

Lesson Plan

Eunice Foote: Scientist and Suffragette



An illustration of Eunice Newton Foote collecting observations for her groundbreaking atmospheric research.

Illustration by Carlyn Iverson

Grade Level(s): 6-8, 9-12

Subject(s): Physics, History, Earth Science

Supplements: Physics Topic

In-Class Time: 50-75 minutes

Prep Time: 15-20 minutes

Materials

- A/V Equipment
- Internet Access
- Copies of Foote vs Tyndall (found in Supplemental Materials)
- Copies of Discussion Questions (found in Supplemental Materials)
- Copies of Declaration of Sentiments (found in Supplemental Materials)

Objective

Eunice Newton Foote discovered the greenhouse effect in 1856. So why did John Tyndall receive the credit for the making the same conclusion three years later? In this history-focused lesson, students will explore her discovery and its implications as well as the context for which she conducted her research. By the end of this lesson, students will connect Foote's unequal treatment to her work as a suffragette, fighting for women's rights. Students will explore unequal treatment of groups in the United States today and use the women's rights movement to inspire activism.

Introduction

Eunice Newton Foote (1819-1888) was a scientist, inventor, and women's rights activist who first discovered carbon dioxide's ability to retain heat and concluded that an increase in the presence of carbon dioxide in the atmosphere would cause global warming. Today, we call this the greenhouse effect and though Foote discovered it in 1856, she did not receive credit for her discovery until 2011.

Very little is known about Eunice Foote's early life. Her father was Isaac Newton Jr. of Bloomfield, New York, her mother unknown.¹ She attended Troy Female Seminary, an all-girls school and took classes at a nearby men's science college, now known as Rochester Polytechnic Institute. Though she never received any specific physics education, she was trained in general science which no doubt aided her future scientific endeavors. In 1841, she married Elisha Foote a mathematician, inventor, and judge.² They were both women's rights activists and attended the 1848 Seneca Falls convention, credited for sparking the women's rights movement. Together they had two daughters, Mary Newton Henderson and Augusta Newton Arnold.³

As a scientist, Eunice Foote was groundbreaking. Though she published just two papers, she was one of the first female scientists published in the United States.⁴ Her first paper, "Circumstances Affecting the Heat of the Sun's Rays," was published in 1856 and covered her experiment to test how different atmospheric conditions such as air density, humidity, and gases respond to heat from the sun. Her discovery in this paper, that carbon dioxide absorbs and retains heat significantly more than the other conditions is what we know today as the greenhouse effect.⁵ Her second paper, "On a New Source of Electrical Excitation," was published in 1858 and addressed how varying moisture content effects the

¹ Reed, Elizabeth W. *American Women in Science Before the Civil War*. Minneapolis, 1992.

² Joseph D. Ortiz and Ronald Jackson. "Understanding Eunice Foote's 1856 Experiments: Heat Absorption by Atmospheric Gases." *Notes and Records: The Royal Society Journal for the History of Science* (26 August 2020), 1-18. <https://doi.org/10.1098/rsnr.2020.0031>.

³ Reed, *American Women in Science Before the Civil War*.

⁴ Ortiz and Jackson, "Understanding Eunice Foote's 1856 Experiments," 1-18.

⁵ Eunice N. Foote, "On the Heat in the Sun's Rays," *The American Journal of Science and Arts* 22 (November 1856): 377-82.

static electricity in the air.⁶ In addition to conducting scientific research, Foote was also an inventor and held the patent for a shoe filling.⁷

Foote's atmospheric experiments were likely motivated by an interest in the geologic past. At the time, scientists were confused why areas of higher elevation contained evidence of plants and animals found in warmer environments and speculated of a warmer past.⁸ To explore what changes to the atmosphere could foster a warmer environment, Foote recreated different atmospheric conditions in glass jars and exposed them to the sun. She filled jars with common air, pumping in more air or removing some to compare different densities, adding moisture to others, or even different gases like carbon dioxide. She measured the difference in temperature of the jars in sunlight and a control jar of each gas left in the shade. Based on her observations, she concluded that higher pressure air, damp air, and some gases are more affected by the sun's rays than common air, the most dramatic effect from carbon dioxide.⁹ Though Foote did not account for *how* the gases cause climate change, understood now to be the invisible infrared wavelengths of light that radiate off Earth's surface in the form of heat, she was the first to recognize the gas's ability to absorb heat its implications.¹⁰

Despite wider recognition than many female U.S. scientists before her, her work received little attention compared to her male counterparts. Comparing the reception of her work to her husband's is a case study in the unequal treatment she received. Both of their research was presented at the 10th American Association of the Advancement of Sciences (AAAS) meeting in 1856. Like most researchers, Elisha Foote presented his own findings, while Eunice's paper was presented by Joseph Henry, then Secretary of the Smithsonian institution. That year, Elisha but not Eunice Foote was voted as a member of AAAS.¹¹ Henry's coverage and remarks on Eunice Foote's work was published by the *American Journal of Science and Arts* and covered by *Scientific American* in an article about skilled female scientists,¹² but it received little coverage outside of that. It is likely that few at the time understood the wider implications of her discovery, but it is also likely that the minimal coverage and subpar treatment was due to Eunice Foote's gender. In 1859, just three years after Foote's findings were published, the Irish scientist John Tyndall arrived at the same conclusion that variations in atmospheric gases absorb radiation differently and contribute to climate change. He was probably unaware of Foote's work and was credited with the discovery of the greenhouse effect for a century and a half. In 2011, geophysicist Raymond Sorenson rediscovered her work and brought her research back into the public eye.¹³

⁶ Eunice N. Foote, "On a New Source of Electrical Excitation," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 15, no. 99 (1858): 239–40. <https://doi.org/10.1080/14786445808642471>.

⁷ Eunice N. Foote, Filling for the soles of boots and shoes, US Patent Office US28265A (Saratoga Springs, NY, 1860).

⁸ Ortiz and Jackson, "Understanding Eunice Foote's 1856 Experiments," 1-18.

⁹ Foote, "On the Heat in the Sun's Rays," 377–82.

¹⁰ Ortiz and Jackson, "Understanding Eunice Foote's 1856 Experiments," 1-18.

¹¹ Ortiz and Jackson, "Understanding Eunice Foote's 1856 Experiments," 1-18.

¹² "Scientific Ladies--Experiments with Condensed Gases," *Scientific American* 12, no. 1 (13 September 1856): 5.

¹³ Raymond P. Sorenson "Eunice Foote's Pioneering Research on CO₂ And Climate Warming," *Search and Discovery*, no. #70092 (31 January 2011).

In addition to science, Eunice Newton Foote was highly involved with the women’s rights movement. In the 19th century, women lacked many of the rights now enshrined in law. For instance, women could not vote, and in many states they could not own property. Many of the activists in the abolition movement began to advocate in a more coordinated format for women’s rights as well. Seneca Falls, New York, was a central gathering point for these activists, who included Elizabeth Cady Stanton and Lucretia Mott. On July 19th and 20th, 1848, approximately 300 men and women gathered in what is now known as the Seneca Falls Convention. This convention, credited for sparking the women’s rights movement, also produced a document entitled the *Declaration of Sentiments*.¹⁴ This widely-read document mimicked the *Declaration of Independence* and listed societal wrongs women faced.¹⁵ Eunice Foote not only attended and signed the document but was also on the editorial committee. Her voice and presence in Seneca Falls likely had a lasting impact in women’s rights.

Instructions/Activities

Engage: 5-10 Minutes

Teachers will introduce topic by discussing rights in society using the provided opening prompts or questions of their own choosing. The opening discussion prompts are listed below and in a separate document found in the Supplemental Materials.

What is the teacher doing?

Leading a discussion with the class to get them thinking about rights in society.

What are the students doing?

Discussing the questions.

Explore: 15-20 Minutes

Students will read “Foote vs. Tyndall” to learn about Eunice Newton Foote’s work and why she did not receive credit until 2011. The teacher will provide students with the questions for the reading.

What is the teacher doing?

Provide students copies of “Foote vs. Tyndall” at the appropriate grade level.

Provide students with copies of the “Foote vs. Tyndall Questions” (found in the Supplemental Materials). Instruct students to answer them as they read through the document.

What are the students doing?

Read a copy of “Foote vs. Tyndall” individually or in small groups.

Answer the questions provided by the teacher as the reading is completed.

Explain: 10-15 Minutes

The teacher will lead students in a class-wide discussion on the answers to the Foote vs. Tyndall Questions. The teacher will also return to the opening questions about rights and discuss what the class learned.

¹⁴ Sally McMillen, *Seneca Falls and the Origins of the Women’s Rights Movement* (Oxford: Oxford University Press, 1999).

¹⁵ John Dick, *Report of the Woman’s Rights Convention Held at Seneca Falls, N.Y., July 19th and 20th, 1848* (Rochester: North Star Office, July 1848).

<p>What is the teacher doing? Lead the class in examining the correct answers to the Foote vs. Tyndall Questions.</p> <p>If desired, collect student answers to the questions for evaluation.</p>	<p>What are the students doing? Review answers to the Discussion Questions as a class.</p> <p>If instructed, submit answers to the questions to the teacher for evaluation.</p>
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Elaborate: 20-30 Minutes

<p>Foote was not only a scientist but a women’s rights activist. The teacher will overview the women’s right’s movement and show a video about the shortcomings of the movement in including Black activists. Afterwards, students will write their own <i>Declaration of Sentiments</i> about a group they feel currently faces oppression.</p>	
<p>What is the teacher doing? Discuss with the class the limitations of women’s rights at the time Eunice Foote was conducting her research. Some examples include:</p> <ul style="list-style-type: none"> • In many states women could not own property • Women were barred from most colleges and universities • Women could vote <p>Introduce the Seneca Falls Convention to students and the <i>Declaration of Sentiments</i>.</p> <p>Next, introduce some of the limitations of the Seneca Falls Convention and the <i>Declaration of Sentiments</i> by showing the video linked below.</p> <p>The teacher will distribute copies of the <i>Declaration of Sentiments</i> and lead the class in reading it. Some terms may need to be defined for the students. The teacher will then instruct students to write their own version about groups today that do not experience the full rights and freedoms they ought to.</p>	<p>What are the students doing? Students are listening to the teacher and learning about the women’s rights movement.</p> <p>As a class and with teacher guidance, students will read the <i>Declaration of Sentiments</i> and write their own version. They may need to do independent research to select a population to write about.</p>

Evaluate:

<p>The teacher will evaluate the students’ revised <i>Declaration of Sentiments</i>. The answers to the “Foote vs. Tyndall” question sheet could also be evaluated for a grade.</p>

Required/Recommended Reading and Resources

Video

- Arpita Aneja, “Black Women and the Right to Vote | The History You Didn’t Learn | TIME,” YouTube Video, Time, Uploaded 28 January 2021.
<https://www.youtube.com/watch?v=noDvceRAfeg>.

Readings

- “Foote vs Tyndall” (High School or Middle School)
- “Declaration of Sentiments”

Discussion and Assignment Questions

Suggested Opening Discussion Questions:

1. What does it mean if something is a “right”? (E.g. a right to vote)
2. What is the difference between a desire or want and a right? Or between a privilege and a right?
3. What are some “rights” you’ve heard of?
4. Who or what is entitled to rights? How has this changed over time?
5. Are there things which should be considered “rights” but currently aren’t?

Foote vs Tyndall Questions:

1. What is the Greenhouse Effect? What gas did Foote and Tyndall discover causes it?
2. How did Foote’s experiment differ from Tyndall’s?
3. What factors lead Tyndall to receive credit as the discoverer of the Greenhouse Gas effect?
4. Why is it important that Foote receive credit?

Further Reading and Additional Resources

- Foote, Eunice N. “On the Heat in the Sun’s Rays.” *The American Journal of Science and Arts* 22 (November 1856): 377–82.
- Joseph D. Ortiz, and Ronald Jackson. “UNDERSTANDING EUNICE FOOTE’S 1856 EXPERIMENTS: HEAT ABSORPTION BY ATMOSPHERIC GASES.” *Royal Society* 0, no. 0 (August 26, 2020).
<https://doi.org/10.1098/rsnr.2020.0031>.
- Sorenson, Raymond P. “Eunice Foote’s Pioneering Research On CO2 And Climate Warming.” *Search and Discovery*, no. #70092 (January 31, 2011).
https://www.searchanddiscovery.com/pdfz/documents/2011/70092sorenson/ndx_sorenson.pdf.html.
- Jackson, Ronald. “Eunice Foote, John Tyndall and a Question of Priority.” *The Royal Institution* 74, no. 1 (February 13, 2019): 105–18. <https://doi.org/10.1098/rsnr.2018.0066>.

Extensions

History Research Activity

Eunice Foote focused primarily on women’s rights after her two papers were published. She attended the Seneca Falls Convention which helped spark the women’s rights movement and inspired many

women to seek the right to vote. Students can research other suffragists and make a presentation about their life and work. Suggestions include: Elizabeth Cady Stanton, Alice Paul, Lucy Stone, Ida B Wells, Frances E.W. Harper, Mary Church Terrell, Sojourner Truth, Lucretia Mott, Amelia Bloomer, and Mary McLeod Bethune.

Related AIP Teacher’s Guides on the History of the Physical Sciences:

Eunice Foote: Climate Scientist

Eunice Foote and the Greenhouse Effect

Scientific Writing in the Chemical and Earth Sciences

Common Core Standards

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

Speaking & Listening	
<u>CCSS.ELA-LITERACY.SL.6.1</u>	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.
<u>CCSS.ELA-LITERACY.SL.6.2</u>	Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study.
<u>CCSS.ELA-LITERACY.SL.6.4</u>	Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.
<u>CCSS.ELA-LITERACY.SL.7.1</u>	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly.
<u>CCSS.ELA-LITERACY.SL.7.2</u>	Analyze the main ideas and supporting details presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how the ideas clarify a topic, text, or issue under study.
<u>CCSS.ELA-LITERACY.SL.7.4</u>	Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
<u>CCSS.ELA-LITERACY.SL.8.1</u>	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
<u>CCSS.ELA-LITERACY.SL.8.4</u>	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

<u>CCSS.ELA-LITERACY.SL.9-10.1</u>	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.
<u>CCSS.ELA-LITERACY.SL.9-10.4</u>	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.
<u>CCSS.ELA-LITERACY.SL.11-12.1</u>	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.
<u>CCSS.ELA-LITERACY.SL.11-12.4</u>	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	
<u>CCSS.ELA-LITERACY.RH.6-8.1</u>	Cite specific textual evidence to support analysis of primary and secondary sources.
<u>CCSS.ELA-LITERACY.RH.6-8.2</u>	Determine the central ideas or information of a primary or secondary source; provide an accurate summary of the source distinct from prior knowledge or opinions.
<u>CCSS.ELA-LITERACY.RH.9-10.1</u>	Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.
<u>CCSS.ELA-LITERACY.RH.9-10.2</u>	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.
<u>CCSS.ELA-LITERACY.RH.11-12.1</u>	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.
<u>CCSS.ELA-LITERACY.RH.11-12.2</u>	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.
Subject Writing (applicable for the Extension Activity)	
<u>CCSS.ELA-LITERACY.WHST.9-10.1</u>	Write arguments focused on <i>discipline-specific content</i> .
<u>CCSS.ELA-LITERACY.WHST.9-10.2</u>	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

<u>CCSS.ELA-LITERACY.WHST.9-10.4</u>	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
<u>CCSS.ELA-LITERACY.WHST.9-10.5</u>	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.
<u>CCSS.ELA-LITERACY.WHST.9-10.7</u>	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
<u>CCSS.ELA-LITERACY.WHST.9-10.8</u>	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.
<u>CCSS.ELA-LITERACY.WHST.9-10.9</u>	Draw evidence from informational texts to support analysis, reflection, and research.
<u>CCSS.ELA-LITERACY.WHST.11-12.1</u>	Write arguments focused on <i>discipline-specific content</i> .
<u>CCSS.ELA-LITERACY.WHST.11-12.2</u>	Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
<u>CCSS.ELA-LITERACY.WHST.11-12.4</u>	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
<u>CCSS.ELA-LITERACY.WHST.11-12.5</u>	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.
<u>CCSS.ELA-LITERACY.WHST.11-12.7</u>	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
<u>CCSS.ELA-LITERACY.WHST.11-12.8</u>	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

<u>CCSS.ELA-LITERACY.WHST.11-12.9</u>	Draw evidence from informational texts to support analysis, reflection, and research.
Science and Technical Subjects	
<u>CCSS.ELA-LITERACY.RST.6-8.1</u>	Cite specific textual evidence to support analysis of science and technical texts.
<u>CCSS.ELA-LITERACY.RST.6-8.2</u>	Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
<u>CCSS.ELA-LITERACY.RST.9-10.1</u>	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
<u>CCSS.ELA-LITERACY.RST.9-10.2</u>	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.
<u>CCSS.ELA-LITERACY.RST.11-12.2</u>	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.

Next Generation Science Standards

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

Earth's Systems	
<u>MS-ESS3-5 Earth and Human Activity</u>	Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
<u>HS-ESS2-4 Earth's Systems</u>	Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. Grade: High School (9-12)

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