Lesson Plan
Women and the Manhattan Project

Oak Ridge National Laboratory and Digital Photo Archive, Department of Energy (DOE), courtesy AIP Emilio Segre Visual Archives

Grade Level(s): 9-12, College	**Subject(s): History, Physics, Chemistry**
In-Class Time: 60-100 Minutes	**Prep Time: 15 Minutes**

Materials

- Manhattan Project Sites Handout (found in Supplemental Materials)
- Recommended Oral Histories list (found in Supplemental Materials)
- Photocopies of Discussion Questions (found in Supplemental Materials)
- (Optional): A map of the United States or the world
- Internet access and A/V equipment to stream a short video that introduces nuclear fission (link found in Required Resources below).
- Some type of soft balls. Quantity: twice the total number of students. Balls should be light weight and small. Example: ping pong balls, small foam balls, or marshmallows.
- One stopwatch

Objective

In this lesson students will learn about the history of the Manhattan Project and how many women contributed in various capacities. This lesson relies on oral histories from a variety of women whose lives were affected in major ways by the Manhattan Project. Students will learn about these women through their oral histories and discuss their work. By the end of the lesson students will have learned more about life at the Manhattan Project sites, as well as more indirect consequences of the Project such as displacement, discrimination, and environmental and health effects. Students will also discuss their opinions and the opinions of the women researched regarding the decision to drop the atomic bombs. Afterward, the teacher will have students conduct a simulation of a nuclear reaction and explain the process of nuclear fission.

Introduction

The Manhattan Project

In August 1939, famous physicists Albert Einstein and Leo Szilard wrote a letter to then President Franklin Roosevelt warning him of German attempts to create "extremely powerful bombs of a new type" and recommending that the United States counter these efforts by producing the bomb first. Thus began what was called the Manhattan Project, one of the largest scientific undertakings in United States history, lasting from 1941-1946. The Project involved the building of three completely new and secret cities in Oak Ridge, Tennessee; Los Alamos, New Mexico and Hanford, Washington and the work of scientists at University of Chicago, University of California, and Columbia University. In all, over 400,000 individuals worked on the Manhattan Project but only a handful of those people knew what they were working toward: the construction of the atomic bomb.

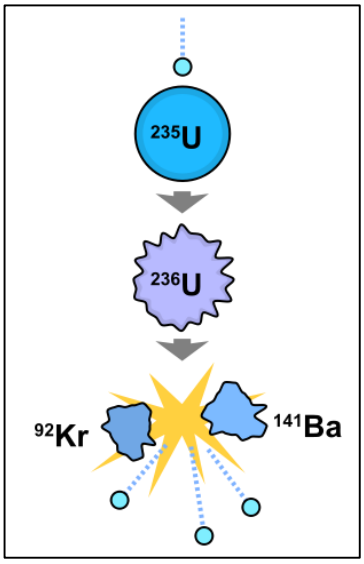
Women of the Manhattan Project

The traditional story of the Manhattan Project centers on the work of key male players such as Robert Oppenheimer, General Leslie Groves, Enrico Fermi, and Hans Bethe. Historical research, however, has revealed the important roles women played at nearly every level in the national enterprise of building a bomb. Famous female physicists who worked on the Project include Maria Goeppert-Mayer, Elizabeth Graves, Joan Hinton, Leona Woods, and Chien-Shiung Wu. In addition to working as scientific researchers, women also contributed to the Manhattan Project as technicians as well as secretaries, clerks, switchboard operators, and truck drivers.[1]

The work of women on the Manhattan Project has been better documented in recent years because of an effort to record individuals' lives through oral histories. In this lesson plan students will learn about the involvement of women at various sites in the Manhattan Project through the study of some of these oral histories. Oral histories from the "Voices of the Manhattan Project" website will be utilized. This website was launched in 2012 as a collaboration between the Atomic Heritage Foundation and the Los Alamos Historical Society.

[1] For more information about the women who worked on the Manhattan Project and the various capacities in which they were employed, read Ruth H. Howes and Caroline L. Herzenberg. *Their Day in the Sun: Women of the Manhattan Project*. Philadelphia: Temple University Press, 1999.

Elaboration: Chain Reaction Activity



Nuclear fission refers to the process by which a massive nucleus splits into two fragments that each have a smaller mass than the original. The fission process often results in the production of free neutrons and photos and releases a great amount of energy. A typical example of nuclear fission is the splitting of the nucleus of uranium-235, an isotope of uranium. This is the process behind nuclear reactors which are used to generate electricity. When U-235 is bombarded by neutrons (the small blue circles in the image to the left), it splits and produces Barium, Krypton, and more neutrons. The fission of one atom of U-235 produces 202.5 MeV = 3.24 x 10^{-11} Joules of energy. (Image on left shows nuclear fission of U-235, courtesy of Wikimedia Commons)

The uranium-235 fission reaction produces two or three neutrons which can then be used to initiate a series of fission reactions. Each neutron released can initiate another fission event, resulting in the emission of more neutrons, followed by more fission events, and so on. This is why nuclear fission is referred to as a chain reaction – the first event triggers several others, which in turn trigger more events, and so on. If a chain reaction will sustain itself, it is called "critical," and the mass of the U-235 needed to produce a critical condition is called the "critical mass." In order to create critical mass there are two important factors: the number of atoms and the spacing of the atoms. In a nuclear power plant the chain reaction is controlled by restricting the number of neutrons available to collide with the uranium. In an uncontrolled chain reaction (such as an atom bomb explosion) there is nothing to control the number of neutrons being released, so the rate of the chain reaction increases dramatically.

In the elaborate section of this lesson plan, each student will represent a single uranium atom inside of a nuclear reactor. Once hit with a neutron, each uranium atom will release two neutrons in the nuclear fission process. The more students that participate, the better the demonstration will be.

Instructions

Engage: 5-25 minutes

Teachers will introduce students to World War II and the Manhattan Project by fostering a short discussion. They will ensure that students recognize the important role women played at the various sites. Use the Introduction to this lesson plan for guidance.	
What is the teacher doing? Ask students to explain how and why the Manhattan Project emerged during WWII. Ask them to name who they typically associate with the development of the bomb (likely responses will be Oppenheimer and other white, male scientists). Explain that women were also crucial contributors.	**What are the students doing?** If known, explain how the Manhattan Project emerged, and who is typically associated with the creation of the atomic bomb. Understand that women were also crucial to the Project's completion.

Lead a discussion about the various sites of the Manhattan Project (distributing copies of the Manhattan Project Sites Handout). It may be helpful to place pins in a map of the United States or the World (e.g. at Los Alamos, Oak Ridge, Hanford, Tinian, Hiroshima, and Nagasaki) to demonstrate the extent of the Manhattan Project. The Voices of the Manhattan Project has created a useful map that locates each Site and provides brief descriptions of each.	Receive the Manhattan Project Sites Handout, and discuss the various sites as a class. If possible, mark their locations on a map.

Explore: 30-35 minutes

Students will work individually or in small groups to profile a woman whose oral history is included on the Voices of the Manhattan Project website: http://manhattanprojectvoices.org/ . A list of twelve oral histories is provided in the Supplemental Materials for this lesson. Students should select an individual from this list and explore their stories through the oral histories and further research. All oral histories can be read as transcripts, and some come with supplementary audio or video. Students will prepare a presentation with their research findings. (Optional): This activity may be modified to be completed as an out-of-class assignment to save in-class time.	
What is the teacher doing? Distribute copies of the Recommended Oral Histories (from the Supplemental Materials). Have students select an individual from the list to research. Allow computer access for students to complete their research, and provide students with copies of the Discussion Questions (located in the Supplemental Materials) to guide their research. Note: not every interview contains answers to ALL questions. Students should complete as many answers as possible. Have students read the transcript of their individual's oral history, and (if possible) conduct additional research about the person's life. Have the students prepare a presentation about their findings, which will incorporate answers to the Discussion Questions.	**What are the students doing?** Receive the Recommended Oral Histories and select an individual from the list. Receive the Discussion Questions from the teacher. Access the individual's oral history at the Voices of the Manhattan Project website. Read the transcript of the oral history, and answer as many Discussion Questions as possible. If possible, conduct additional research on the individual's life. Prepare to present research findings to the class, including answers to the Discussion Questions.

Explain: 10-20 minutes

Students will present their research findings to the class, incorporating Discussion Questions. Each Presentation should be two to five minutes in length. Afterward, students will reconvene as a class and discuss similarities and differences among the stories.	
What is the teacher doing? Ask students questions about the women they researched, including name, place of origin, role and location in the Project, and later occupation. Encourage other non-presenting students to ask questions during presentations.	**What are the students doing?** Present research findings to the class in a two to five-minute presentation. Incorporate answers to the Discussion Questions into the presentations. If available, denote on the map which site the woman worked at.
Lead a discussion in which students compare and contrast the stories of the individuals that were presented.	As a class, discuss the similarities and differences between the stories of the women. Discuss why these experiences may have been similar or different.

Elaborate: 15-20 minutes

Teachers will introduce students to nuclear fission through a short lecture or video (link found in the Required/Recommended Reading and Resources). Then, students will partake in an activity using balls that will demonstrate the process of nuclear fission. The activity will consist of three trials.	
What is the teacher doing? Explain nuclear physics to students through a very brief lecture. Or: Have the class watch the short video: "Fission Reaction" (1 min. 6 sec.) Link provided below in Required/Recommended Reading and Resources	**What are the students doing?** Observe lecture or video introducing the process of nuclear fission.
1. Give each student two balls and take a ball for yourself. Tell the students that each ball represents a neutron and they are each a uranium atom inside a nuclear reactor. 2. One student should volunteer to time the "nuclear reaction" (this student can alternate with each repetition). The timer should start the stopwatch when the first ball is thrown and stop the clock when the last ball is thrown. Record the times on the board. 3. For the first trial, have students stand in a square approximately 3 feet apart. 4. To begin, throw your ball up into the air or at a student (gently). Any student that is hit with this ball throws their two balls straight up into the air. Any student hit by these balls then throws their balls into	1. Each student receives two balls, and holds one ball in each hand. 2. One student should volunteer to time the nuclear reaction (this student can alternate with each repetition). The timer should start the stopwatch when the first ball is thrown and stop the clock when the last ball is thrown. Record the times on the board. 3. Stand in a large square, each student approximately three feet apart. 4. The teacher will begin by tossing a ball into the air or towards a student. If a student is hit by a ball, they throw their balls up into the air without aiming directly at fellow students. Students must not throw their balls unless they are hit by a ball. This "reaction" should continue until there are no more balls to

the air. Continue the reaction until there are no more balls to throw or no student is forced to throw their balls. The first time, the reaction will probably die out quickly. Explain how this is called a **subcritical reaction**. 5. For trial two, have the students stand 1 foot apart and repeat the process. This time, the reaction should be self-sustaining. Explain how this represents a **critical reaction**. 6. Have the students stand close together without any space between them. This time, there should be lots of balls in the air at one time. Explain how this represents a **supercritical reaction**. 7. Collect balls and stopwatch.	be tossed, or no student is hit by a toss. Timekeeper should record the time this took. Listen to how the teacher identifies this type of reaction. 5. Reset, each student reacquiring two balls apiece, with one per hand. Now, students should form a square with each student approximately one foot apart. Repeat the reaction process, timekeeper recording the new time. Listen to how the teacher identifies this type of reaction. 6. Reset again, and form a square with minimal space between students. Repeat the reaction process again, timekeeper recording new time again. Listen to how the teacher identifies this type of reaction. 7. Return balls and stopwatch to the teacher.

Evaluate:

Evaluation during this lesson is possible during the explore/explain sections. Teachers may collect students' reports on their selected woman, which would necessitate evaluating whether they included answers to the Discussion Questions. Or, teachers may evaluate the student presentations themselves, checking for the same information.

Required/Recommended Reading

- Oral histories of the Recommended Women, located at the Manhattan Project website: http://manhattanprojectvoices.org/
    - Voices of the Manhattan Project has collected and conducted many oral histories of participants in the Manhattan Project. They provide transcripts for all oral history interviews, and audio/video is also available for many of the interviews. The website also features an interactive map and links to other online resources including more oral histories. All content is free and open access.
    - The Voices of the Manhattan Project has also created a useful map that locates the sites and provides brief descriptions of each: http://www.manhattanprojectvoices.org/locations
- Video: "Fission Reaction," CLI Production Team, May 18, 2011, https://www.youtube.com/watch?annotation_id=annotation_696116&feature=iv&src_vid=kHXMiYsFSrU&v=Ezbyg2iNdQs (1 min. 6 sec.)

Discussion Questions

Discussion Questions can be found as a Handout with a corresponding Answer Key in the Supplemental Materials to this lesson plan.

1. When was the person you selected born and where were they from?
2. Did the person you selected go to college? If so, where, and what did they study?
3. Why did the person you selected decide to start working on (what was eventually revealed to be) the Manhattan Project? Was it money, professional opportunity, family, etc.?
4. Describe the work or research of the person you selected. What did they do during their time on the Manhattan Project?
5. The women of the Manhattan Project faced many challenges, both at work and at home.
    a. What was the most difficult aspect of life during the Manhattan Project for the person you selected?
    b. What was the most surprising thing they shared about their life during this time?
6. Did the person you selected face discrimination in the workspace or elsewhere? Were they the only woman working at their type of job?
7. What was life like outside of work at the development sites? What was the living situation of the person you selected? What kinds of recreation did they take part in?
8. Secrecy was of the upmost importance during the Manhattan Project. Employees were given just enough information to fulfill their responsibilities, but they were left in the dark as to the purpose of the Project and their contributions to it.
    a. How much did the person you researched know about what was being developed?
    b. How was secrecy and security enforced at their station?
    c. When did they find out it was an atomic bomb?
9. How did the person you selected react to the news of the bombing of Hiroshima? Do you agree with them? Why or why not?
10. How would you rate the oral history interview overall? Are there additional questions you feel were not asked or clarified? What are they?

Further Reading and Additional Resources

Videos:

- Denise Kiernan, author of *Girls of Atomic City*, talks about Oak Ridge in an interview with the Atomic Heritage Foundation. (4:55)
  http://www.atomicheritage.org/tours/Oak%20Ridge
- Denise Kiernan, author of *Girls of Atomic City*, talks about her book in an interview with the Atomic Heritage Foundation. (54:59)
  http://manhattanprojectvoices.org/oral-histories/denise-kiernans-interview

Further Reading:

- Ruth H. Howes and Caroline L. Herzenberg. *Their Day in the Sun: Women of the Manhattan Project*. Philadelphia: Temple University Press, 1999.
- Denise Kiernan. *Girls of Atomic City*. New York: Simon & Schuster, 2013.

- S. L. Sanger and Craig Wollner, *Working on the Bomb: an Oral History of WWII Hanford* (Portland, OR: Portland State University Continuing Education Press, 1995).
- Cynthia C. Kelly, ed. *The Manhattan Project: The Birth of the Atomic Bomb in the Words of Its Creators, Eyewitnesses, and Historians*. Black Dog & Leventhal Publishers, 2009.

Other Resources:

- The National World War II Museum has an interactive timeline on the history of the Manhattan Project that includes many primary sources such as Einstein's 1939 letter to Roosevelt, http://www.ww2sci-tech.org/timeline/timeline.html.
- The Atomic Heritage Foundation provides histories of the various Project sites as well as other aspects of the Manhattan Project: http://www.atomicheritage.org

Extensions

Related AIP Teacher's Guides on Women and Minorities in the Physical Sciences:

- African Americans and the Manhattan Project
- Lise Meitner, Austrian Nuclear Physicist
- The Struggle for Employment
- Chien-Shiung Wu, Chinese Nuclear Physicist
- Leona Woods, American Nuclear Physicist

Common Core Standards

For more information on Common Core Standards, visit http://www.corestandards.org/.

Speaking & Writing	
CCSS.ELA-LITERACY.SL.9-10.1	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
CCSS.ELA-LITERACY.SL.9-10.4	Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
CCSS.ELA-LITERACY.SL.11-12.1	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
CCSS.ELA-LITERACY.SL.11-12.4	Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.

History/Social Studies	
CCSS.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.
CCSS.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.
CCSS.ELA-LITERACY.RH.9-10.9	Compare and contrast treatments of the same topic in several primary and secondary sources.
CCSS.ELA-LITERACY.RH.11-12.1	Cite specific textual evidence to support analysis of primary and secondary sources, connecting insights gained from specific details to an understanding of the text as a whole.
CCSS.ELA-LITERACY.RH.11-12.2	Determine the central ideas or information of a primary or secondary source; provide an accurate summary that makes clear the relationships among the key details and ideas.
CCSS.ELA-LITERACY.RH.11-12.9	Integrate information from diverse sources, both primary and secondary, into a coherent understanding of an idea or event, noting discrepancies among sources.
Science & Technical Subjects	
CCSS.ELA-LITERACY.RST.9-10.2	Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
CCSS.ELA-LITERACY.RST.11-12.2	Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
Subject Writing	
CCSS.ELA-LITERACY.WHST.9-10.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
CCSS.ELA-LITERACY.WHST.9-10.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
CCSS.ELA-LITERACY.WHST.9-10.9	Draw evidence from informational texts to support analysis, reflection, and research.
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Next Generation Science Standards

For more information on the Next Generation Science Standards, visit http://www.nextgenscience.org/.

Dimension One: Practices	1. Asking questions (for science) and defining problems (for engineering) 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 6. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument from evidence 8. Obtaining, evaluating and communicating information
Dimension Two: Crosscutting Concepts	1. Patterns 2. Cause and Effect 3. Scale, Proportion, and Quantity 4. Systems and System Models 5. Energy and Matter: Flows, Cycles, and Conservation 6. Structure and function 7. Stability and Change of Systems
Dimension Three: Disciplinary Core Ideas	PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions PS1.C: Nuclear Processes ETS2.A: Interdependence of Science, Engineering and Technology ETS2.B: Influence of Engineering, Technology, and Science on Society and the Natural World