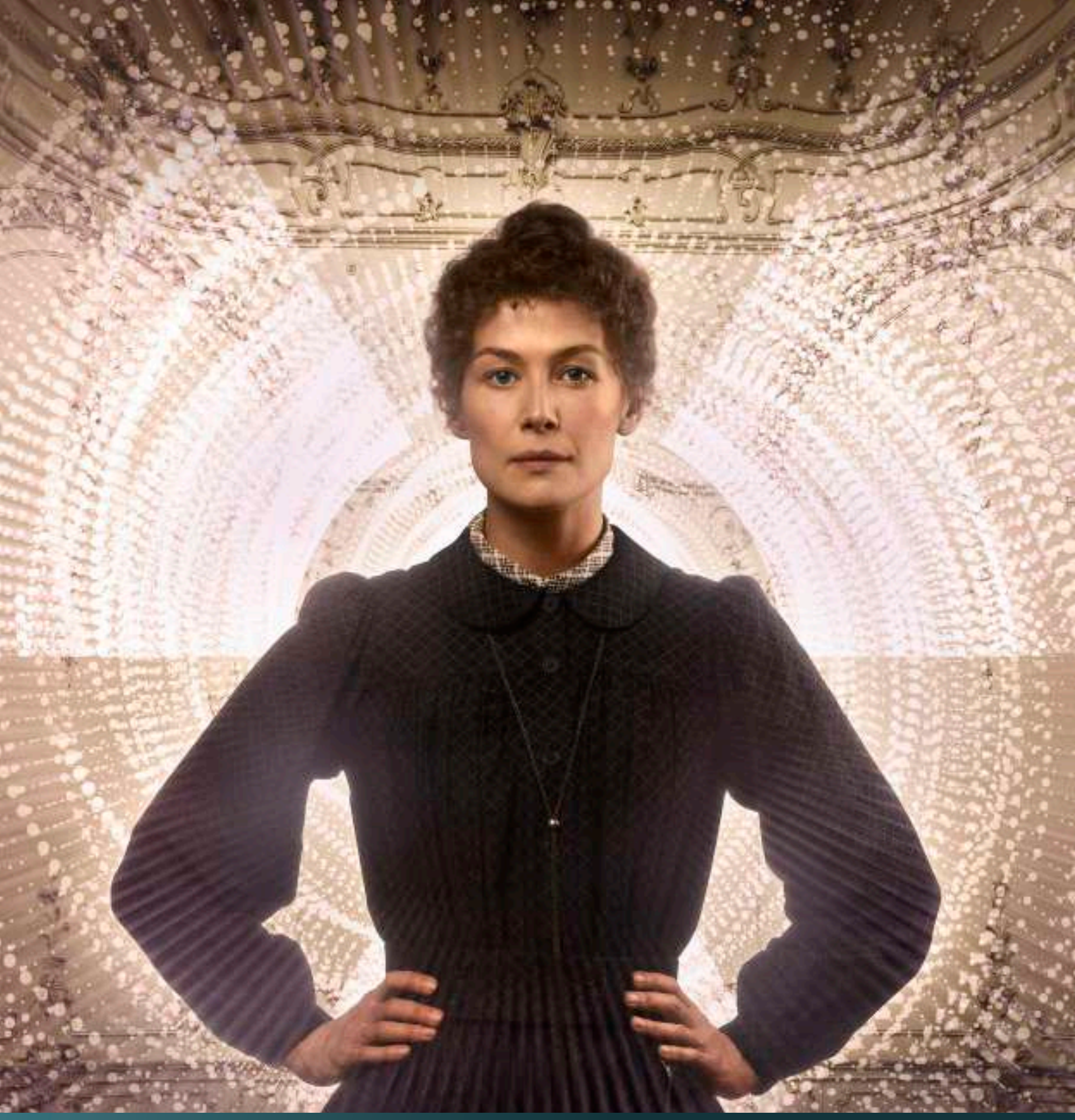


RADIOACTIVE

EDUCATIONAL RESOURCES
LESSON THREE

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

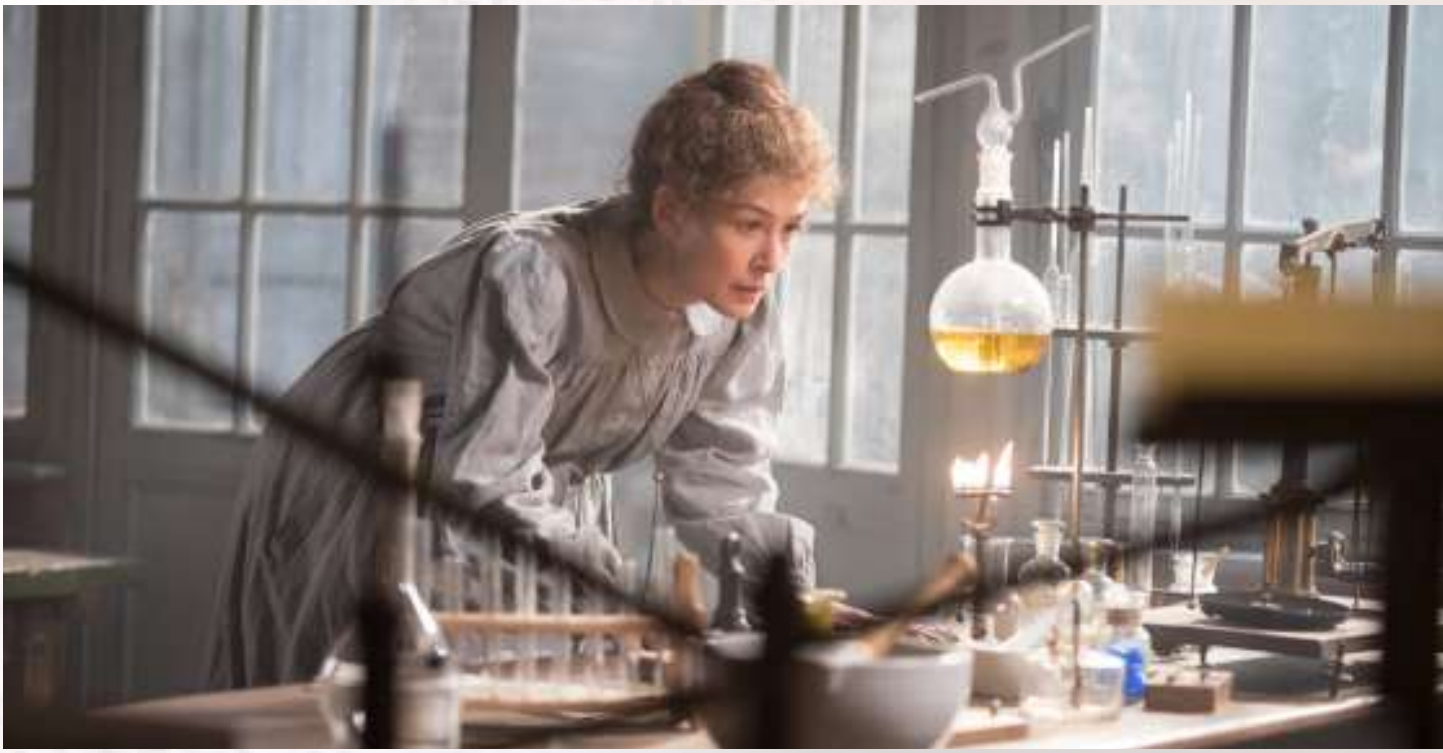
MARIE CURIE'S SCIENCE: EXPERIMENTATION AND DISCOVERY

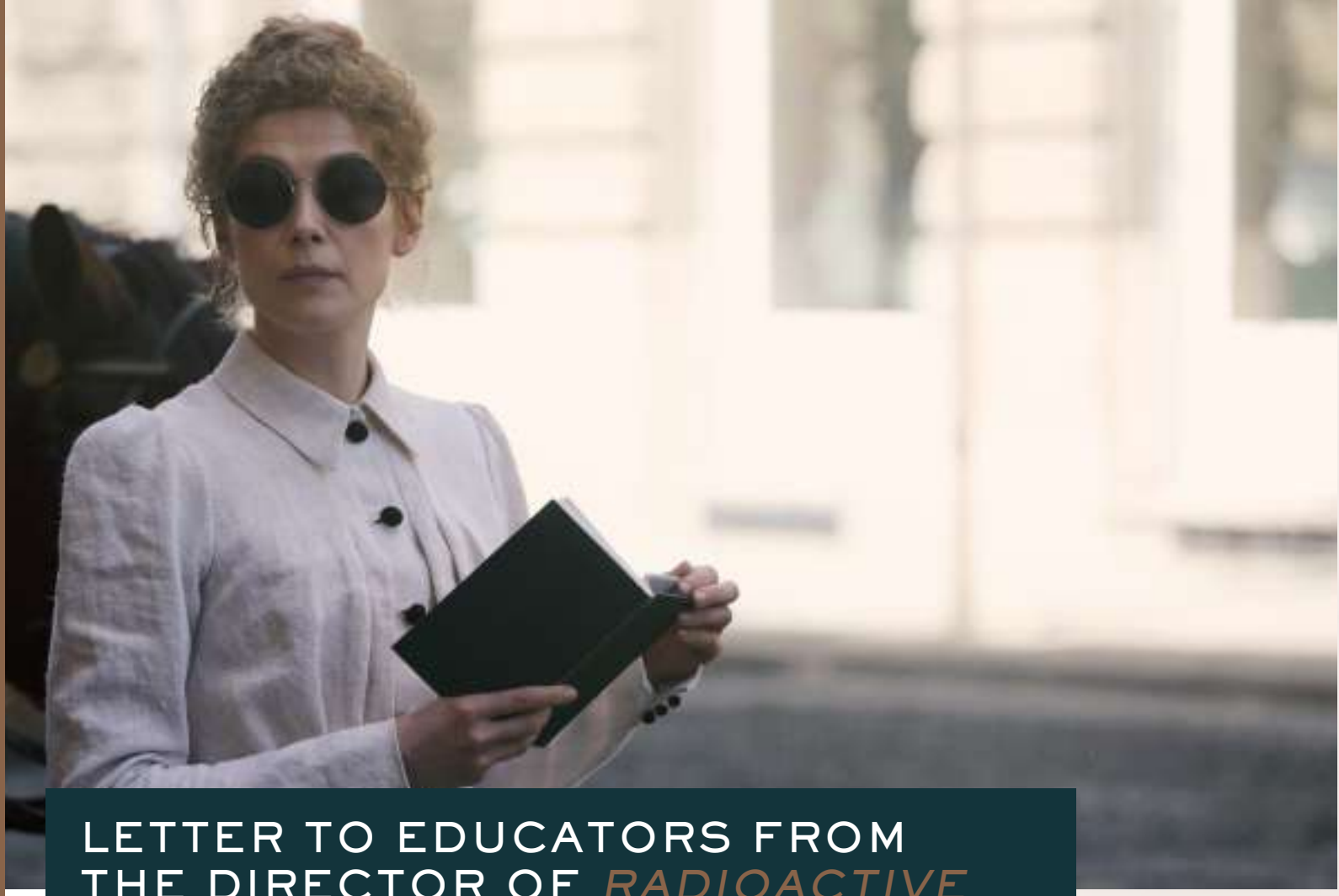
In this lesson students will learn about the power of observation and the need for creativity in sparking scientific inquiry. Students will look closely at Marie and Pierre Curie's process for discovering the phenomenon of radioactivity, their identification of radium and polonium, and develop their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

THE LEGACY OF MARIE CURIE

LESSON OVERVIEW

Marie Curie died on July 4, 1934 at the age of 66 from aplastic pernicious anemia, a result of an accumulation of radiation over many years of work. Her scientific and humanitarian legacy is far reaching and continues to inspire further discovery and advances within the fields of medicine, chemistry, and physics.

In this two-day lesson, students will reflect on what they learned about Marie Curie's life and work from the lessons and the film ***Radioactive*** and research a specific legacy topic to share in a final Socratic Seminar discussion.

DURATION

Two, 55 minute class periods.

GRADE LEVEL

8th -12th Grade

MATERIALS

- Copy Lesson Three Packet for each student
- Film clips and equipment to project Clips Four and Five from the film, ***Radioactive***

PLAN OF INSTRUCTION

DAY ONE: SOCRATIC SEMINAR QUESTIONS PREPARATION

1. Open the class by organizing students into small groups and assign each group one topic. (Ideally, there would be two groups per topic area.) Explain that each of these topics is directly, or closely associated, with the work and life of Marie Curie. Once your group is assigned a topic, your task is to prepare responses to these questions through research and collaboration.

Legacy Topics

- Nuclear Energy
- Atomic Weapons
- Medical Applications of Radiation

2. To inspire student exploration, project or distribute **Handout One - Quotes on the Legacy of Marie Curie.** Students can refer to the quotes as they prepare to discuss these questions in the Socratic Seminar.

Guiding Questions for Socratic Seminar

- How is the work and life of Marie Curie associated with your Legacy Topic?
- Marie and Pierre Curie's work was a scientific breakthrough and changed the world. In your legacy topic, what are the breakthroughs that are happening today?
- What are parallels between Marie Curie's work and scientific discoveries today?
- What are the opportunities, concerns, and ethical considerations that may arise from the new discoveries?

3. As part of their research, students may watch one or both of these suggested film segments from ***Radioactive*** to reference during the Socratic Seminar.

Film Clip 4: "A Test" of the Bomb (runtime 6:20)

- Nuclear Energy
- Atomic Weapons

Film Clip 5: Nobel Prize in Chemistry and WW I Involvement (runtime: 7:20)

- Medical Applications of Radiation

Important Note: *Traditionally Socratic Seminars are based upon a shared text or texts. For this lesson, we are broadening the scope of texts to include documents from previous lessons and from independent research completed in small groups. It is essential that students cite the texts they are referencing during the discussion.*

DAY TWO: SOCRATIC SEMINAR DISCUSSION

After students have read reflected on their texts and made notes, display and talk about the **Discussion Norms of the Socratic Seminar**. The norms are what is to be followed during the actual discussion. They may include (but are not limited to):

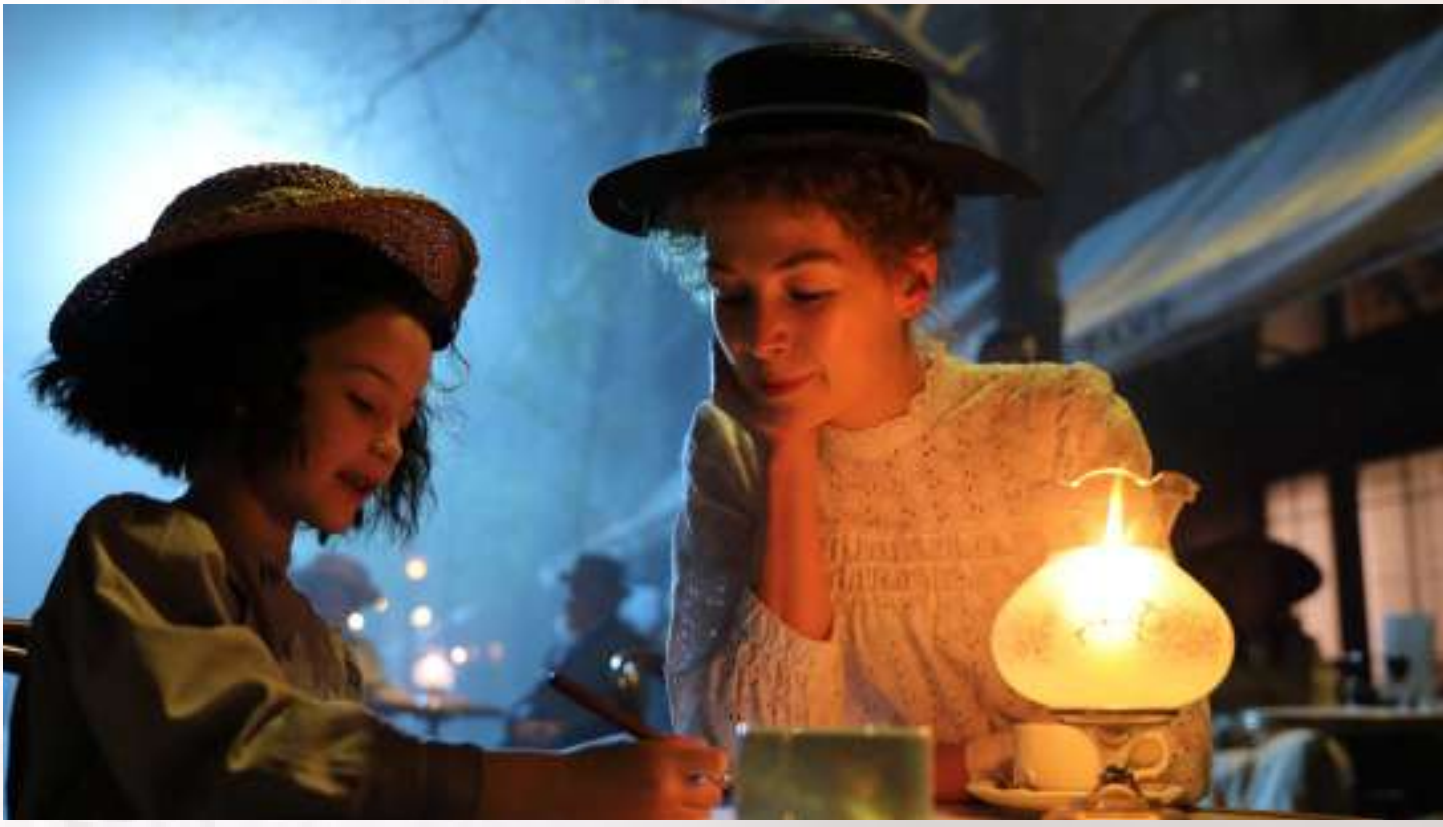
- No side conversations
- Listen carefully and with intent
- Don't raise hands
- Address each other with respect

Begin with the Guiding Questions for Socratic Seminar to start off the discussion:

Give students time to think, pause, and reflect on each question before contributing to the discussion. Encourage students to cite texts (evidence) to support their thoughts and questions they pose from the readings or from the film. The discussion should flow organically, but be aware that more Guiding Questions may be needed to keep the conversation moving.

At the end of the Seminar, ask the students to complete the **Participant Self-Assessment Rubric** and offer feedback to show students their areas of improvement. Some examples for Closing Questions, along with a template, can be found here.

If time permits, you may choose to conduct a Debriefing Session after students complete their self-assessment. This time is where students are asked for feedback as to how they think the session went, what they would suggest for improvements, and shortcomings of the discussion, in order to help the teacher iterate the process for next time. Depending on class size, this could be done in small groups, or as a technology-assisted process using a digital medium such as Google Forms.



LESSON THREE PACKET

HANDOUT ONE: THE LEGACY OF MARIE CURIE AND RADIOACTIVITY

"I AM AMONG THOSE WHO THINK THAT SCIENCE HAS GREAT BEAUTY. A SCIENTIST IN HIS LABORATORY IS NOT ONLY A TECHNICIAN: HE IS ALSO A CHILD PLACED BEFORE NATURAL PHENOMENA WHICH IMPRESS HIM LIKE A FAIRY TALE. WE SHOULD NOT ALLOW IT TO BE BELIEVED THAT ALL SCIENTIFIC PROGRESS CAN BE REDUCED TO MECHANISMS, MACHINES, GEARINGS, EVEN THOUGH SUCH MACHINERY ALSO HAS ITS OWN BEAUTY. NEITHER DO I BELIEVE THAT THE SPIRIT OF ADVENTURE RUNS ANY RISK OF DISAPPEARING IN OUR WORLD. IF I SEE ANYTHING VITAL AROUND ME, IT IS PRECISELY THAT SPIRIT OF ADVENTURE, WHICH SEEMS INDESTRUCTIBLE AND IS AKIN TO CURIOSITY..."[11] –MARIE CURIE, 1933 CONFERENCE IN MADRID, SPAIN ON "THE FUTURE OF CULTURE."

"I BELIEVE THAT IN ORDER TO DEFEND THE PEACE BY PEACEFUL AND EFFECTIVE MEANS, WE MUST TRANSLATE OUR WILL INTO ACTIONS. . . .IF TOMORROW WE WERE ASKED . . . TO WORK ON THE ATOMIC BOMB, WE MUST REPLY – NO!"[15] –FRÉDÉRIC JOLIOT-CURIE

"[I]N THE BIOLOGICAL SCIENCES THE RAYS OF RADIUM AND ITS EMANATION PRODUCE INTERESTING EFFECTS WHICH ARE BEING STUDIED AT PRESENT. RADIUM RAYS HAVE BEEN USED IN THE TREATMENT OF CERTAIN DISEASES (LUPUS, CANCER, NERVOUS DISEASES). IN CERTAIN CASES THEIR ACTION MAY BECOME DANGEROUS. . . IT CAN EVEN BE THOUGHT THAT RADIUM COULD BECOME VERY DANGEROUS IN CRIMINAL HANDS, AND HERE THE QUESTION CAN BE RAISED WHETHER MANKIND BENEFITS FROM KNOWING THE SECRETS OF NATURE, WHETHER IT IS READY TO PROFIT FROM IT OR WHETHER THIS KNOWLEDGE WILL NOT BE HARMFUL FOR IT. THE EXAMPLE OF THE DISCOVERIES OF NOBEL IS CHARACTERISTIC, AS POWERFUL EXPLOSIVES HAVE ENABLED MAN TO DO WONDERFUL WORK. THEY ARE ALSO A TERRIBLE MEANS OF DESTRUCTION IN THE HANDS OF GREAT CRIMINALS WHO ARE LEADING THE PEOPLES TOWARDS WAR. I AM ONE OF THOSE WHO BELIEVE WITH NOBEL THAT MANKIND WILL DERIVE MORE GOOD THAN HARM FROM THE NEW DISCOVERIES."[12] –PIERRE CURIE, 1905 NOBEL LECTURE

"NUCLEAR ENERGY HAS ONLY ONE OBJECTIVE, THE IMPROVEMENT OF THE ECONOMY IN OUR DAILY LIVES."[13] –IRÈNE JOLIOT-CURIE

"IN DISCOVERING ARTIFICIAL RADIOACTIVITY MY PARENTS [IRÈNE JOLIOT-CURIE AND FRÉDÉRIC JOLIOT-CURIE] DID WHAT MY GRANDMOTHER [MARIE CURIE] HAD DONE BUT IN REVERSE. IN EACH CASE, THEY CREATED A SITUATION IN WHICH THE SCIENCE HAD TO BE RETHOUGHT. MARIE UPSET THE APPLE CART BY FINDING RADIOACTIVITY AND THEN IRÈNE DID THE SAME THING BY FINDING ATOMIC FISSION, ONLY SHE DIDN'T KNOW WHAT SHE HAD DONE. THEORETICALLY IT COULD NOT EXIST, BUT CHEMICALLY IT DID."[16]–HÉLÈNE LANGEVIN-JOLIOT

"MARIE AND PIERRE CURIE RESIDE TODAY IN PARIS'S RESPLENDENT NECROPOLIS, THE PANTHÉON. SEVENTY-FIVE PEOPLE, SOME REPRESENTED SIMPLY BY AN URN BEARING THEIR HEART, ARE INTERNED THERE INCLUDING VOLTAIRE, ROUSSEAU, VICTOR HUGO, EMILE ZOLA, AND PAUL LANGEVIN. HELD IN THE BIBLIOTHÈQUE NATIONALE, THE CURIES' LABORATORY NOTEBOOKS ARE STILL RADIOACTIVE, SETTING GEIGER COUNTERS CLICKING 100 YEARS ON. STAMPS AND COINS ACROSS THE GLOBE ARE EMBLAZONED WITH LIKENESSES OF CURIE FAMILY MEMBERS. STREETS, SCHOOLS, SUBWAY STOPS, AND HOLIDAYS TAKE THEIR NAME. THE "CURIE" WAS THE FIRST OFFICIAL MEASURING UNIT OF RADIOACTIVITY. RARE EARTH ELEMENT ATOMIC NUMBER 96 ON THE PERIODIC TABLE, SYNTHESIZED AT BERKELEY IN 1944, IS KNOWN AS CURIUM. ON THE FAR SIDE OF THE MOON ARE THE CURIE CRATER, THE SKLODOWSKA CRATER, AND THE JOLIOT CRATER. THERE IS A CRATER NAMED FOR MARIE ON MARS, AND THE ASTEROID 7000 CURIE ORBISTS INSIDE THE ASTEROID BELT BETWEEN MARS AND JUPITER."[17]–LAUREN REDNISS, AUTHOR/ARTIST, *RADIOACTIVE* (GRAPHIC BIOGRAPHY THAT WAS A SOURCE OF INSPIRATION FOR THE FILM)

"I WILL NEVER FORGET THE EXPRESSION OF INTENSE JOY WHICH CAME OVER HER [MARIE] WHEN IRÈNE AND I SHOWED HER THE FIRST ARTIFICIALLY RADIOACTIVE ELEMENT IN A LITTLE GLASS TUBE. I CAN STILL SEE HER TAKING IN HER FINGERS (WHICH WERE BURNT WITH RADIUM) THIS LITTLE TUBE CONTAINING THE RADIOACTIVE COMPOUND–IN WHICH THE ACTIVITY WAS STILL VERY WEAK. TO VERIFY WHAT WE HAD TOLD HER, SHE HELD IT NEAR THE GEIGER-MÜLLER COUNTER AND SHE COULD HEAR THE RATE METER GIVING OFF A GREAT MANY CLICKS. THIS WAS DOUBTLESS THE LAST GREAT SATISFACTION OF HER LIFE."–FRÉDÉRIC JOLIOT-CURIE

"IN 1945, WHEN THE ATOM BOMBS HAD FALLEN ON HIROSHIMA AND NAGASAKI, IRÈNE SAID THAT SHE WAS GLAD HER MOTHER HAD NOT LIVED TO SEE THAT DAY."[14]

PARTICIPANT SELF-ASSESSMENT RUBRIC - MARIE CURIE SOCRATIC SEMINAR

	PROFICIENT	IN PROGRESS	NOT YET
PROFICIENT	I attended the seminar fully prepared, with my research of the topic completed. I have evidence that I read the texts/film closely and made notes. I have thoughtful questions that will contribute to the discussion.	I attended the seminar slightly prepared. I read over the material but didn't spend enough time to understand it or interpret it completely. I felt somewhat lost during the seminar because I did not prepare as much as I should have.	I attended the seminar unprepared. I did not complete the requirements of the assignment, and as a consequence, did not contribute meaningful examples to the was unfamiliar with the overall topic.
PROFICIENT	I brought strong text or other evidence to the discussion and my research stimulated a thoughtful exchange of ideas between myself and my classmates. I was able to respond to others' questions using specific examples, and posed other insightful commentary and questions during the discussion.	I somewhat participated in the discussion, but my questions and answers were vague and not well thought out. I was able to cite some evidence but my contribution did not necessarily keep the conversation moving forward.	I did not participate in the discussion.
PROFICIENT	I supported my classmates during the discussion by actively listening, maintaining eye contact, and showing appropriate body language. My responses show that I was engaged in the conversations with my classmates and thought about the commentary deeply and thoroughly	I listened actively sometimes, but my mind tended to wander or I was distracted by my classmates and/or materials.	I did not listen to my classmates and disrupted the flow of the discussion with inappropriate or distracting behavior. My responses to comments did not stay within the spirit of the Socratic Seminar guidelines

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.

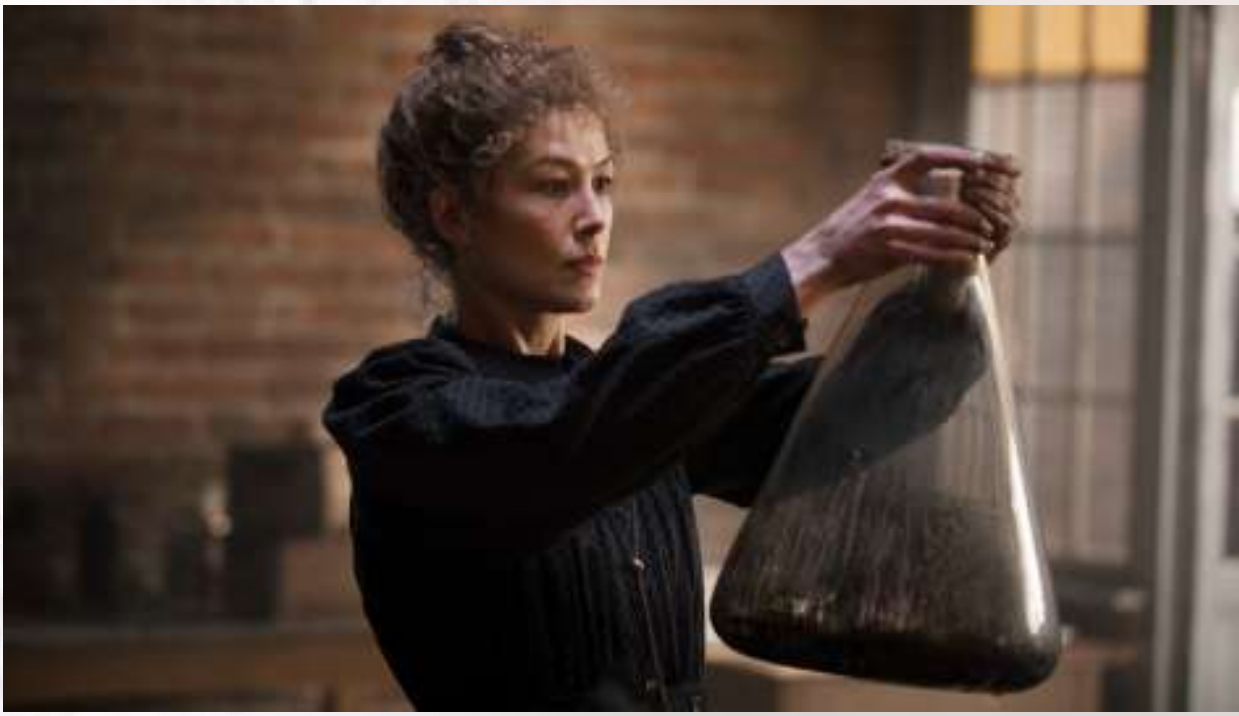
ELA-LITERACY.RH.9-10.2: Determine the central ideas or information of a primary or secondary source; provide an accurate summary of how key events or ideas develop over the course of the text.

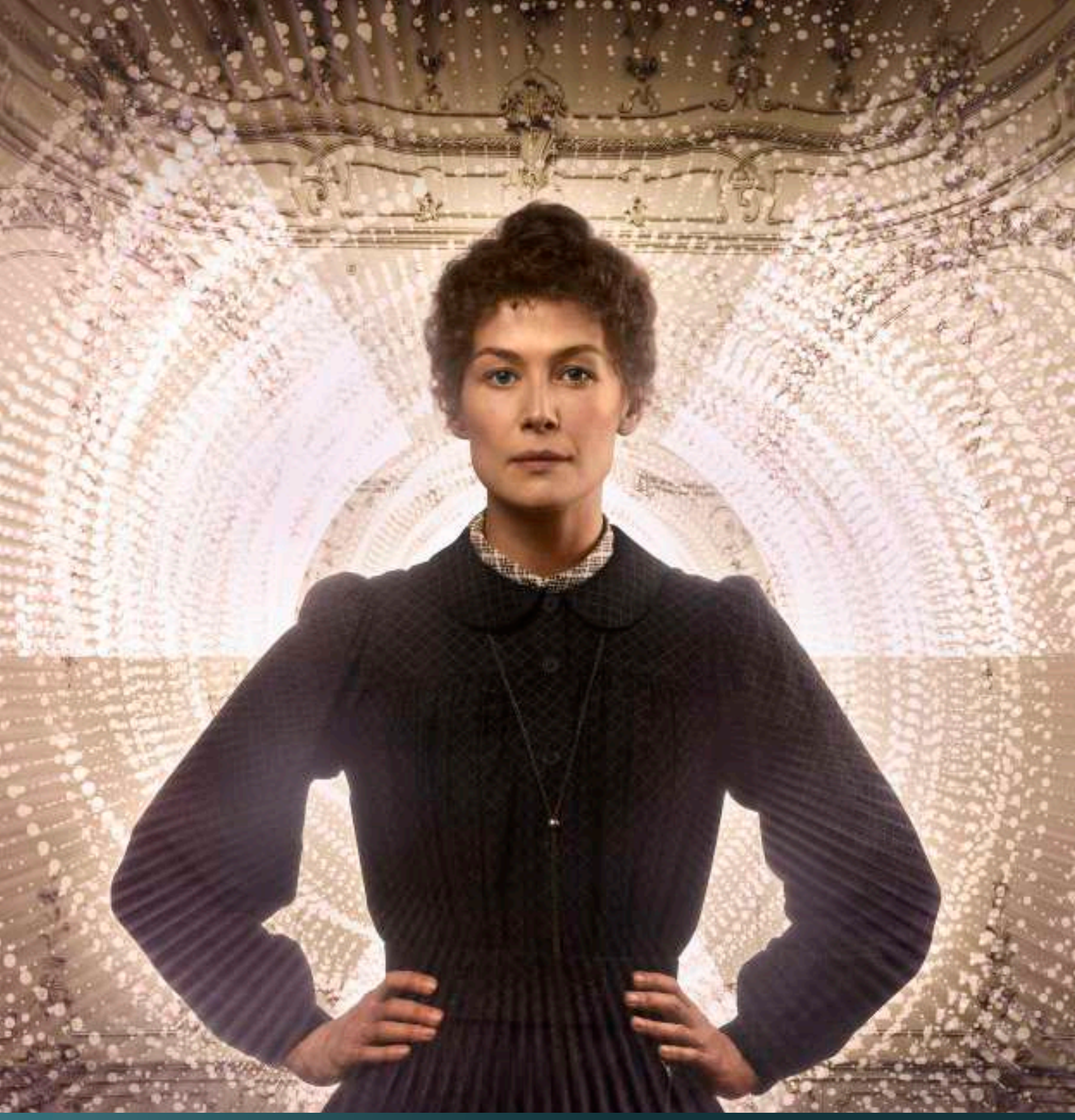
WHST.9-12.2
Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1-2)

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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