feet from exterior doors and windows and at least 1 foot away from walls.
    vi. Make sure the Sampler has at least 6 inches of space between it and any objects above or to the side of it.
d. DO NOT:
    i. Do not puncture, rip, tear, peel, or remove the paper side of your Radon Sampler.
    ii. Do not place the Sampler near heating or air conditioning vents, or in a place where it will be exposed to constantly moving air.
    iii. Do not place the Sampler where it will get wet.
    iv. Do not place the Sampler in rooms with high humidity (i.e. bathroom, kitchen, sump, or crawl space).
    v. Do not place the Sampler in crawl spaces or closets.
    vi. Do not place the Sampler in direct sunlight or within 1 foot of heat sources.

4. Planning the Test Start & Stop
    a. For best results, expose your Sampler between 48 and 96 hours. Longer exposures do not increase accuracy.
    b. Samplers exposed less than 2 days (48 hours) or more than 7 days (168 hours) are invalid.
    c. All test dates & times are required for a result.
5. Starting the Test
    a. Record the test start time & date online at aelabs.com/register
    b. To start the test, remove the Radon Sampler from the plastic bag. The test begins immediately when the Radon Sampler is removed and exposed to air.
6. Stopping the Test
    a. Record the test stop time & date online at aelabs.com/register
    b. To stop the test, seal the Radon Sampler in the included Return Mailer. Include payment (if applicable).
    c. If you have more than one test kit, seal each Radon Sampler individually in its own Return Mailer.

HOME TEST

Test Kit Serial #	**Prediction** (Test results Will be above, at or below 4pCi/L action level, *and why*)	**Environmental Observations** (external & internal variables over duration of test)	**Actual Test Results** (pCi/L)	**Inferences** (Variables that may impact reliability of test)

PART 3B: RADON TESTING CONTINUED
(4 DAYS LATER)

Note: Remind students to complete the end of test procedures.

Note: Use the provided paid postage envelope to mail in your kits on Friday afternoon. Early arrival assists with accuracy. Ensure each test kit is sealed and labeled properly with the separate locations. Results are typically available the same day the lab receives the test packet by mail.

At-Home Activity : "The Only Way to Know"
"End Test" Procedures: (Ending Thursday evening)

a. Refer to original test kit instructions and carefully follow steps 1-3 for ending the radon test.
b. Update observations in table (see page 6 in student booklet) during test duration such as indoor/outdoor temperature, draft, movement of people, proximity to weather factors (warmer indoor temperature), building design factors (vents, chimneys) and activities within buildings (ovens, exhaust fans) relative to heating or cooling vents, types.
c. Return a completely labeled and sealed test kit (with tag and draft shield removed) to your teacher on Friday's class or a designated drop-off location on Friday.

PART 3C: RADON TESTING CONTINUED

Note: Provide students the results.

Note: The test results will be mailed to the homeowner.

At-Home Activity : "The Only Way to Know"

Procedures:

a. Record test results.
b. Compare results to your prediction.
c. Review observations and record your inferences in the table whether there may be any variables that would impact the reliability of the test results.

Note: Engage class in discussion of results in relation to prediction and indicate any inferences.

TEACHER'S NOTES AND DEBRIEFING:

Houses in the same neighborhood are built differently, which can account for different pathways for radon to enter and different ventilation systems to expel radon. Houses with kids and dogs typically have more ventilation because doors are opened more often. Each location has individual rock and soil

characteristics, even when next door to each other. Some sites may have greater concentrations of radon in rocks and soil because of the higher uranium and radium concentrations in them. Various building materials may have radioactive materials contained within them (cinder blocks, fireplace stones, etc).

Because radon gas is invisible, odorless, and tasteless, special devices are necessary to test for its presence. Charcoal detectors are the most affordable and easily accessible option for an initial test. They can be purchased at most hardware stores for $10-$20. Charcoal detectors have activated charcoal inside. The kit is opened to start the test and radon gas is trapped on the surface of the charcoal particles. The kit is then resealed after a 72-120 hour testing period, and immediately mailed to the laboratory for analysis.

Radon test devices should be placed in the lowest level of the house where it will not be disturbed, and where it will be at normal breathing level (3-5 ft. from the floor). Testing under the "worst possible case" situations will indicate the highest radon reading possible which offers some assurance of the worst case scenario. This includes limiting ventilation of the house or test area, keeping doors and windows closed, and testing when it is colder outside than it is inside (such as late fall, winter, early spring). Extreme high winds or the test period and extreme rain would also be examples of the worst case scenarios, but it also may cause an extreme spike in radon levels than normal high readings. In this case it may be recommended to repeat the test at another time.

Another testing device is the continuous radon monitor. It is reusable and produces immediate test results on a printout. It is expensive and is typically purchased by agencies involved in frequent radon testing activities. It will provide a "real time" reading as well as the average for an interval in time within a 24-48 hour period. This provides an interesting view of fluctuations in radon levels.

Radioactive concentrations are measured in picocuries per liter of air (pCi/L). The curie (Ci) unit, named for Marie Curie's discovery of radium, is the activity of 1 gram of pure radium 226. Pico is a scientific notation term which means $1*10^{-12}$. There is no safe radon level, but the Environmental Protection Agency (EPA) has set an allowable level of 4 pCi/L of air because present mitigation technology can typically reduce radon concentrations to below 4pCi/L.

FOR QUESTIONS OR MORE INFORMATION, CONTACT THE NEW HAMPSHIRE RADON PROGRAM AT (603) 271-1708 AND RADON@DHHS.NH.GOV.

REFERENCES:

- Connecticut Department of Public Health, Mrs. Sullivan: radon lesson (no date). *Radon Lesson*. [PowerPoint presentation]
- DESP 3R's: teacher resource (no date). *Unit 3: What is Radon?* [Word document]
- Utah Department of Environmental Quality, Eleanor Divver: radiology lesson (no date). *Radiological Basics*. [PowerPoint presentation]
- Utah Department of Health: radon lesson (2018).
- Colorado Department of Public Health: infographic (2018). *Is Your Home Safe from Radon.* [PDF]