Women in Physics

LESSON PLAN

STEP UP
PHYSICS TOGETHER

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QUICK REFERENCE GUIDE

Help students **examine the conditions for women in physics** and **discuss gender issues** with respect to famous physicists, gendered professions, and personal experience to **neutralize the effect of stereotypes and bias**. Students participate in an interactive presentation by the teacher, in which data about women in physics around the world are discussed. The role of culture and society are considered.

1. Students perform an Internet search for physicists to identify trends in stereotypes about those who work in physics.

2. Students read biographies of historical physicists as well as one modern physicist and complete a reflection worksheet.

3. Students participate in an interactive presentation by the teacher, in which data about women in physics around the world are discussed. The role of culture and society are considered.

4. Students discuss the outcomes of their Internet search and biographical analyses, and synthesize conclusions from the whole class discussion.

5. Students voluntarily contribute their own experiences with gender bias to a class discussion, and consider how this might influence their own views about gendered careers and a future in physics.

6. Students respond to a prompt about their own experience with gender bias.

Learn more at STEPUPphysics.org and register to access instructional support & FAQs

WOMEN IN PHYSICS SUPPORTING RESEARCH

Lesson Topic: In this lesson, students will examine the conditions for women in physics drawing on current statistics/research and their experiences with physics. The goal of the lesson is to help students reflect and think critically about the issue in order to neutralize the effect of bias, particularly for female students.

Lesson Evidence: This lesson has been shown to improve students' future physics intentions (e.g. majoring in physics in college, intending physics-related careers) in classes across the US (N=823). Figure 1 shows that both female and non-female students have positive gains from the lesson. In addition, the overall gains from the lesson across all students are positive (Cheng et al., 2018).

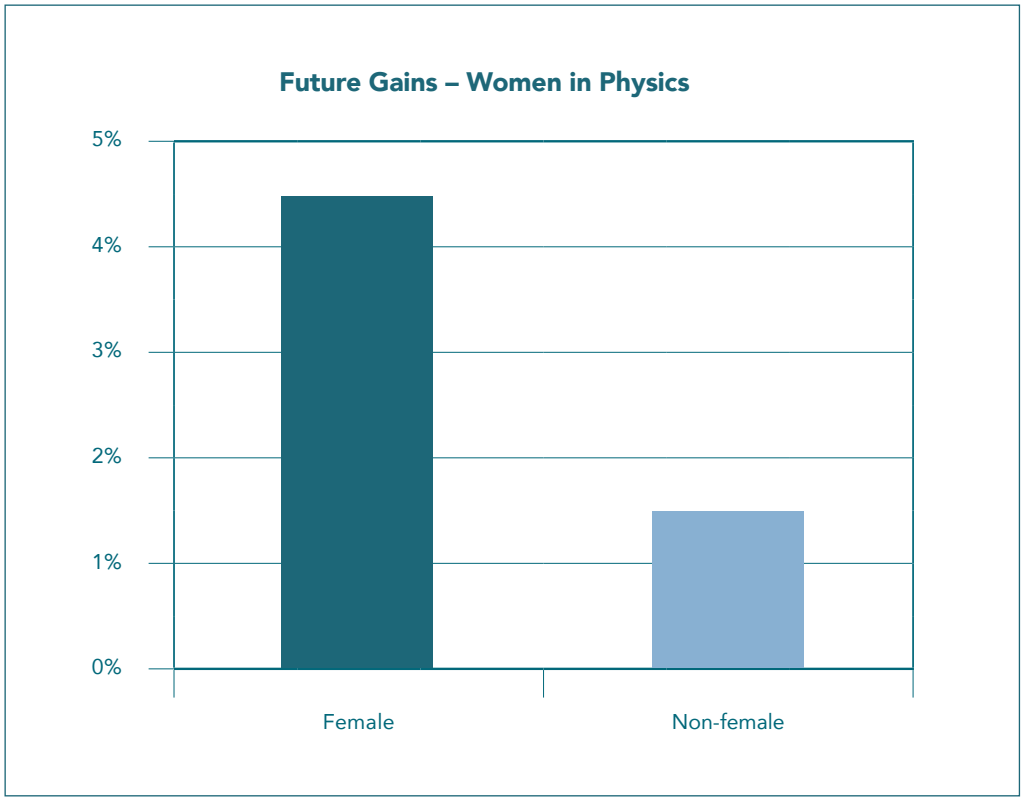

Figure 1. *Percentage gains in female and non-female students' future physics intentions (towards majoring/pursuing a career) due to the lesson.*

Teacher Motivations: Quotes about why physics teachers did the lesson.

- "We are the only way that these women are going to realize the opportunities that are available to them."
- "It shows the women in the class that it is important to you, the teacher, if you discuss these issues. That they are important to you."
- "It challenges misconceptions about what helps women."
- "I was nervous about it but then I realized how much students got out of it."

Explaining It to Students: Quotes about how physics teachers justified it to students.

- "As a white guy, these may not be things I have experienced but that doesn't mean that these things aren't important to talk about."
- "I want to hear what you, the students, think about these issues."
- "It is important to not exclude others from opportunities."
- "It is important to understand what society thinks about physics and whether these beliefs are valid."

Implementation Timing: Physics teachers suggested the optimal timing for implementation is (i) after a classroom community is established and (ii) around a time when a topic of interest to women is being covered (e.g. astronomy, light/waves, biophysics applications, alternative energy) (iii) before college applications are due (for any seniors), if possible.

LESSON PLAN: WOMEN IN PHYSICS

CONTENT AREA(S): Physics		TITLE: Women in Physics
GRADE LEVEL: 11-12	DATE(S): Prior to college applications, but after a supportive classroom environment has been established	LESSON LENGTH: 60-90 minutes

OVERARCHING PURPOSE OF THE LESSON

In this lesson, students will examine the conditions for women in physics starting with an assignment and interactive presentation that draws out their prior knowledge, illustrates the current state of women in physics, and reveals implicit biases and core equity issues. The students will then engage in a discussion (drawing on evidence) about gender issues with respect to famous physicists, gendered professions, and personal experience. The purpose of the lesson is to reveal students' prior perceptions about women in physics as well as current conditions for women in physics in order to neutralize the effect of stereotypes and bias, particularly for female students.

Standard(s) Alignment: This lesson addresses NGSS Appendix F – Science and Engineering Practices in the NGSS

- **Engaging in Argument from Evidence**
  - Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.
  - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
  - Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions.
  - Construct, use, and/or present an oral and written argument or counter-argument based on data and evidence.

NGSS Appendix H – Understandings about the Nature of Science

- **Science is a Human Endeavor**
  - Scientific knowledge is a result of human endeavor, imagination, and creativity.
  - Individuals and teams from many nations and cultures have contributed to science and to advances in engineering.
  - Scientists' backgrounds, theoretical commitments, and fields of endeavor influence the nature of their findings.
  - Science and engineering are influenced by society and society is influenced by science and engineering.

Performance Objectives

- Students will be able to compare the challenges faced by women in physics in the past (conscious bias) to the challenges faced today (more unconscious bias).
- Students will be able to give examples of gender inequalities with respect to science present in society today.
- Students will be able to define unconscious bias and give one example of the effect of unconscious bias.
- Students will be able to explain their own views on the current state of women in physics.

Assessments (formative and summative)

- Students' pre-lesson essays about famous female physicists and their views about women in science today.
- Students' responses during the whole class discussion during which they share their views about famous scientists, gendered professions, and classroom experiences.
- Students' post-lesson essays about women in physics in the present day.

Accommodations

- English Language Learners: Allow extra time for ELL students to complete written responses to prompts, allow extra time for ELL students to formulate their responses prior and during discussions, pair them with a student who knows their native language and/or is willing to help, allow the usage of a device for them to translate
- Students with Disabilities: Depending on the disability, limit the need to move around the classroom during the writing prompt exchange, situate students where they can clearly see/hear slides and discussions, and allow extra time as necessary.

Materials/Resource List

- **Women in Physics Pre-Assignment** and **Women in Physics Post-Assignment** handouts (1 each per student, Appendix 1 and Appendix 3)
- Class whiteboard, projector, computer (for teacher use for presenting Women in Physics Slides, see Appendix 2, which shows slide thumbnails. Full presentation available at STEPUPphysics.org).
- A document that can be projected / shared
- Pieces of paper for writing prompt activities (2 per student)
- (Optional) Devices with internet access to participate in polls
- Preparation material: **Women in Physics Internationally** (Appendix 4)

Teacher Preparation

Critical lesson component: Read **Women in Physics Internationally** (Appendix 4) before implementing the lesson. Teachers who have previously done this lesson felt more comfortable having more information for themselves beforehand.

INSTRUCTIONAL PROCEDURES

INTRODUCTION: In this part of the lesson, the goal is to prime the issue of gender and get students' prior conceptions about gender issues in physics (est. time = 10 minutes)

What the Teacher Does	Anticipated Behaviors/Responses from Students
Pre-lesson: Assign students to complete the pre-class assignment prior to class (Appendix 1). The assignment requires them to: • Recall famous physicists and conduct a Google search, then answer a few questions about what they find *(this primes gender issues given the lack of diversity that results from the search)* • Read two biographies. One of a historical physicist, choosing between Lise Meitner or Jocelyn Bell Burnell, and one of a modern female physicist from the list provided *(this illustrates the difficulties that women have faced and the capability of women to contribute)* • Respond to related questions	Pre-lesson: Students will complete the **Women in Physics Pre-Assignment**.
1. ***In class (Appendix 2, Slide 2; est. time = 10 minutes)*** Project the Google search for "famous physicist." Ask students about the physicists they found in their Google search. • What trends do they notice about the names? • When did the women on the list live? It may be important to point out that men have been participating in physics for a long time and that even after Marie Curie, there is a lack of women on the list. (No need to discuss specific biographies; students can bring these examples up in the discussion later).	1. ***In class*** Students respond to what they found in their Google search. • Possible Answers: They are mostly men. They are mostly white. They are mostly of European heritage. They are mostly dead. • Possible Answers: Marie Curie lived around 100 years ago.

BODY OF THE LESSON: In this part of the lesson, students will engage in an interactive presentation and discussion that will allow them to make predictions, view statistics and results of studies, and discuss gender issues in physics drawing on the evidence and their own experience (est. time = 65 minutes)

What the Teacher Does	Anticipated Behaviors/Responses from Students
Interactive presentation (est. time = 65 minutes) Lead a whole class discussion organized around the slides (Appendix 2). Think/Pair/Share technique (see here or other online resources) can be used throughout this discussion to stimulate conversation	
1. ***Introduce guidelines (Critical lesson component):*** Slide 3; est. time = 5 minutes. At the beginning of the presentation/ discussion (after the Google search discussion), introduce these guidelines to students (or refer to your class conduct rules if you have already established them): • **Share air time equitably.** Know yourself, balance your listening and talking. • **Value differences.** Remember that your perspective is not the only one. • **Argue using evidence.** Back what you have to say with data. • **Make sure everyone feels safe.** Safe is not the same as comfortable. • **Discomfort is OK.** Identify your learning edge and push it. • **Own your impact.** Your intentions may not be the same as your impact.	**1.** Students will read the guidelines and ask questions to ensure they understand.
2. ***Opening Slides:*** slides 4–18; est. time = 20 minutes. • **Prompt each slide with the questions in the presentation.** Encourage a few minutes of discussion on each slide, in particular regarding the role of the individual versus the role of culture and society (e.g. social norms). • In Slide 6, students are asked to suggest reasons why women are better represented in some fields than in others. Make sure to have students come up with ideas, and then the teacher can categorize these responses (for example, can have a "culture/socialization" category and a "biology/inherent traits" category).	**2.** Students might conclude that because the percentage of women in physics varies by country, the representation of women in physics is a cultural issue rather than a biological one. The included slides (with references to articles) about unconscious bias should help students see that bias can exist even if no one is overtly sexist, but that bias can be overcome with conscious effort and training.
3. ***Gendered professions:*** slides 19–20; est. time = 10 minutes. Prompts: **A.** Why do you think women appear in particular science fields more than others? **B.** What gender are your doctors and nurses? What about people you know in other technical professions (e.g. engineering)? What gender are your teachers in various subjects? **C.** What patterns have you noticed in who pursues different careers? Why do you think we see these differences? • Encourage students to notice gender disparities in any particular field and to consider why these disparities exist.	**3.** Possible responses to gendered professions: **A.** Stereotypes - Students may notice that many female scientists portrayed in the media are in fields other than physics (e.g. on the Big Bang Theory, forensic shows, medical shows). **B.** Students may notice that most engineers are men or that most nurses are women, for example. Terms indicating that a profession has a default gender may be shared, such as "male nurse" since the default gender of nurses is stereotyped to be female. **C.** Nature versus Nurture arguments will likely emerge. Some students might say that women "naturally" gravitate to fields other than physics and engineering. Other students may believe this is due to stereotypes and other societal influences.

4. ***Personal experiences (Critical lesson component):*** slide 21; est. time = 20 minutes. • Stop and Reflect: Give students two minutes to write a first response to the prompt below, then give them time to share it with a partner. Next, students will have 5 minutes to write another response on a second piece of paper that they would like to share anonymously. The responses should be *related to science and gender issues*. Collect the papers, mix them up, and pass them out to be read anonymously. This structure supports discussing challenging topics. • Prompt: Describe experiences you or a friend has had related to science and gender issues. Detailed questions: who do you feel comfortable working with in class? Do you feel more comfortable in any particular class? Have you felt your abilities being questioned? Have you seen or experienced gender biases in your own life, either purposeful or unintentional? • As students share anonymous experiences, make sure to challenge sexist or racist comments that might emerge. For example, if someone comments about women's lack of ability in physics, turn to the class and ask if there is disagreement. Students will raise objections themselves. These occasions are valuable because they reveal the presence of hidden bias. Challenge statements that generalize any group since these types of statements are particularly problematic.	**4.** Students will write a response to the prompt on a piece of paper and then share with a partner. They will then write a comment, experience, etc. on a piece of paper and turn it in directly to the teacher. Possible responses include students mentioning occasions when: • someone has said something disparaging • others have dominated a conversation/activity • they have been made to feel stupid • they prefer the environment in certain classes over others • they prefer working with people of certain genders more than others • they heard about experiences from friends or family • "women just aren't interested in science" • no experience of gender issues at all
5. ***Career Influences:*** slide 22; est. time = 10 minutes. • Ask students: Do you think societal beliefs related to gender have any influence on the career you want to pursue? Or on careers you would not consider? ***General tips for class discussion*** • Encourage students to disagree constructively (e.g. with evidence or argumentation). • If the students aren't challenging each other, encourage them to, or jump in yourself (e.g. if students mention women's disinterest in physics being biological, ask why the same trends are not seen in all countries). • Always encourage students to think about WHY gender disparities exist. At some point, a 'nature vs. nurture' discussion is likely to arise. Students need to become aware of the sociocultural pressures impacting their individual decisions.	**5.** Students will voluntarily share viewpoints and experiences and be responded to by other students.

LESSON CLOSURE: In this part of the lesson, students will come up with strategies to support diversity in physics and will be encouraged to enact the best strategies proposed (est. time = 10 minutes)

What the Teacher Does	Anticipated Behaviors/Responses from Students
1. ***Proposing strategies:*** slide 23; est. time = 5 minutes. • Ask students to write a response to the prompt on a piece of paper to be shared anonymously. Collect the papers, mix them up, and pass them out. • Prompt: What can be done to support diversity in physics? What could you do?	**1.** Students will write their ideas about how to support diversity in physics.

2. ***Discussion:*** est. time = 5 minutes.

- Ask for a volunteer to share what is written on their paper. Write the strategy in a Google Doc (or other projected digital document) or on the board. Poll the class to see how many other students have similar responses on their paper. Do this until there are no new strategies proposed.
- Assess and comment on strategies that will not be supportive or that have unintended consequences, e.g. offering to help struggling women in the class might not be supportive since it undermines women's capabilities.
- When you have the compiled list, say to the students, "This is our commitment to change." Share the document with your students, ideally in a digital form.

Post-Lesson: Assign students to complete the **Women in Physics Post-Assignment** (Appendix 3). The assignment has them write about their views after the class discussion.

2. Students will volunteer to share ideas from the anonymous paper they have. Possible responses from students include the following:

- *Supporting diversity is not important (suggested counterpoints in this situation are: (1) Diverse teams produce better results. This is supported by research on teamwork; (2) Our current STEM workforce is insufficient. If we do not actively recruit women, we could be missing out on half of the potential workforce.)*
- *Encouraging peers to take physics*
- *Encouraging everyone to participate*
- *Making sure conversations and activities are not dominated by any individual.*
- *Encouraging classmates but letting them figure things out for themselves*
- *Giving help to women who are struggling in class (Note the counterpoint that this could undermine women's capabilities if you think they always need help.)*

EXTENSIONS

Potential tech enhancements for live visualization of student responses

- spsedtech.wordpress.com/2013/08/24/socrative-and-wordle-on-day-one-getting-to-know-your-students/ - This article describes how to use Socrative and Wordle to make a word cloud, which could be used to visualize the physicists students can remember as part of the pre-class assignment.
- polleverywhere.com - Poll everywhere can automatically make word clouds from open-ended questions, which can also be used to poll students about what physicists they remember. Poll everywhere can also be used to poll the class on presentation questions.
- mentimeter.com - Mentimeter can also be used to create visualizations of students' responses

Curriculum enhancements: (additional lessons on underrepresentation)

- Teachers interested in additional lessons and resources on underrepresentation in physics, including issues of race and ethnicity, can implement curriculum from the The Underrepresentation Curriculum (underrep.com)

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- Next Generation Science Standards – Appendix H on the Nature of Science. Retrieved from: www.nextgenscience.org/sites/default/files/Appendix%20H%20-%20The%20Nature%20of%20Science%20in%20the%20Next%20Generation%20Science%20Standards%204.15.13.pdf

PHYSICIST INFORMATION WEBSITES:

- Lise Meitner: www.sdsc.edu/ScienceWomen/meitner.html
- Jocelyn Bell Burnell: biography.com/people/jocelyn-bell-burnell-9206018

DATA ON RACE AND ETHNICITY:

- Data on underrepresented minorities among undergraduates: aip.org/statistics/undergraduate/minorities
- Graph of physical science bachelor's degrees earned by African Americans: aip.org/statistics/data-graphics/trends-bachelor%E2%80%99s-degrees-earned-african-americans-physical-science-fields
- Graph of physical science bachelor's degrees earned by Hispanic Americans: aip.org/statistics/data-graphics/trends-bachelor%E2%80%99s-degrees-earned-hispanics-physical-science-fields-2002

WHY WOMEN HAVE A HIGHER REPRESENTATION IN SOME COUNTRIES:

- blogs.scientificamerican.com/voices/countries-with-less-gender-equity-have-more-women-in-stem-huh/

Women in Physics Pre-Assignment

APPENDIX 1

Name: _____ **Date:** _____

PRE-ASSIGNMENT

Google search:

1. Before doing the Google search below, **write the names** of any physicists you can think of (be honest - don't cheat and look them up beforehand).
2. Google "famous physicist." **Write down the names** of the first five physicists you found.
3. How many **years ago** did the earliest physicist on the list live?
4. How many **women** appear on the list?

Read two biographies, as follows:

- Lise Meitner article (www.sdsc.edu/ScienceWomen/meitner.html) or Jocelyn Bell Burnell (biography.com/people/jocelyn-bell-burnell-9206018)
- One of the following scientist profiles: Claudia Alexander, Deborah Berebichez, Ellen Ochoa, or Shirley Ann Jackson (aps.org/careers/physicists/profiles)

Respond to the following questions on the women from the two biographies:

What are the contributions made by these women? Summarize your response in your own words in a few sentences. Look up anything you don't understand!

_____

_____

_____

_____

What obstacles did the women overcome in their career paths?

_____

_____

_____

_____

In your view, is the opportunity to excel in physics any easier for women now than it was in the 20th century? Explain how, including what is easier and what is unchanged.

_____

_____

_____

_____

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Women in Physics

FIU STEM Transformation Institute · APS physics · AAPT Physics Education · Texas A&M University Commerce · NSF

1

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Stephen Hawking · Albert Einstein · Nikola Tesla · Isaac Newton · Galileo Galilei · Marie Curie · Richard Feynman

What trends do you notice about the physicists you found in your google search?

2

STEP UP

Guidelines for Conduct During Discussion

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Share air time equitably	Value differences	Own your impact
Make sure everyone feels safe	Discomfort is okay	Argue using evidence

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STEP UP

Percentage of Women in Science

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- Which science field do you think has the highest percentage of women in it?

A. Math **B.** Biology **C.** Chemistry **D.** Physics **E.** All about the same

- Which field do you think has the lowest percentage of women?

A. Math **B.** Biology **C.** Chemistry **D.** Physics **E.** All about the same

4

STEP UP

Percentage of Bachelor's Degrees Earned by Women, by Major

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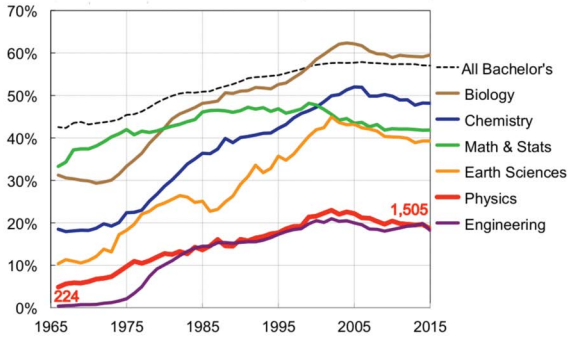

Source: APS and IPEDS Completion Survey

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STEP UP

Why are women better represented in some fields over others?

STEPUPphysics.org

- For example, in the US, why does physics/engineering have a lower proportion of bachelors degrees awarded to women than biology/chemistry?
- Which of the following countries has the highest percentage of women in physics? The lowest?

A. Germany **B.** Argentina **C.** Iran **D.** USA **E.** All about the same

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Percentage of Undergraduate Physics Degrees Awarded to Women

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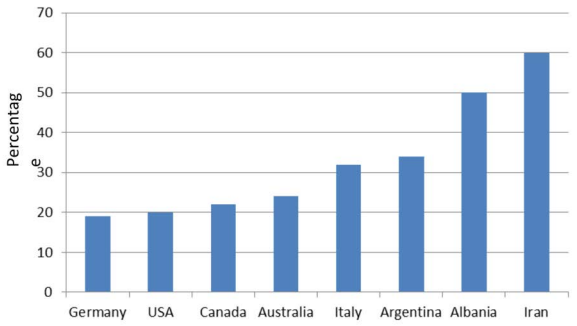

Source: IUPAP International Conference on Women in Physics Proceedings (2005-2013)

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What is happening in Iran?

STEPUPphysics.org

- Families invest in the education of girls
- National policies support girls in physics
- Boys losing interest in physics

A. Iraji Zad, F. Roshani, and D. Izadi, "Improving the status of Iranian women in physics," AIP Conference Proceedings 1697, 060024 (2015); doi: 1063/1.4937671

(IOP, 2017)

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What is happening in Germany?

STEPUPphysics.org

- Women take the primary role in parenthood
- Women's accomplishments are underappreciated
- Women underpaid
- Only now considering recruiting women into physics at the secondary level

Anja Sommerfeld, Susanne Krankl, and Barbara Sandow, "Area of actions: Equal opportunities for women in physics in Germany," AIP Conference Proceedings 1697, 060020 (2015).

(IOP, 2017)

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Women in Physics Internationally

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What does the information about women in physics internationally suggest about the causes of women's underrepresentation in physics in the US?

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Academic Achievement

STEPUPphysics.org

- Do you think there are gender differences in physics grades in high school or college?
- If you think there are differences, what are the causes? Exam bias, ability differences, or something else? Why?

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Academic Achievement

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- Men and women achieve similar grades in high school and university physics
- The difference in science and math achievement between boys and girls is very small and varies more with country than between genders

Hazari et al., 2007; Hazari et al., 2008; Hyde and Linn, 2006

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Unconscious Bias

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- Even small grade differences that do exist may be due to bias. How does this happen?


Home | Publications | APS News | April 2016 (Volume 25, Number 4) | Physics
Grading Biased Against Women

APS NEWS

Physics Grading Biased Against Women

By Emily Conover

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What is unconscious bias?

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- Unconscious bias refers to the unconscious sorting of people, often based on stereotypes and beliefs, bypassing rational and logical thinking
  - Sexist behavior can arise even when people are not consciously sexist.
- All people have some degree of unconscious bias and many people even hold unconscious bias towards the groups that they belong
- Becoming aware of your own unconscious biases is the first step to overcoming them

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How early can unconscious bias emerge?

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Gender stereotypes about intellectual ability emerge early and influence children's interests

Science AAAS

Lin Bian, Sarah-Jane Leslie, Andrei Cimpian

In the US, girls age 6 are less likely than boys to believe that members of their gender are 'really, really smart'," and avoid activities associated with being "really, really smart". **Why?**

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Another example of unconscious bias

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RESEARCH ARTICLE

Males Under-Estimate Academic Performance of Their Female Peers in Undergraduate Biology Classrooms

Daniel Z. Grunspan, Sarah L. Eddy, Sara E. Brownell, Benjamin L. Wiggins, Alison J. Crowe, Steven M. Goodreau

Published: February 10, 2016 • https://doi.org/10.1371/journal.pone.0148405

Even after accounting for actual class performance and outspokenness, men assumed other men knew the content better than women. **Does this happen here?**

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Women in Physics Today

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- The challenges faced by women today are often not as obvious as the challenges faced by women in the past, but they are still very real.
- Sociocultural issues influence women's career decisions.
- Sexism today often occurs in the form of unconscious biases. Having these biases does not make anyone a bad person. Becoming aware of our own unconscious biases is necessary in order to overcome them.

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Have you considered physics?

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- In the US, UK, and Canada, thousands of women physics majors and their allies gather each year in support

- Don't let unconscious bias keep you from considering a physics career!

Source: Conferences for Undergraduate Women in Physics (CUWiP)

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Gendered Professions

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- Why do you think women appear in particular science fields more than others?
- What gender are your doctors and nurses?
- What about people you know in other technical professions (e.g. engineering)?

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Gendered Professions

STEPUPphysics.org

- What gender are your teachers in various subjects?
- What patterns have you noticed in who pursues different careers?
- Why do you think we see these differences?
- Describe experiences you or a friend has had related to science and gender issues.
- Examples: Who do you feel comfortable working with in class? Do you feel more comfortable in any particular class? Have you felt your abilities being questioned?

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Stop and Reflect – write your answers

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- Describe experiences you or a friend has had related to science and gender issues.
- Examples: Who do you feel comfortable working with in class? Do you feel more comfortable in any particular class? Have you felt your abilities being questioned?

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Does this influence you?

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- Do you think societal beliefs related to gender have any influence on the career you want to pursue?
- Careers you would not consider?

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What can we do?

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- What can be done to support diversity in physics? What could you do?

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Supplemental Slides

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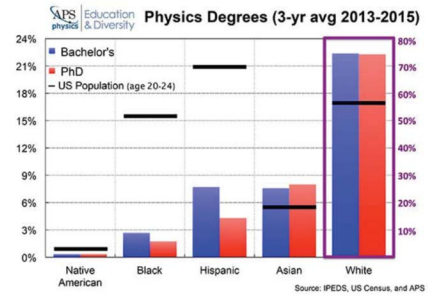
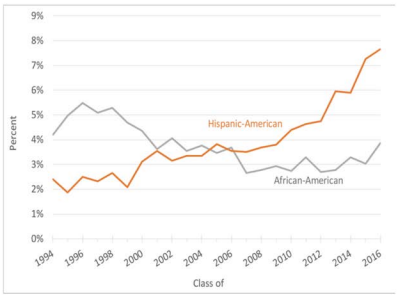


Credit: APS/Source: IPEDS Completion Survey

26

STEPUPphysics.org

The Proportion of Physics Bachelor's Degrees Awarded to African-Americans and Hispanic-Americans.



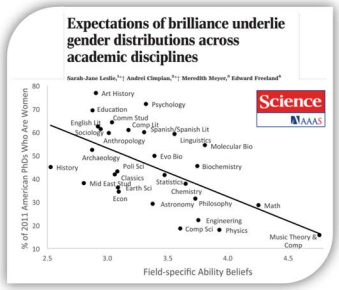
AIP | Statistics aip.org/statistics

27

An effect of unconscious bias

STEPUPphysics.org

- The more a field is associated with intellectual ability, the lower the percentage of PhDs in that field who are women.



28

An effect of unconscious bias

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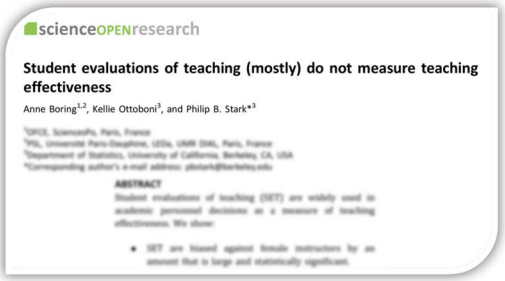
In identical online classes, instructors received better evaluations using a man's name than a woman's name. Gender bias in evaluations also occurs for physics teachers.



29

An effect of unconscious bias

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- Women are treated unfairly in science even today though scientists may not be consciously aware of this.
- How can we counteract these effects?

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Women in Physics Post-Assignment

APPENDIX 3

Name: _____ **Date:** _____

POST-ASSIGNMENT

Respond to the following questions by crafting at least a paragraph for each section:

Based on the class discussion, do you believe society discourages (subtly or obviously) women from becoming interested in physics careers? Why or why not? If so, what do you think could be done to reduce the effect of discouragement?

In what ways do you think societal beliefs about gender have influenced your career interests? Does this influence bother you? Why or why not?

Women in Physics Internationally

APPENDIX 4

Summary

The representation of women in physics at the undergraduate level varies widely between countries, with Iran having the highest percentage of women in physics and western cultures such as the US and Germany having the lowest. Even in countries with relatively high percentages of female undergraduates, women are underrepresented at the faculty level.

The reasons for these disparities are not well known, but representatives from different countries do posit some ideas. Albania has the clearest reason for its lack of a gender gap: students are assigned their majors based on their grades and are not free to choose. This shows that women have equal abilities in physics, a fact also reported by Italy and Iran. Iranian sources cite families' investments in educating girls, national policies, and boys' decreasing interest in physics as reasons for the high representation of women in undergraduate physics. The state of physics is in flux in Argentina, where widespread government funding for science has been implemented only recently and where a positive perception of scientists is generally on the rise. In Italy, female physicists are disproportionately represented in the subfields of applied physics, history of physics, and didactics of physics, while in Albania, women in graduate level physics gravitate towards environmental physics, physics education, and biophysics. Countries such as Canada, Germany, and Australia invest in initiatives to attract women into physics but have seen relatively little success. Included below is a summary of multiple papers from the IUPAP International Conference on Women in Physics, with information from each country & a relative reference.

Germany

Anja Sommerfeld, Susanne Krankl, and Barbara Sandow, "Area of actions: Equal opportunities for women in physics in Germany," AIP Conference Proceedings 1697, 060020 (2015); doi: 10.1063/1.4937667

In 2012, the percentage of university degrees in physics awarded to women in Germany was slightly less than 20%. The percentage of physics Ph.D.'s awarded to women was similar, but the percentage of women in the German Physical Society (*Deutsche Physikalische Gesellschaft*, DPG) was lower (14%). The participation of women in undergraduate physics remained relatively constant from 2005-2015, but the percentage of women at the faculty level increased. The report cites that parenthood affects female physicists' careers "distinctly more strongly than it does for men" and found that female physicists' professional competence and accomplishments are less appreciated. Furthermore, women in physics careers make less money than men with the same duties, responsibilities, and educational level. The efforts of the DPG Working Group on Gender Equality, founded in 1998, are credited with increasing the number of women in leadership positions in their organization and the number of women giving DPG plenary talks. Further efforts of that group include organizing the German Conference of Women in Physics and the DPG Mentoring program. They were also considering a program to encourage girls at the high school level to enter physics.

Canada pt. 1

Li-Hong Xu, Shohini Ghose, Marina Milner-Bolotin, Janis McKenna, Sampa Bhadra, Adriana Predoi-Cross, Arundhati Dasgupta, Melanie Campbell, Svetlana Barkanova, and Michael Steinitz, "Women in physics in Canada," AIP Conference Proceedings 1697, 060009 (2015); doi: 10.1063/1.4937656

(The 2015 paper does not have the statistics for physics, specifically, but the 2005 paper does. See below.) In 2015, 24% of all undergraduates in the physical sciences, computer science, engineering, and mathematics were women. Additionally, at the full professor level, only 9% of physicists were women. There are many efforts to increase the representation of women in physics in Canada. The Natural Sciences and Engineering Research Council (NSERC) supports parental leave for trainees and grant deferral during times of leave. The Canadian Conference for Undergraduate Women in Physics aims to support women at the undergraduate level. Additionally, many outreach programs aim to recruit middle school and high school girls into physics. Despite these efforts, women remain underrepresented in physics.

Canada pt. 2

Maria Kilfoil, Janis McKenna, Adriana Predoi-Cross, and Michael Steinitz, "Women in physics in Canada: Progress and shortcomings," AIP Conference Proceedings 795, 103 (2005); doi: 10.1063/1.2128284

In 2005, 22% of undergraduate physics students were women. Compared with the percentage for the physical sciences, computer science, engineering, and mathematics in 2015, this suggests that there has not been a significant change over the past decade.

Australia

C.P. Foley, "Status of women in physics in Australia," AIP Conference Proceedings 1517, 72 (2013); doi: 10.1063/1.4794225

The percentage of women in physics undergraduate majors in Australia decreased seven points from 2002 to 2013 (28% to 21%). The report cited that 21% of physics staff at universities were women. On average, women were paid less and held less senior positions than men. Women's careers were also seen to be more disrupted by private life concerns than men's, causing women to take more breaks from their careers, spend more time on teaching, and complete less postdoctoral/research fellowships than men. Pointing to the fact that the Australian Institute of Physics women's group has not been active since 2010, the report says perhaps "the physics community has taken their 'eye off the ball.'" Thus, despite a perceived "high level of goodwill" towards women in physics, the research suggests that this is not enough.

Italy

F. Albertini, P. Cenci, A. Di Virgilio, and G. Trichieri, "Women and physics research in Italy," AIP Conference Proceedings 1119, 126 (2009); doi: 10.1063/1.3137735

The report from Italy found that though women constituted the majority of graduate students (58%) across all fields, women were a minority in physics graduate degrees and reported no significant changes since 2003. Women represented ~40% of the undergraduate and graduate "physics science" degrees and only ~32% of "pure physics" degrees at these levels. Note that "physics science" includes pure and applied physics, history of physics, and didactics of physics. The percentage of women steadily drops at the researcher, assistant professor, and full professor levels, and the report notes that these drops are not due to performance since women and men perform at equal levels in their studies. In 1997, the European Union adopted an Equal Opportunity policy to achieve gender equity. Subsequent affirmative action plans that were required included such practices as balancing work and personal life and being culturally aware. However, the widespread implementation of these policies does not appear to have resulted in appreciable changes in women's representation in physics careers over the intervening years.

Argentina

Vera Brudny, Cecilia Lagorio, Marisa Frechero, and Francisco Tamarit, "Update on women in physics in Argentina," AIP Conference Proceedings 1517, 70 (2013); doi: 10.1063/1.4794224

Though the total female enrollment in undergraduate physics in Argentina dropped from 31% in the 1990's to 27% in the 2000's, the percentage of graduating students was 34% women for the latter decade. Government support for scientific research increased significantly from 2003 to 2013 thus attracting more people to scientific careers. The percentage of graduate scholarships and research grants awarded to women has increased, and several women hold leadership positions in scientific agencies. However, the percentage of women that are employed in research positions decreased. Hence, the trends for women's representation in physics in Argentina are mixed.

Albania

Antoneta Deda, Mirela Alushllari, and Silvana Mico, "Albanian women in physics," AIP Conference Proceedings 1697, 060001 (2015); doi: 10.1063/1.4937648

Only one university in Albania supports physics doctoral students, the University of Tirana. At the graduate level, the percentage of women was 70% in 2012, up nearly 30% from the prior year. However, women are concentrated in specific fields. The majority of doctoral students in the areas of physics education, environmental physics, and biophysics are women. At the undergraduate level, 50% of the physics majors were women in 2014. This is due in part to the fact that students are assigned their majors based on their grades rather than their preferences. Challenges facing physics students of all genders after graduate school include a paucity of government funding and lack of affordable child care. Despite these problems, large percentages of women physicists are being promoted in academia and have begun taking on upper-level administration positions. The Ministry of Education and Science is funding gender equality initiatives primarily to connect Albanian women physicists with women physicists in other countries, and both this ministry and the Institute of Applied Nuclear Physics are directed by women.

Iran

A. Iraji zad, F. Roshani, and D. Izadi, "Improving the status of Iranian women in physics," AIP Conference Proceedings 1697, 060024 (2015); doi: 10.1063/1.4937671

Overall, representation of women in physics in Iran has increased dramatically. For example, from 2012-2015 the representation of women at the Ph.D. level rose from 39% to 47%. Additionally, 60% of undergraduate and master's students in physics were women in 2015. This increase of women in physics is attributed to families investing in the education of girls, supportive national policies, and boys' decreasing interest in physics. Interestingly, both genders perform similarly on physics assessments. Since there is some lag in women matriculating into higher degrees and careers in physics, women still make up a very small fraction of physics faculty members and instructors. Women are very active in the Physical Society of Iran (PSI), with 39% of associate members and 28% of permanent members being women in 2013. A Women in Physics branch of PSI was established in 2012 and has established plans to further increase the representation of women in physics.