GRADES 6–8

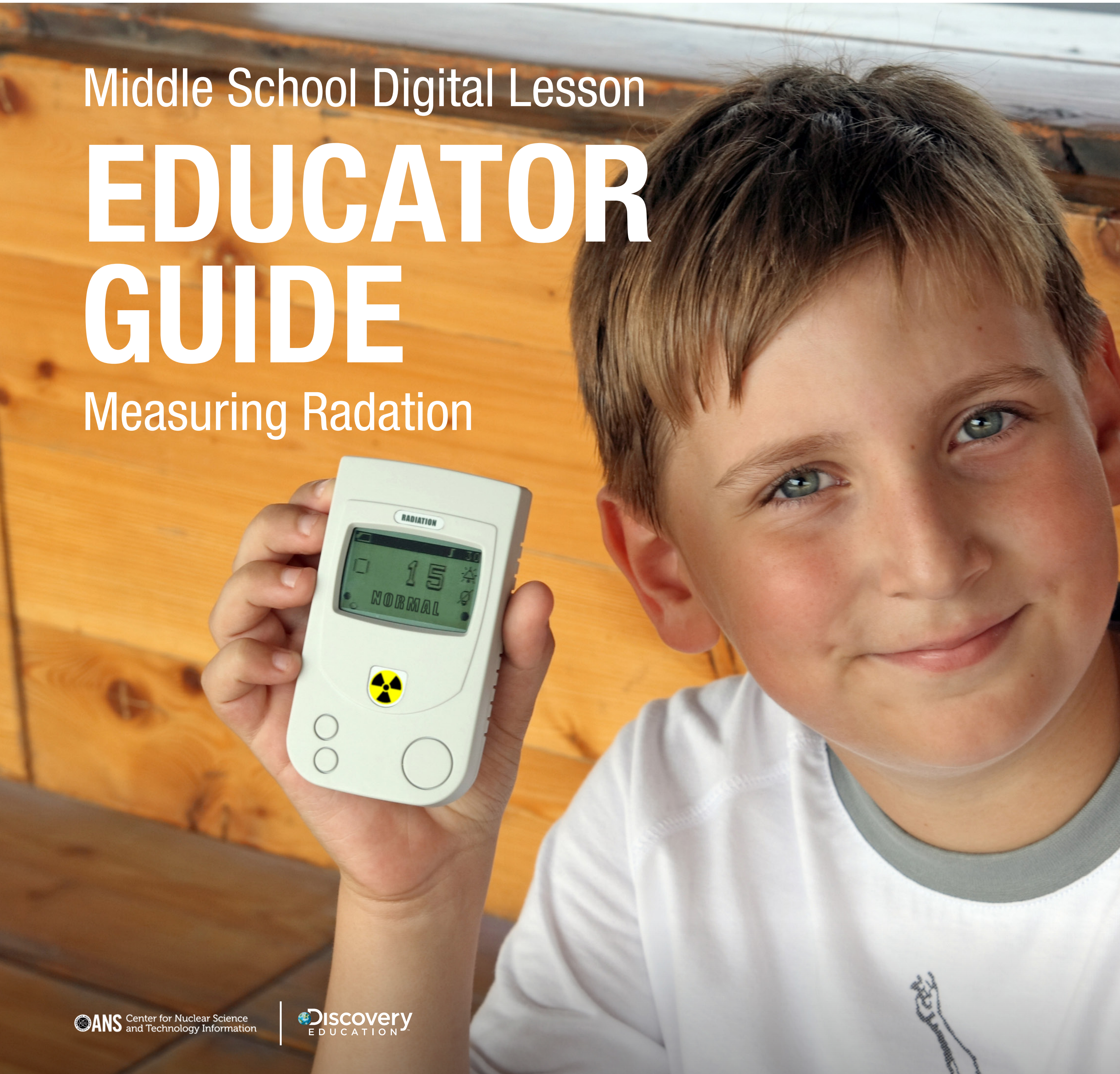
NAVIGATING™ NUCLEAR

Energizing Our World

Middle School Digital Lesson

EDUCATOR GUIDE

Measuring Radation



ANS Center for Nuclear Science and Technology Information | Discovery EDUCATION

Lesson Overview

Radiation is ubiquitous in our world, with the leading sources of radiation being Earth's rocks and outer space. Nearly half of human exposure to radiation is from natural sources and half is from medical sources; very little comes from industrial uses like power plants. There are many misconceptions, however, about the radiation we receive. At the beginning of this lesson, students will examine misconceptions and facts about radiation. Through a series of investigations, they will explore the science behind measuring radiation and analyze the relative risks and benefits. Students will discover that some radiation is beneficial and some presents risks but that all types have essential roles to play in our modern world. They will apply what they learn to explain and communicate the science behind real-life uses of measuring radiation in detecting smoke in their homes, determining the properties of high-mass radioactive nuclei, and scanning shipments at ports and airports.

Duration

135–180 minutes

Content Areas

Earth Science/Environmental Science, Physics

Grade Level

Grades 6–8

Essential Questions

1. How much radiation do we receive, and where does it come from?
2. How can we detect the different kinds of radiation?
3. How can radiation be used to improve our world?

National Standards

Next Generation Science Standards (NGSS)

Science and Engineering Practice	Disciplinary Core Idea	Crosscutting Concept
Developing and Using Models Develop a model to predict and/or describe phenomena.	**PS1.A: Structure and Properties of Matter** Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.	**Scale, Proportion, and Quantity** Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
Asking Questions and Defining Problems Define a design problem that can be solved through the development of an object, tool,	**ETS1.A: Defining and Delimiting an Engineering Problem** The more precisely a design task's criteria and constraints	**Influence of Science, Engineering, and Technology on Society and the Natural World** All human activity draws on natural

process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions. **ETS1.B: Developing Possible Solutions** A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.	resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

Materials

- Computers connected to the Internet
- Comparing Electromagnetic and Nuclear Radiation student activity sheet (one per student)
- THINK-PAIR-SHARE student activity sheet (one per student)
- Geiger-Müller Counter
- Materials students can test for radiation: Rocks (granite), food (bananas), calculator, a computer or a smartphone, and textbook

Geiger-Müller counters are instruments used to detect and measure ionizing radiation. This instrument allows students to test items for radiation and assign a quantitive value. Listed below are different ways to aquire this piece of equipment for your classroom.

- Contact your state, county, or local municipality's emergency management organizations. Many of them have access to Geiger-Müller detectors and may be willing to lend them out.
- Contact the ANS local or student section in your area.
- Contact a local university that has a nuclear engineering department.
- Purchase one for your school through a local or online source

Objectives

- Describe the types of radiation we receive and identify the sources.
- Use a Geiger-Müller counter to detect radiation.
- Analyze and communicate the science behind uses of radiation.

Background

Prior to this lesson, students should be familiar with sub-atomic particles, especially protons, neutrons and electrons. Specifically, they should know that nuclei consist of protons and neutrons and the nucleus varies in size based on the element. They should know the basic structure of the atom and that electrons circulate around the atomic nucleus. They should know radiation can be in the form of particles (protons, neutrons, and electrons) or waves (gamma or X-rays).

Procedure

Day 1 (Slides 1–6)

Slide 1

- As an activator and to establish the context for the lesson, have students complete the calculation at "Calculate Your Radiation Dose" from the EPA.
  Link to Video: https://www.epa.gov/radiation/calculate-your-radiation-dose
  Strategy:
  - Give students the link and direct them to fill out the calculator. You may need to guide them through a handful of the questions, especially about your elevation, whether X-ray luggage inspection machines are used at your local airport, and whether you live within 50 miles of a nuclear or coal power plant.
  - After everyone has completed the calculator, collect a handful of students' results and compare them. Note the sources to which students were exposed and which sources were most significant.
  - Ask students if they think there are sources of radiation that are not listed in the EPA calculator. How could they measure the radiation coming from each of those sources?
  - Ask students why some sources of radiation are high (like radon) and others are low (like nuclear power plants). Have students write out the things that most surprised them about the nuclear radiation calculator.

Slide 2

- Review the lesson objectives for the three-day lesson.

Slide 3

- Review the background for the three-day lesson.

Slide 4

- Pass out the Think-Pair-Share Capture Sheet.
- Give students an opportunity to complete the first column of the capture sheet for the four questions individually. Then, invite students to share their responses with a partner to complete the second column for the four questions. As a pair, students should decide what they will share with the rest of the class. They should focus on items on which they disagree.
- Call on students to share their answers to these questions using equitable calling strategies. Anticipated responses include the following:
  - Radiation consists of the emission of energy either as waves (photons) or as subatomic particles (proton, neutron, or electron).
  - Many of the stated risks will be inaccurate, including that radiation leads to immediate death or that radiation only comes from nuclear power plants. The risks of radiation are health-related, but the degree of potential positive health effects depends on the exposure level.
  - The biggest benefits of radiation include medical applications, like detecting broken bones, sterilizing equipment, and attacking cancerous growths. It is also used in smoke detectors, for dating artifacts and long-dead organisms, in horticulture, and industries such as construction.
  - We can detect radiation with Geiger-Müller counters and scintillators, which luminesce when struck by ionizing radiation.
- Direct the class to keep an eye out for information that refutes their initial ideas about measuring radiation. Encourage them to share those misconceptions with the class as they learn information that refutes these misconceptions.

Slide 5

- Distribute the Comparing Electromagnetic and Nuclear Radiation sentence framework. Show the video, Is Radiation Dangerous? (5:20) and invite students to compare and contrast electromagnetic radiation and nuclear radiation.

Slide 6

- Summarize radiation by reviewing the slide. Radiation is energy that can travel as a wave or stream of particles. Electromagnetic radiation is a form of energy that travels in waves. Nuclear radiation originates in the atomic nucleus. It is energy or particles that come out of a nucleus.

Day 2 (Slides 7–11)

Slide 7

Review the information provided in the slide about the common sources of radiation. Have students identify general or specific sources of radiation.

Slide 8

- Recall the definition of ionizing radiation: it creates ions of atoms by stripping them of electrons. Note that Geiger-Müller counters measure this radiation by capturing the stripped electrons. The stripped electrons move through a wire to a counter, which registers the event by incrementing the counter and making a beep or a click.
- If you can obtain a few Geiger-Müller counters, divide the class into groups so that each group has one Geiger-Müller counter.
- Give groups a series of items that includes rocks, especially granite; food, especially bananas; a smoke detector; their calculator, a computer or a smartphone; their textbook; the floor tiles; the walls of the room; and other items.
- Have students predict which items will have detectable levels of radiation and explain their predictions.
- Have students measure the background radiation or give them that information.
- Have students test the series of objects and, ideally, measure the radiation counts. The information students can collect will depend on the type of Geiger-Müller counter you have available.
- Collect the data as a class, discuss outliers, and analyze the data together, noting the objects that were emitting the most ionizing radiation.
- Have the class consider their initial predictions. What misconceptions did they have about the radiation that would be emitted by the different potential sources?

Slide 9

- Review how the types of radiation can be blocked by different items.
- Specifically note that paper can block alpha particles and aluminum foil can block beta particles.
- Direct students to devise a procedure whereby they can differentiate among the types of radiation that they are detecting.
- If you have Geiger-Müller counters that are sensitive enough, have students use their procedure to determine the type of radiation that is emanating from each of the objects considered in the previous slide. It may be best to conduct this part of the test in conjunction with the previous one.

Slide 10

- Ask students the following questions:
  - Why might a respirator (gas mask) be useful when working with radiation?
  - How could you protect yourself from radiation in general?
  - What principles should guide your exposure to radiation?
- Review the slide and address any misconceptions that may have arisen as a result of the initial questions.

Slide 11

- As an activator, have students watch the video “Celebrating 20 Years of Cyberknife Technology” from Stanford University.
  Video is available at this link:
  https://radonc.stanford.edu/about.html
  Strategy:
  - Before showing the video to the students, briefly describe the Cyberknife. The Cyberknife is a robotic

image-guided radiosurgical system, which means that it uses pictures of the brain and other parts of the body to locate and direct radiation. It is able to accurately direct radiation to specific locations in the body, which allows it to better target tumors and cause less damage to surrounding cells.

- Then, show the video and direct students to take notes to answer a handful of questions, such as the following: What type of radiation does the Cyberknife use? Why would that radiation be used and not some other type? What would the radiation do to the cancerous cells?
- After briefly discussing the Cyberknife, discuss other forms of nuclear medicine. You may need to remind students of the radiation calculator you used at the beginning of the lesson to connect this to the radiation they might receive from scans.
- Review the slides and discuss the examples

Day 3 (Slides 12–14)

Slide 12

- Examine the data provided on sources of radiation. This data is for the average American over the course of a year and comes from the National Council on Radiation Protection & Measurements. Once students have examined the pie chart, have them compare these results to their initial radiation dose calculation. Ask them the following questions.
    - How does your initial radiation calculation compare to the average?
    - Why is it higher or lower?
    - What sources cause the largest difference?
- Note that the greatest nuclear power plant accident in American history was at Three Mile Island. This resulted in an additional 1 mrem of radiation for the 2 million people living near the facility (https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html).
- For comparison, note that a plane ride exposes you to 1 mrem per 1,000 miles travelled. The trip from New York to Los Angeles is roughly 2,500 miles and results in an additional 2.5 mrem of radiation. This is more than twice the dose from the worst nuclear power plant accident in American history!
- If time allows, direct students to find the radiation exposure from eating a banana a day, living with granite countertops, and other incidental sources of radiation.

Slide 13

- Direct students to examine examples of the uses of radiation (e.g., smoke detectors, scanning technologies at ports, and measuring high-mass nuclei). They should apply what they learned throughout the lesson to explain the science behind one of these uses. You may want to break up the class into small groups to complete this project. Their explanation of how measuring radiation is used should address at least one misconception from the beginning of the lesson. They will create a presentation on their example that includes multimedia elements.

  To start, they may want to use the following resources.Smoke detectors:
  https://www3.epa.gov/radtown/americium-smoke-detectors.html
  https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/smoke-detectors.html
  Scanning technologies at ports:
  https://www3.epa.gov/radtown/shipping-port-security.html
  https://www.cbo.gov/publication/51478
  https://sites.lafayette.edu/berkins/2013/02/15/nuclear-port-security/
  http://news.mit.edu/2016/startup-improved-nuclear-threat-detection-0622
  Measuring high-mass nuclei (note that this will almost certainly be the most difficult example):
  https://www.phy.anl.gov/gammasphere/
  http://www.phy.anl.gov/gammasphere/pub/logos_98.html
  http://nucalf.physics.fsu.edu/~riley/gamma/gamma2.html
  https://www.energy.gov/articles/how-particle-accelerators-work

Slide 14

- Explain to students that radiation is used for many purposes—some of which save lives and some of which can cause harm. Like any tool, radiation can be helpful, harmful, or neutral. Given what they know about radiation, have students consider the case studies of radium girls, nuclear medicine and the thyroid, or radioactive dishes and other radioactive consumer goods.

- After students consider one of these case studies, pass out the handout 8 Step Engineering Design Process and the students' engineering journals.
- Tell students that they will be working in small engineering teams to identify a problem/need involving radiation and to investigate the underlying context through more in-depth research.

  Radium Girls: https://text-message.blogs.archives.gov/2018/01/04/the-radium-girls-at-the-national-archives/
  The thyroid and nuclear medicine: https://med.uc.edu/radiology/sections/nuclear-medicine/history
  https://endocrinenews.endocrine.org/january-2016-thyroid-month-the-saga-of-radioiodine-therapy/
  https://health.ucsd.edu/news/features/Pages/2016-07-01-radiation-therapy.aspx

  Radioactive dishes and other radioactive consumer goods:
  http://www.bbc.com/future/story/20180405-why-people-collect-radioactive-objects
  https://www.orau.org/ptp/collection/consumer%20products/fiesta.htm
  https://www.orau.org/ptp/collection/consumer%20products/consumer.htm
  https://www.epa.gov/radiation/tenorm-consumer-products
  http://www.bbc.com/future/story/20180405-why-people-collect-radioactive-objects

Name: ______________________________ Date: ________ Pd.: ____

STUDENT HANDOUT

THINK-PAIR-SHARE Capture Sheet

Questions	What I Thought	What My Partner Thought	What We Will Share
What Is Radiation?			
What Are Some Risks Associated with Radiation?			
What Are Some Benefits of Radiation?			
How Can We Detect Radiation?			

Name: ________________ Partner's Name: _________________ Date: ________ Pd.: ____

STUDENT HANDOUT

Comparing Electromagnetic and Nuclear Radiation

____ and ____ are similar because they both:

____.

____.

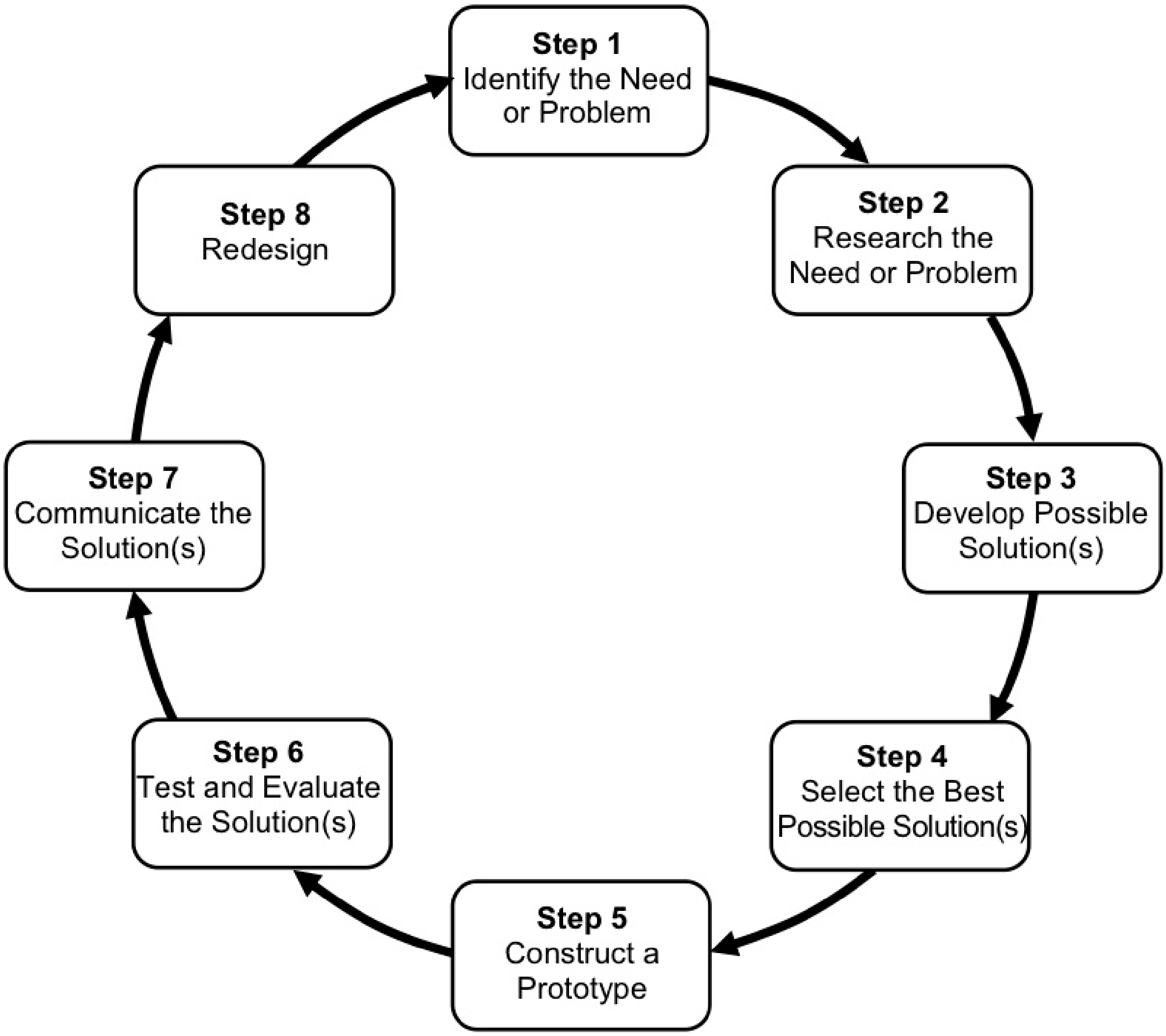
____.

____ and ____

are different because: ____.

____.

____.



Source: https://tinyurl.com/e-designprocess