Radioactivity

STEM Road Map for High School

Grade 11

Edited by Carla C. Johnson,
Janet B. Walton, and Erin Peters-Burton

NSTA press
National Science Teachers Association

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See *www.routledge.com/products/9781138804234* for more information about *STEM Road Map: A Framework for Integrated STEM Education.*

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RADIOACTIVITY MODULE OVERVIEW

Janet B. Walton, Bradley D. Rankin, Erin Peters-Burton, Anthony Pellegrino, Jennifer Drake-Patrick, and Carla C. Johnson

THEME: The Represented World

LEAD DISCIPLINES: Science and Mathematics

MODULE SUMMARY

Since the mid-1940s, interest in harnessing radioactivity as a source of electricity has altered the energy production industry. The understanding that radioactive materials could be used as alternatives to fossil fuels sparked an ongoing societal debate about the safety and efficiency of nuclear energy that continues today. In this module, students consider this debate from various perspectives as they investigate the science, history, and public health implications of nuclear energy. Students learn about nuclear fission and the process of radioactive decay, as well as the history and societal implications of using nuclear energy as a power source, and also have the opportunity to explore nuclear fusion and its potential as an energy source. Through research and inquiry, including accessing primary documents related to the development and use of nuclear technologies and creating models of radioactive decay, nuclear fission, and nuclear fusion, student teams gain an understanding of the potential and dangers of atomic energy. Using this understanding and the engineering design process (EDP), student teams assume the role of various stakeholder groups in creating a response to a fictional nuclear power plant accident (adapted from Peters-Burton et al. 2015).

ESTABLISHED GOALS AND OBJECTIVES

At the conclusion of this module, students will be able to do the following:

- Create models of nuclear fission using physical models, computer-generated simulations, mathematical computations, and other student-created methods
- Calculate the energy yield of an individual nuclear event (decay, fission, and fusion), and use exponential functions to represent chain reactions

- Explain how radioactive decay, nuclear fission, and nuclear fusion work
- Identify the safety and environmental concerns related to using nuclear fission in power-generating plants
- Explain how a pressurized water nuclear reactor works
- Explain the history of the use of nuclear energy and identify key milestones and events that influence societal perspectives on nuclear energy use
- Apply understanding of the science and history of nuclear energy to take a particular stakeholder group stance and create a solution to a problem presented in the form of a fictional nuclear accident
- Use the EDP to formulate a solution to a complex problem
- Collaborate with peers to solve a problem

The lessons in this module take into account that it may not be possible for a teacher to collaborate with teachers from other content areas or that teachers from two different subject areas may not have the same students, so teaching in an integrated way in each class may not make sense. Therefore, the lessons are written so that the science teacher can teach the science classes and only a little of each other content area. That is, if you are teaching the module alone, you may choose to follow only the lead subject, offering enrichment activities in the other connecting subjects. You may want to collaborate with peers in the other subjects to get ideas for ways to incorporate the supporting connections seamlessly. If you are able to teach an integrated curriculum, you can use the module as written for all four subjects in each of the Learning Components sections of the module.

CHALLENGE OR PROBLEM FOR STUDENTS TO SOLVE: GAMMATOWN CRISIS CHALLENGE

Student teams are challenged to take on the roles of stakeholder groups to create responses to a fictional nuclear accident in Gammatown, U.S.A., in the Gammatown Crisis Challenge. Teams synthesize their understanding of the history, science, and current context of nuclear energy use to prepare a presentation for a target audience from the viewpoint of a stakeholder group and to create a model of a scientific phenomenon or technological object or process related to their objective.

Driving Question: How does the use of nuclear energy to meet our energy demands affect society?

CONTENT STANDARDS ADDRESSED IN THIS STEM ROAD MAP MODULE

A full listing with descriptions of the standards this module addresses can be found in the appendix. Listings of the particular standards addressed within lessons are provided in a table for each lesson in Chapter 4.

STEM RESEARCH NOTEBOOK

Each student should maintain a STEM Research Notebook, which will serve as a place for students to organize their work throughout this module (see p. 12 for more general discussion on setup and use of the notebook). All written work in the module should be included in the notebook, including records of students' thoughts and ideas, fictional accounts based on the concepts in the module, and records of student progress through the EDP. The notebooks may be maintained across subject areas, giving students the opportunity to see that although their classes may be separated during the school day, the knowledge they gain is connected. You may also wish to have students include the STEM Research Notebook Guidelines student handout on page 26 in their notebooks.

Emphasize to students the importance of organizing all information in a Research Notebook. Explain to them that scientists and other researchers maintain detailed Research Notebooks in their work. These notebooks, which are crucial to researchers' work because they contain critical information and track the researchers' progress, are often considered legal documents for scientists who are pursuing patents or wish to provide proof of their discovery process.

STUDENT HANDOUT

STEM RESEARCH NOTEBOOK GUIDELINES

STEM professionals record their ideas, inventions, experiments, questions, observations, and other work details in notebooks so that they can use these notebooks to help them think about their projects and the problems they are trying to solve. You will each keep a STEM Research Notebook during this module that is like the notebooks that STEM professionals use. In this notebook, you will include all your work and notes about ideas you have. The notebook will help you connect your daily work with the big problem or challenge you are working to solve.

It is important that you organize your notebook entries under the following headings:

1. **Chapter Topic or Title of Problem or Challenge:** You will start a new chapter in your STEM Research Notebook for each new module. This heading is the topic or title of the big problem or challenge that your team is working to solve in this module.
2. **Date and Topic of Lesson Activity for the Day:** Each day, you will begin your daily entry by writing the date and the day's lesson topic at the top of a new page. Write the page number both on the page and in the table of contents.
3. **Information Gathered From Research:** This is information you find from outside resources such as websites or books.
4. **Information Gained From Class or Discussions With Team Members:** This information includes any notes you take in class and notes about things your team discusses. You can include drawings of your ideas here, too.
5. **New Data Collected From Investigations:** This includes data gathered from experiments, investigations, and activities in class.
6. **Documents:** These are handouts and other resources you may receive in class that will help you solve your big problem or challenge. Paste or staple these documents in your STEM Research Notebook for safekeeping and easy access later.
7. **Personal Reflections:** Here, you record your own thoughts and ideas on what you are learning.
8. **Lesson Prompts:** These are questions or statements that your teacher assigns you within each lesson to help you solve your big problem or challenge. You will respond to the prompts in your notebook.
9. **Other Items:** This section includes any other items your teacher gives you or other ideas or questions you may have.

MODULE LAUNCH

Show students photos or videos depicting various uses of nuclear energy as well as some of the well-publicized nuclear power plant accidents (Three Mile Island, Chernobyl, and Fukushima). Have students share their prior understanding of nuclear energy and discuss their current opinions of nuclear energy as an electric power source and whether they believe it should be used, asking questions such as the following:

- What is nuclear energy?
- Is it safe?
- Is it clean?
- Is it renewable?
- Why was it first used?
- What can it do for humans in the future?

Next, show students a video about nuclear energy such as "The Future of Clean Nuclear Energy Is Coming" at *www.youtube.com/watch?v=t7FvxN_gkt4*. Then, introduce students to the module challenge, the Gammatown Crisis Challenge, and have students work in groups to create lists of knowledge they think they will need to address the challenge.

PREREQUISITE SKILLS FOR THE MODULE

Students enter this module with a wide range of pre-existing skills, information, and knowledge. Table 3.1 (p. 28) provides an overview of prerequisite skills and knowledge that students are expected to apply in this module, along with examples of how they apply this knowledge throughout the module. Differentiation strategies are also provided for students who may need additional support in acquiring or applying this knowledge.

Table 3.1. Prerequisite Key Knowledge and Examples of Applications and Differentiation Strategies

Prerequisite Key Knowledge	Application of Knowledge by Students	Differentiation for Students Needing Knowledge
Science • Understand subatomic particles (electrons, neutrons, protons). • Able to read the periodic table of elements and identify atomic numbers and atomic weights. • Understand that isotopes of a given element vary in their numbers of neutrons and thus their stability.	*Science* • Apply knowledge of elements and isotopes to understand and model nuclear reactions.	*Science* • Provide students with resources about the periodic table and atomic composition (tutorial videos, websites, tables with additional explanations), as well as models of radioactive elements used in nuclear processes. • Conduct a short lesson about the periodic table, reviewing atomic number, atomic weight, and isotopes.
Mathematics • Understand exponential functions. • Able to express quantities using scientific notation.	*Mathematics* • Apply exponential functions to model the decay of radioactive elements and the energy yields in fission and fusion reactions. • Use scientific notation to express the amount of energy released from nuclear reactions.	*Mathematics* • Model the use of exponential growth equations. • Provide problems to work through as a class that use exponential growth and decay, such as compound interest (growth) and the atmospheric pressure at increasingly higher altitudes (decay). • Review procedures for using scientific notation with the class; provide sample problems for students to work through, both as a class and individually; provide online tutorials about scientific notation.

POTENTIAL STEM MISCONCEPTIONS

Students enter the classroom with a wide variety of prior knowledge and ideas, so it is important to be alert to misconceptions, or inappropriate understandings of foundational knowledge. These misconceptions can be classified as one of several types: "preconceived notions," opinions based on popular beliefs or understandings; "nonscientific beliefs," knowledge students have gained about science from sources outside the scientific community; "conceptual misunderstandings," incorrect conceptual models based on incomplete understanding of concepts; "vernacular misconceptions," misunderstandings of words based on their common use versus their scientific use; and "factual misconceptions," incorrect or imprecise knowledge learned in early life that remains unchallenged (NRC 1997, p. 28). Misconceptions must be addressed and dismantled in order for students to reconstruct their knowledge, and therefore teachers should be prepared to take the following steps:

- *Identify students' misconceptions.*
- *Provide a forum for students to confront their misconceptions.*
- *Help students reconstruct and internalize their knowledge, based on scientific models. (NRC 1997, p. 29)*

Keeley and Harrington (2010) recommend using diagnostic tools such as probes and formative assessment to identify and confront student misconceptions and begin the process of reconstructing student knowledge. Keeley's *Uncovering Student Ideas in Science* series contains probes targeted toward uncovering student misconceptions in a variety of areas and may be useful resources for addressing student misconceptions in this module.

Some commonly held misconceptions specific to lesson content are provided with each lesson so that you can be alert for student misunderstanding of the science concepts presented and used during this module. The American Association for the Advancement of Science has also identified misconceptions that students frequently hold regarding various science concepts (see the links at *http://assessment.aaas.org/topics*).

SRL PROCESS COMPONENTS

Table 3.2 (p. 30) illustrates some of the activities in the Radioactivity module and how they align with the self-regulated learning (SRL) process before, during, and after learning.

Table 3.2. SRL Process Components

Learning Process Components	Example From Radioactivity Module	Lesson Number and Learning Component
BEFORE LEARNING		
Motivates students	A class discussion about nuclear energy gives students the opportunity to share their current understanding of nuclear energy and discuss their opinions about nuclear energy as a power source.	Lesson 1, Introductory Activity/Engagement
Evokes prior learning	Students connect their knowledge about the Manhattan Project and nuclear weapons development to understand the development of nuclear energy for peaceful (energy production) purposes.	Lesson 2, Activity/Exploration
DURING LEARNING		
Focuses on important features	Students compare the energy output of a fission reaction with their typical yearly home energy consumption.	Lesson 2, Activity/Exploration
Helps students monitor their progress	Students respond to a STEM Research Notebook prompt in which they apply their learning about nuclear energy to express and support with evidence an opinion about the safety of nuclear power plants.	Lesson 2, Elaboration/Application of Knowledge
AFTER LEARNING		
Evaluates learning	Students are challenged to analyze the response to a historic nuclear accident using what they have learned about nuclear science and technology.	Lesson 4, Activity/Exploration
Takes account of what worked and what did not work	Students practice their presentations for their Gammatown Crisis Challenge response and incorporate feedback to improve their presentations.	Lesson 5, Elaboration/Application of Knowledge

STRATEGIES FOR DIFFERENTIATING INSTRUCTION WITHIN THIS MODULE

For the purposes of this curriculum module, differentiated instruction is conceptualized as a way to tailor instruction—including process, content, and product—to various student needs in your class. A number of differentiation strategies are integrated into lessons across the module. The problem- and project-based learning approach used in the lessons is designed to address students' multiple intelligences by providing a variety of entry points and methods to investigate the key concepts in the module. Differentiation strategies for students needing support in prerequisite knowledge can be found in Table 3.1 (p. 28). You are encouraged to use information gained about student prior knowledge during introductory activities and discussions to inform your instructional differentiation. Strategies incorporated into this lesson include flexible grouping, varied environmental learning contexts, assessments, compacting, and tiered assignments and scaffolding.

Flexible Grouping. Students work collaboratively in a variety of activities throughout this module. Grouping strategies you might employ include student-led grouping, grouping students according to ability level or common interests, grouping students randomly, or grouping them so that students in each group have complementary strengths (for instance, one student might be strong in mathematics, another in art, and another in writing).

Varied Environmental Learning Contexts. Students have the opportunity to learn in various contexts throughout the module, including alone, in groups, in quiet reading and research-oriented activities, and in active learning through inquiry and design activities. In addition, students learn in a variety of ways, including through doing inquiry activities, journaling, reading texts, watching videos, participating in class discussion, and conducting web-based research.

Assessments. Students are assessed in a variety of ways throughout the module, including individual and collaborative formative and summative assessments. Students have the opportunity to produce work via written text, oral and media presentations, and modeling. You may choose to provide students with additional choices of media for their products (for example, PowerPoint presentations, posters, or student-created websites or blogs).

Compacting. Based on student prior knowledge, you may wish to adjust instructional activities for students who exhibit prior mastery of a learning objective. You may wish to compile a classroom database of research resources and supplementary readings for a variety of reading levels and on a variety of topics related to the module's topic to provide opportunities for students to undertake independent reading.

Tiered Assignments and Scaffolding. Based on your awareness of student ability, understanding of concepts, and mastery of skills, you may wish to provide students with variations on activities by adding complexity to assignments or providing more or fewer learning supports for activities throughout the module. For instance, some students may need additional support in identifying key search words and phrases for web-based research or may benefit from cloze sentence handouts to enhance vocabulary understanding. Other students may benefit from expanded reading selections and additional reflective writing or from working with manipulatives and other visual representations of mathematical concepts. You may also work with your school librarian to compile a set of topical resources at a variety of reading levels.

STRATEGIES FOR ENGLISH LANGUAGE LEARNERS

Students who are developing proficiency in English language skills require additional supports to simultaneously learn academic content and the specialized language associated with specific content areas. WIDA (2012) has created a framework for providing support to these students and makes available rubrics and guidance on differentiating instructional materials for English language learners (ELLs). In particular, ELL students may benefit from additional sensory supports such as images, physical modeling, and graphic representations of module content, as well as interactive support through collaborative work. This module offers ongoing opportunities for ELL students to work collaboratively. The focus on the production of electrical energy affords an opportunity for ELL students to share culturally diverse experiences with primary energy sources, including fossil fuels, nuclear energy, and renewables such as wind and solar energy.

When differentiating instruction for ELL students, you should carefully consider the needs of these students as you introduce and use academic language in various language domains (listening, speaking, reading, and writing) throughout this module. To adequately differentiate instruction for ELL students, you should have an understanding of the proficiency level of each student. The following 9–12 WIDA standards are relevant to this module:

- Standard 1: Social and Instructional Language. Focus on study skills and strategies, information gathering, workplace readiness.
- Standard 2: The language of Language Arts. Focus on autobiographical and biographical narratives, critical commentary, research, note taking.
- Standard 3: The language of Mathematics. Focus on coordinate planes, graphs, and equations; data displays and interpretation; mathematical relations and functions; problem solving; scale and proportion.
- Standard 4: The language of Science. Focus on atoms and molecules/nuclear structures; chemical and physical change; conservation of energy and matter; elements and compounds; nuclear change; scientific research and investigation.

- Standard 5: The language of Social Studies. Focus on behaviors of individuals and groups; historical figures and times; the story of the United States.

SAFETY CONSIDERATIONS FOR THE ACTIVITIES IN THIS MODULE

For precautions, see the specific safety notes after the list of materials in each lesson. For more general safety guidelines, see the Safety in STEM section in Chapter 2 (p. 18).

DESIRED OUTCOMES AND MONITORING SUCCESS

The desired outcomes for this module are outlined in Table 3.3, along with suggested ways to gather evidence to monitor student success. For more specific details on desired outcomes, see the Established Goals and Objectives sections for the module and individual lessons.

Table 3.3. Desired Outcomes and Evidence of Success in Achieving Identified Outcomes

	Evidence of Success	
Desired Outcome	Performance Tasks	Other Measures
Students can apply an understanding of exponential functions, nuclear reactions, and the societal implications of the use of nuclear reactions to produce electrical energy to respond to a fictional scenario from a stakeholder group perspective.	• Students maintain STEM Research Notebooks that contain data from investigations, sketches, ideas, questions, and research notes. • Students create models of nuclear fission and fusion. • Students create models of scientific phenomena or technological items related to the team challenge. • Students describe the production of electrical energy using nuclear reactions. • Students respond to a fictional nuclear power plant accident from a specific stakeholder group's perspective. • Students are assessed using project rubrics that focus on content and application of skills related to academic content.	Student collaboration is evaluated using a collaboration rubric.

ASSESSMENT PLAN OVERVIEW AND MAP

Table 3.4 provides an overview of the major group and individual *products* and *deliverables*, or things that student teams will produce in this module, that constitute the assessment for this module. See Table 3.5 for a full assessment map of formative and summative assessments in this module.

Table 3.4. Major Products and Deliverables in Lead Disciplines for Groups and Individuals

Lesson	Major Group Products and Deliverables	Major Individual Products and Deliverables
1	• Radioactive Decay Chain Models • Group contribution to Radioactivity Timeline	• STEM Research Notebook entries • Sweetium Half-Life handout and graphs
2	• Nuclear reactor schematic diagram • Nuclear Fission Model • Thorium reactor jigsaw essay • Nuclear history presentations	• STEM Research Notebook entries • Letter to President Roosevelt • Evidence of collaboration
3	• Nuclear Fusion Model • Product Development Challenge product and presentation	• STEM Research Notebook entries • Evidence of collaboration
4	• Anatomy of an Accident team posters and presentations	• STEM Research Notebook entries • Anatomy of an Accident Study Guide • Evidence of collaboration
5	• Gammatown Crisis stakeholder group presentation • Gammatown Crisis stakeholder group printed materials • Gammatown Crisis stakeholder group prototype	• Engineering design process entries in STEM Research Notebook • Evidence of collaboration

Table 3.5. Assessment Map for Radioactivity Module

Lesson	Assessment	Group/ Individual	Formative/ Summative	Lesson Objective Assessed
1	Radioactivity *timeline*	Group	Formative	• Discuss how radioactive decay was discovered and how scientific understanding of the process progressed to our present-day understanding. • Describe how the minuscule amount of energy released in a single alpha, beta, or gamma decay is significant because of the proportion of atoms in matter. • Discuss the major nuclear power plant accidents of the 20th and 21st centuries, and identify implications of these accidents. • Identify several uses of radioactive elements, and imagine ideas for future use.
1	Radioactive Decay Chain Model *rubric*	Group	Formative	• Model the decay chain of a radioactive element. • Apply the engineering design process (EDP) to solve a problem. • Collaborate with peers to solve a problem.
1	STEM Research Notebook *prompt*	Individual	Formative	• Understand that radioactive decay is an exponential function. • Create real-world examples of exponential functions other than radioactive decay.
2	Nuclear Fission Model *rubric*	Group	Summative	• Understand that fission is a nuclear process in which a large atomic nucleus splits into smaller nuclei, releasing the energy stored in the nuclear bonds. • Understand that some fission reactions occur spontaneously, while others, such as those used in nuclear reactors, require an energy input. • Understand that a nuclear chain reaction occurs when neutrons released during fission cause fission in one or more other nuclei. • Create a model of nuclear fission. • Apply the EDP to solve a complex problem. • Collaborate with peers to solve a problem.

Continued

Table 3.5. (*continued*)

Lesson	Assessment	Group/ Individual	Formative/ Summative	Lesson Objective Assessed
2	Thorium Reactor Jigsaw Essay *rubric*	Group	Formative	• Identify thorium as an alternative to uranium for nuclear fission reactions, and discuss the advantages and disadvantages of using thorium in nuclear reactors. • Collaborate with peers to solve a problem.
2	Letter to President Roosevelt STEM Research Notebook *prompt*	Individual	Formative	• Apply understanding of the history of nuclear science to understand the current scientific and environmental context of using nuclear power to meet society's energy needs. • Understand that fission is a nuclear process in which a large atomic nucleus splits into smaller nuclei, releasing the energy stored in the nuclear bonds.
2	Team nuclear history *presentations*	Group	Formative	• Apply understanding of the history of nuclear science to understand the current scientific and environmental context of using nuclear power to meet society's energy needs.
2	STEM Research Notebook *prompt*	Individual	Formative	• Understand that there are ecological implications of using fission reactions to produce electricity.
3	Nuclear Fusion Model *rubric*	Group	Formative	• Explain the differences between fission and fusion reactions. • Explain the potential of nuclear fusion as a power source. • Describe the challenges associated with using nuclear fusion as a power source. • Create a model of nuclear fusion, exhibiting an understanding of why intense heat and pressure are necessary to generate a fusion reaction. • Apply the EDP to solve a complex problem. • Collaborate with peers to solve a problem.
3	Product Development Challenge *rubric*	Group	Summative	• Use their understanding of fusion energy to propose a novel product. • Apply the EDP to solve a complex problem. • Collaborate with peers to solve a problem.

Continued

Table 3.5. (*continued*)

Lesson	Assessment	Group/ Individual	Formative/ Summative	Lesson Objective Assessed
3	STEM Research Notebook *prompt*	Individual	Formative	• Use understanding of fission and fusion to clearly explain to others the product developed by student's team in challenge.
4	Anatomy of an Accident *study guide*	Individual	Formative	• Use primary source documents to understand the Three Mile Island nuclear accident. • Apply understanding of nuclear fission reactions to provide a scientific explanation for the accident. • Analyze the response of various stakeholder groups to the accident.
4	Anatomy of an Accident *posters and presentations*	Group	Formative	• Apply their understanding of the Three Mile Island nuclear accident to create a poster providing an overview of one aspect of the accident.
4	STEM Research Notebook *prompt*	Individual	Formative	• Solve mathematical problems related to the Three Mile Island nuclear accident using dimensional analysis.
5	Stakeholder Group Presentation *rubric*	Group	Summative	• Apply understanding of nuclear energy to create a stakeholder-specific response to a fictional nuclear accident. • Demonstrate understanding of nuclear science in the presentation. • Demonstrate understanding of the mathematics concepts introduced in the module. • Use mathematical modeling to convey information about nuclear reactions. • Use persuasive language to present an argument to a target audience. • Apply the EDP to solve a complex problem. • Collaborate with peers to solve a problem.

Continued

Table 3.5. (*continued*)

Lesson	Assessment	Group/ Individual	Formative/ Summative	Lesson Objective Assessed
5	Stakeholder Group Printed Materials *rubric*	Group	Summative	• Apply understanding of nuclear energy to create a stakeholder-specific response to a fictional nuclear accident. • Use persuasive language to present an argument to a target audience. • Apply the EDP to solve a complex problem. • Collaborate with peers to solve a problem.
5	Stakeholder Group Prototype Design *rubric*	Group	Summative	• Create a prototype related to a science or technology aspect of nuclear energy. • Apply the EDP to solve a complex problem. • Collaborate with peers to solve a problem.
5	STEM Research Notebook *prompt*	Individual	Formative	• Apply the EDP to solve a complex problem.

MODULE TIMELINE

Tables 3.6–3.10 (pp. 39–41) provide lesson timelines for each week of the module. The timelines are provided for general guidance only and are based on class times of approximately 45 minutes.

Table 3.6. STEM Road Map Module Schedule for Week One

Day 1	Day 2	Day 3	Day 4	Day 5
Lesson 1 *Putting Radioactivity to Work* • Launch the module by introducing nuclear energy and radioactive decay. • Introduce module challenge, the Gammatown Crisis Challenge.	*Lesson 1* *Putting Radioactivity to Work* • Students work in groups to develop a timeline of discoveries related to and uses of radioactivity. • Students explore the concept of half-life as an exponential function.	*Lesson 1* *Putting Radioactivity to Work* • Students continue work on Radioactivity Timeline and exponential functions. • Introduce engineering design process and Nuclear Fission Model project.	*Lesson 1* *Putting Radioactivity to Work* • Students work in groups to create Radioactive Decay Chain Models.	*Lesson 1* *Putting Radioactivity to Work* • Student groups complete their Radioactive Decay Chain Models.

Table 3.7. STEM Road Map Module Schedule for Week Two

Day 6	Day 7	Day 8	Day 9	Day 10
Lesson 2 *Harnessing the Atom's Power* • Introduce nuclear fission. • Students explore the energy output of an atomic bomb, expressing this output in a variety of units.	*Lesson 2* *Harnessing the Atom's Power* • Students work in teams to create schematic diagrams of pressurized water reactors (PWRs)	*Lesson 2* *Harnessing the Atom's Power* • Students complete PWR diagrams and begin work on Nuclear Fission Models. • Students calculate energy outputs of fission reactions.	*Lesson 2* *Harnessing the Atom's Power* • Students continue work on Nuclear Fission Models.	*Lesson 2* *Harnessing the Atom's Power* • Students complete Nuclear Fission Models. • Students begin work on thorium reactor jigsaw essay.

Table 3.8. STEM Road Map Module Schedule for Week Three

Day 11	Day 12	Day 13	Day 14	Day 15
Lesson 2 *Harnessing the Atom's Power* • Students complete thorium reactor essays.	*Lesson 3* *Nuclear Fusion: Harnessing the Power of the Stars* • Introduce nuclear fusion. • Students calculate the energy output of a fusion reaction as compared to a nuclear fission reaction.	*Lesson 3* *Nuclear Fusion: Harnessing the Power of the Stars* • Students begin work on Nuclear Fusion Models. • Students begin creating a plan for a product powered by nuclear energy.	*Lesson 3* *Nuclear Fusion: Harnessing the Power of the Stars* • Students continue work on Nuclear Fusion Models. • Students research current innovations in nuclear fusion technologies.	*Lesson 3* *Nuclear Fusion: Harnessing the Power of the Stars* • Students complete Nuclear Fusion Models. • Students complete work on product plans.

Table 3.9. STEM Road Map Module Schedule for Week Four

Day 16	Day 17	Day 18	Day 19	Day 20
Lesson 4 *Anatomy of a Nuclear Accident* • Introduce the Three Mile Island (TMI) nuclear accident. • Students begin reading and analyzing an account of the accident. • Introduce measures of human exposure to radiation.	*Lesson 4* *Anatomy of a Nuclear Accident* • Students continue reading and analyzing TMI accident account. • Students calculate radiation doses associated with various activities.	*Lesson 4* *Anatomy of a Nuclear Accident* • Students continue reading and analyzing TMI accident account. • Student teams create topic-specific posters. • Students continue working with radiation emission and exposure calculations.	*Lesson 4* *Anatomy of a Nuclear Accident* • Student teams complete and present topic-specific posters about the TMI accident. • Students continue working with radiation emission and exposure calculations.	*Lesson 5* *The Gammatown Crisis Challenge* • Review challenge requirements and assign team stakeholder groups. • Students work on Define step of EDP to create challenge solutions.

Table 3.10. STEM Road Map Module Schedule for Week Five

Day 21	Day 22	Day 23	Day 24	Day 25
Lesson 5 *The Gammatown Crisis Challenge* • Students work on Learn step of EDP to create challenge solutions.	*Lesson 5* *The Gammatown Crisis Challenge* • Students work on Plan step of EDP to create challenge solutions.	*Lesson 5* *The Gammatown Crisis Challenge* • Students work on Try step of EDP to create challenge solutions.	*Lesson 5* *The Gammatown Crisis Challenge* • Students work on Test and Decide steps of EDP to create challenge solutions.	*Lesson 5* *The Gammatown Crisis Challenge* • Students present stakeholder group–specific challenge solutions in a town hall meeting.

RESOURCES

The media specialist can help teachers locate resources for students to view and read about nuclear energy, the history of energy production, the development of nuclear weapons in the United States, and related physics and chemistry content. Special educators and reading specialists can help find supplemental sources for students needing extra support in reading and writing. Additional resources may be found online. Community resources for this module may include mechanical engineers, nuclear engineers, power plant representatives, specialists in occupational safety and health, and community emergency response coordinators.

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Grade 11

STEM Road Map for High School

Radioactivity

What if you could challenge your 11th graders to figure out the best response to a partial meltdown at a nuclear reactor in fictional Gammatown, USA? With this volume in the *STEM Road Map Curriculum Series*, you can!

Radioactivity outlines a journey that will steer your students toward authentic problem solving while grounding them in integrated STEM disciplines. As are the other volumes in the series, this book is designed to meet the growing need to infuse real-world learning into K–12 classrooms.

This interdisciplinary module uses project- and problem-based learning to help students understand the debate over the safety and efficiency of nuclear power for meeting the country's energy demands. Teams of students will apply what they learn about the science and history of nuclear energy to convey the views of particular stakeholder groups and propose solutions to the crisis. At the end of the module, students will be able to do the following:

- Explain how radioactive decay, nuclear fission, and nuclear fusion work.
- Model nuclear fission, create computer-generated simulations, and perform mathematical computations.
- Calculate the energy yield of an individual nuclear event (decay, fission, and fusion) and use exponential functions to represent chain reactions.
- Identify the safety and environmental concerns involved in using nuclear fission in power plants.
- Explain the history of nuclear energy use and identify key milestones that have influenced society's perspectives on it.
- Make a presentation about solving the crisis from their stakeholder group's perspective.

The *STEM Road Map Curriculum Series* is anchored in the *Next Generation Science Standards*, the *Common Core State Standards*, and the Framework for 21st Century Learning. In-depth and flexible, *Radioactivity* can be used as a whole unit or in part to meet the needs of districts, schools, and teachers who are charting a course toward an integrated STEM approach.

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