RADIOACTIVE

EDUCATIONAL RESOURCES
LESSON TWO

MARIE CURIE:
TEACHING *RADIOACTIVE* IN THE CLASSROOM

Radioactive is a biopic full length film based on the life of Marie Curie. Awarded two Nobel Prizes, the first in physics (1903) shared with Pierre Curie (her husband) and Henri Becquerel for the discovery of the phenomenon of radioactivity, and the second in chemistry (1911) for the discovery of the radioactive elements polonium and radium, Marie Curie remains one of the most formidable and accomplished scientists of our time. Her body of scientific work birthed the idea of particle physics, changed our perception of matter and the universe, and led to such monumental developments from nuclear energy to treatments for cancer.

To inform and inspire future generations of students, and to honor the scientific work of Marie Curie, Amazon Studios and Blueshift Education have developed a set of lessons for upper middle and high school educators to incorporate **clips of *Radioactive*** within the classroom. These inquiry based lessons support units on the history of science, the process of scientific discovery, as a tool for strengthening critical media literacy, and for thoughtful reflection and connection to the legacy of her work today. **Each lesson includes classroom appropriate curated short film clips, primary and secondary source material, and inquiry based activities for students to delve deep into these lesson topics.**

TEACHERS PLEASE NOTE

RATING AND CONTENT:

Radioactive is rated PG-13 for thematic elements, disturbing images, brief nudity and a scene of sensuality. However, the lessons created for the film do not include any of the more mature content. **Only curated, classroom appropriate clips are used in the resource.**

DRAMATIZATION:

Radioactive is a biopic and not a non-fiction biography. A *biopic* is a dramatization of the real-life events of a person's life. The writer, director, and actors in ***Radioactive*** use artistic license to interpret Marie Curie's story - including the timeline, events, and characterizations of people represented in the film.

LESSON ONE

MARIE CURIE: THE IMAGE AND THE REALITY

Students will learn about the early years of Marie Curie and her journey as a scientist, as a partner with Pierre Curie, and as a mother at the turn of the 20th century. Through their discovery students will apply a critical media literacy lens to ***Radioactive*** and compare this depiction with select primary and secondary source materials on Marie Curie.

LESSON TWO

MARIE CURIE'S SCIENCE: EXPERIMENTATION AND DISCOVERY

In this lesson students will learn about the power of observation and the need for creativity in sparking scientific inquiry. Students will look closely at Marie and Pierre Curie's process for discovering the phenomenon of radioactivity, their identification of radium and polonium, and develop their own scientific investigations, and models for explaining radioactivity.

LESSON THREE

THE LEGACY OF MARIE CURIE

From nuclear energy and the atomic bomb, to medical applications of radiation, students will reflect on the legacy of Marie Curie's discovery of radium and share their views in a Socratic Seminar.

LETTER TO EDUCATORS FROM THE DIRECTOR OF *RADIOACTIVE* MARJANE SATRAPI

When I read the ***Radioactive*** script, I felt that it was a very important story to tell and that I had to do it. I grew up with two role models, Marie Curie and Simone de Beauvoir. My mother wanted me to become an independent woman. It was her obsession. I did not become a philosopher or a scientist, however, I managed to become an independent woman.

It is true that everyone has, more or less, heard the name of Marie Curie but almost no one really knows the breadth and depth of her story. Not only is she the only person in the world to have received two Nobel Prizes in two separate disciplines, Physics and Chemistry, but she is also of extraordinary modernity.

I did a lot of research on this. There are quite a few biographies about her, but every biographer always has an element of subjectivity. I then read all of her correspondence and her diary. By reading her own words I tried to get close to her and understand her. There were points on which I felt close to her.

"MARIE CURIE NEVER CALLED HERSELF A FEMINIST. SHE WAS A DE FACTO FEMINIST. SHE NEVER THOUGHT THAT HER GENDER PRESENTED AN OBSTACLE TO CARRY OUT HER SCIENTIFIC WORK, AND SHE WAS RIGHT. SHE SHOWED SHE WAS EQUAL (AND EVEN SUPERIOR) TO MEN JUST BY DOING. NO SLOGANS, JUST ACTION."

- MARJANE SATRAPI

She, like me, came to France at the start of our twenties to do what we could not do in our home countries. She came from Poland where scientific studies were prohibited for women. Me, from Iran where my artistic activity was compromised by religious censorship. Because of this, she, like me, as foreigners had to do three times more to achieve what we wanted to achieve.

I found in her someone who was uncompromising and who followed at all and any costs her passion, SCIENCE. It sometimes makes her not "lovable" as we expect a woman to be, but should we always be charming when we are a woman? Did she even have time to worry about the consideration of others?

When we talk about a genius man, we can safely say that he was certainly not an easy person, but since he had a superior intelligence, he had the right to be unpleasant. For women it's another matter. They always have to be gentle and accommodating.

Marie Curie never called herself a feminist. She was a de facto feminist. She never thought that her gender presented an obstacle to carry out her scientific work, and she was right. She showed she was equal (and even superior) to men just by doing. No slogans, just action.

Unfortunately our girls don't always think they can be geniuses. Studies show that up to the age of seven, they can associate the word "genius" with themselves, but very quickly this word is only attributed to boys! This is not because of their lack of intellectual capacity but because they have no concrete role models to follow. I think ***Radioactive*** can help awaken more girls to science as a vocation. Let's teach our daughters that they don't always have to apologize, that it's okay not to please everyone.

But I don't think you should put young boys aside. The reason Marie Curie succeeds is also largely due to her collaboration with Pierre Curie. He was the Physicist, she the Chemist. He was gentle and calm, she was tornadoes and fire and their love-passion joins their passion for science and discovery. It is a couple model where the two parties are equal and where the relationship is based on respect and collaboration. There is never any question of domination. Even today the couple Marie and Pierre Curie are a couple of the future.

I think it is necessary to pass the following message to our children: There is nothing more attractive than intelligence and there is nothing more modern than the equality that concerns genders and races. And obviously this fight must be waged with men, not against them.

Finally the title of the film is ***Radioactive*** and not "Marie Curie." We are talking here about the effects of the discovery of radioactivity which changed the face of the world at the beginning of the last century. In a positive way because it made it possible to find a cure against cancer, and in a negative way because it also gave rise to the atomic bomb and the nuclear disasters.

Is it the fault of science? The answer is obviously NO. Science is the expression of human curiosity trying to understand the world around it. As Marie Curie said so well: "In life, nothing is to be feared, everything is to be understood."

However, what is our responsibility as human beings in relation to these new discoveries?

Thank you.

Marjane Satrapi
DIRECTOR

LESSON TWO

EXPERIMENTATION AND DISCOVERY

LESSON OVERVIEW

"A great discovery does not issue from a scientist's brain ready-made, like Minerva springing fully armed from Jupiter's head; it is the fruit of an accumulation of preliminary work."

- Marie Curie[5]

In this lesson students will learn about the concept of radioactivity by mirroring the scientific inquiry Marie Curie undertook as she identified the phenomenon of radioactivity and the discovery of the radioactive elements radium and polonium.

GUIDING QUESTIONS

- What methods of scientific inquiry did Marie and Pierre Curie undertake in order to identify radioactivity?
- What is radioactivity?
- How can models be used to communicate complex scientific information?

TEACHER'S NOTES

- In order to make this lesson as broadly accessible as possible, it does not include experiential activities using radioactive materials. To learn more about safe experimentation using radioactive materials in high school classrooms, visit: www.epa.gov/radtown/radioactive-material-science-classrooms
- The Grape Fermentation Model in Clip Two is not a perfect model for radioactivity. A Critical Media Literacy exercise may delve deeper into the students discussing how to verify scientific information portrayed in fictionalized media.

DURATION

Two - three, 55-minute class periods with homework, depending on student investigation time allotted.

MATERIALS

- Film clips and equipment to project Clips Two and Three from the film, ***Radioactive***
- Copy Lesson Two Packet for each student
- Access to the internet or textbooks for individual research
- Where appropriate - materials to support physical investigations, such as geiger counters

GRADE LEVEL

8th -12th Grade

PLAN OF INSTRUCTION

1. INTRODUCE BECQUEREL'S ACCIDENTAL FINDING

In 1896, a French scientist named Henri Becquerel hypothesized that uranium crystals that had been charged by the sun would emit x-rays that would permeate soft tissue to create images of what is inside, such as the bones inside a body.

Read aloud this description of what happened:

> *In the course of an experiment designed to study x-rays ... Henri Becquerel stored some uranium-covered plates in a desk drawer next to photographic plates wrapped in dark paper. Because it was cloudy in Paris for a couple of days, Becquerel was not able to "energize" his photographic plates by exposing them to sunlight as he had intended. On developing the photographic plates, however, he found to his surprise strong images of his uranium crystals. He had discovered natural radioactivity, due to nuclear transformations of uranium.*[6]

Marie Curie was fascinated by this finding, and it became the spark for her groundbreaking identification of the phenomenon of radioactivity.[7]

Ask students - what research questions would they pose to help them understand Becquerel's finding? List their questions on a white board.

2. SMALL GROUP WORK: RESEARCH GROUP QUESTIONS

In an interview with the director Marjane Satrapi about the film, she said, "To be a scientist you have to be really creative, have to imagine something that is not there. **The basis of being a good scientist is to be creative - the basis is creation."**[8]

Using one of the following Graphic Organizers, have students create a plan for investigation to answer one of the questions they generated in response to the phenomenon that Becquerel observed in his lab.[9]

- Middle School Graphic Organizer
- High School Graphic Organizer

For classrooms planning on carrying out physical investigations, allow an extra class period for students to conduct their investigations.

Ideas for investigations (Middle or High School):

Research in textbooks or online to understand:

- The difference between Becquerel's hypothesis and his findings
- The definition of and atomic structure of a radioactive element

Hypothetical experiments, based on evidence and information they find through individual research:
(High School)

- How the uranium crystals in Becquerel's drawer impressed their image onto the photographic plates
- How the Curies separated the elements from the pitchblende
- The difference between radium and polonium, and how the Curies detected it
- The difference between alpha, beta, and gamma rays

Physical investigation that helps them understand radioactivity:
(High School)

- Measuring the presence of natural radioactivity in their classroom or schoolyard
  (Materials needed: Geiger counter)
- Understanding the nature of radioactive decay (half-life)

**** Note:** The investigations may require one or more full class periods.*

3. WATCH CLIP TWO FROM *RADIOACTIVE*

***Teacher Note:** In this clip, Marie Sklodowska (not yet Curie) and Pierre Curie are at dinner with friends, and Marie uses grape fermentation as a model to describe radioactivity.*[10]

Distribute **Handout One: Experimentation and Discovery Note Catcher** and have students take notes on what they see.

Watch Clip Two: The Grape Fermentation Module (runtime 3:20)

Group discussion questions:

1. Ask the group to explain their understanding of radioactivity based on their investigations. The grape fermentation model in the clip is imperfect, as fermentation is a chemical reaction that changes a substance (sugar into alcohol), where radioactivity is a reaction that changes the element itself. Ask students to critically analyze the difference.
2. Ask students whether and how the Curies' investigations mirrored their own.

4. CREATE A MODEL THAT REPRESENTS AN ESSENTIAL CONCEPT RELATED TO RADIOACTIVITY

(Depending on class timing, this step may be assigned as homework)

The grape fermentation used in the film to describe radiation is an example of a model that explains radioactivity - imperfect though it may be.

Students create their own model that communicates the findings from their investigations. Let students know they will be presenting their models to a small group for peer review the following day. Models may use one or more of the following methods:

- A metaphor that they can back up with an explanation in their own words
- A graphic organizer that represents how radioactivity occurs
- A physical model
- Other creative ideas

5. WATCH CLIP THREE FROM *RADIOACTIVE*

Teacher Note: *In this clip, the Curies conduct their investigations in the lab. They announce their findings to an audience of their peers, and describe radioactivity. Though Marie describes the structure of the atom in the clip, that was not known at the time. That was later described by J.J. Thompson, and then Ernest Rutherford.*

Watch Clip Three: The Announcement (runtime 4:13)

Group discussion questions:

- Why is it important for scientists to communicate to one another about their findings?
- What is your assessment of how their peers received the Curies' findings?
- What other sources might you check to find out whether this scene is an accurate portrayal of their announcement?

6. SCIENTIFIC COMMUNICATION: PEER REVIEW

In small groups with students who planned different investigations from one another, have students present their models to one another. Using the peer review rubric in **Handout Two**, have students offer one another constructive feedback on their models.

Offer students time to make improvements to their models based on their peers' feedback.

7. CONCLUSION

Create a Gallery Walk in honor of Marie Curie, exhibiting the models students created to explain radioactivity so students can see the work of the whole class. Gallery walk may be made into a school exhibit, or filmed to share with an online community.

FURTHER LEARNING RESOURCES

Expand on students' understanding of the radioactivity and the science of Marie and Pierre Curie using the following resources:

EPA's Radtown, Radioactivity Learning Materials:
https://www.epa.gov/radtown

NSTA's STEM Roadmap on Radioactivity:
http://static.nsta.org/pdfs/samples/PB425X8web.pdf

Center for Nuclear Science and Technology Information:
http://nuclearconnect.org/in-the-classroom
https://www.navigatingnuclear.com/classroom-resources/middle-school
https://www.navigatingnuclear.com/classroom-resources/high-school/

For Advanced Placement Students:
http://www.bozemanscience.com/radiation-radioactive-decay

LESSON TWO PACKET

CAUSE AND EFFECT
FOR MIDDLE SCHOOL STUDENTS

CAUSE

2 Describe the cause

MECHANISM

3 Describe the process that connects the cause & effect

EFFECT

1 Describe the phenomenom.

Credit: thewonderofscience.com Adapted from: Amy & Jeremy Peacock

PLANNING AND CARRYING OUT INVESTIGATIONS FOR HIGH SCHOOL STUDENTS

1 Identify the **Research Question**

3 Identify the **Independent Variable**

Mechanism

4 Identify the **Dependent Variable**

2 Sketch and label the **Lab Setup**

5 List the **Constants**

6 Record the **Data**

Credit: thewonderofscience.com

HANDOUT ONE: EXPERIMENTATION AND DISCOVERY NOTE CATCHER

Clip Two Note Catcher

As you watch the clip, take note of how Marie and Pierre plan on designing their investigation.

1. What is the phenomenon they are investigating?

2. What evidence do they plan to gather?

3. How will they go about gathering that evidence?

HANDOUT TWO: PEER REVIEW RUBRIC

ACTIVITY	NEEDS IMPROVEMENT	FAIR	EXCELLENT
RESEARCH QUESTION	Question is unclear, or unrelated to the phenomena	Question is clear and logical, based on the phenomena	Question is well-stated and sparks curiosity
PLAN FOR GATHERING DATA OR EVIDENCE	Plan is not evident or does not make sense	Plan seems clear and logical	Plan is clear and logical, includes all necessary data to replicate the investigation
PROCEDURE	Plan was not executed, or did not generate data	Data was generated according to plan	Data was generated by clear steps, and with controls in place
EVIDENCE/DATA GATHERED	Results not gathered, or not clearly represented	Evidence recorded and reported	Evidence clearly recorded and reported, perhaps with a graph, chart, or other tool to help communicate findings
CONCLUSIONS/ FURTHER QUESTIONS	Presentation does not include conclusions	Conclusions are presented	Conclusions are presented including lessons learned, and suggestions for an improved investigation, or further learning

STANDARDS

NGSS

MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures
https://www.nextgenscience.org/sites/default/files/evidence_statement/black_white/MS%20PS%20Evidence%20Statements%20June%202015%20asterisks.pdf

HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
https://www.nextgenscience.org/pe/hs-ps1-2-matter-and-its-interactions

HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
https://www.nextgenscience.org/pe/hs-ps1-8-matter-and-its-interactions

Common Core State Standards Connections:

ELA/Literacy
ELA-LITERACY.RI.9-10.1: Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.

ELA-LITERACY.RI.9-10.2: Determine a central idea of a text and analyze its development over the course of the text, including how it emerges and is shaped and refined by specific details; provide an objective summary of the text.

ELA-LITERACY.RI.9-10.3: Analyze how the author unfolds an analysis or series of ideas or events, including the order in which the points are made, how they are introduced and developed, and the connections that are drawn between them.

ELA-LITERACY.RI.9-10.7: Analyze various accounts of a subject told in different mediums (e.g., a person's life story in both print and multimedia), determining which details are emphasized in each account

ELA-LITERACY.RH.9-10.1: Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.

ELA-LITERACY.RH.9-10.2: Determine the central ideas or information of a primary or secondary source; provide an accurate summary of how key events or ideas develop over the course of the text.

WHST.9-12.2
Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2)

WHST.9-12.5
Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2)

SOURCE

1 https://www.nobelprize.org/prizes/chemistry/1911/marie-curie/photo-gallery/
2 https://chroniclingamerica.loc.gov/lccn/sn83030214/1899-12-17/ed-1/seq-8/#date1=1898&index=1&rows=20&searchType=advanced&language=&sequence=0&words=Curie+radium&proxdistance=10&date2=1900&ortext=&proxtext=curie+radium&phrasetext=&andtext=&dateFilterType=yearRange&page=1
3 https://www.nobelprize.org/uploads/2018/06/pierre-curie-lecture.pdf
4 https://chroniclingamerica.loc.gov/lccn/sn83045462/
5 https://www.nobelprize.org/prizes/chemistry/1911/marie-curie/lecture/
6 Marie Curie, quoted on p 20, Obsessive Genius, by Barbara Goldsmith, Atlas Books, New York, New York, 2005.
7 A glimpse of the solution. NobelPrize.org. Nobel Media AB 2020. Tue. 12 May 2020. https://www.nobelprize.org/prizes/themes/a-glimpse-of-the-solution
8 Interview with Blueshift Education and Marjane Satrapi, May 19, 2020.
9 The organizers are from TheWonderofScience.org, which also includes videos and teacher resources to support student use.
10 The “grape fermentation model” was written for the film, there is no evidence of Marie Curie using it to describe radioactivity.
11 Eve Curie, *Madame Curie: A Biography* (New York: Doubleday, 1937), p. 341.
12 https://www.nobelprize.org/uploads/2018/06/pierre-curie-lecture.pdf
13 Barbara Goldsmith, *Obsessive Genius: The Inner World of Marie Curie* (New York: W.W. Norton, 2005) p. 229.
14 Ibid, p. 229.
15 Ibid., p. 229.
16 Ibid., p. 226.
17 Lauren Redniss, *Radioactive* (New York: Harper Collins, 2011), p. 183.

THE EDUCATIONAL CONTENT FOR RADIOACTIVE WAS DEVELOPED BY Blueshift Education

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