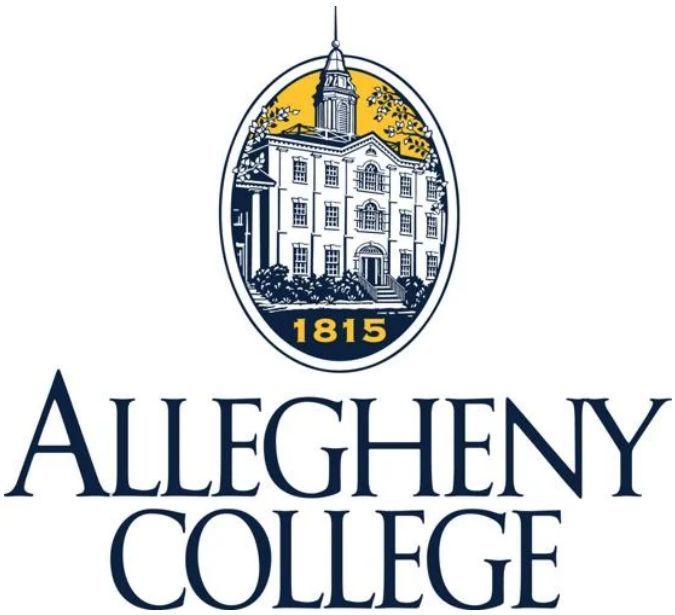
Modification of "Scientist": The Intersection Between Physics Education and Sense of Belonging



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This work is mine unless otherwise cited.

Dr. Adele Poynor	Dr. Sarah Stanger
Date	Date

For every woman and gender minority in physics departments around the world.

This one is for all of us.

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Abstract

Women and minorities have been historically underrepresented in physics. This is true in every branch of physics from teachers to students, to the figures spoken about in classes. To combat stereotypes that are currently impacting women and minorities, previous studies have worked to design lessons and interventions centered around sense of belonging, identity, and interest in physics. The present study used a set of interactive lessons centered around diverse voices in physics to teach students in introductory astronomy-based classes about physics concepts as well as women and their discoveries in astrophysics. These lessons were hypothesized to increase sense of belonging, identity with the terms "physicist" and "scientist", and interest in physics. Paired-sample t-tests were used to look at changes in students' identity and their sense of belonging. Qualitative analysis was used to find gaps in the quantitative measures and was coded with four major themes in mind: physics content, classroom components, difficulties, and dedication while looking at students' beliefs about their sense of belonging, identity, and interest in physics. The hypotheses were largely unsupported due to logistical issues with the duration and implementation of the lessons. However, students were able to learn from these lessons and had significant learning gains. This project can be used to better understand how interactive lessons affect students and how the implementation of those lessons can affect student learning. Future directions for this include helping students belong in the scientific community, identify as scientists, and continue to progress in science.

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INTRODUCTION

Oftentimes when people think about science, they think of experiments, measurements, lab coats, sterile environments, and men with gray hair and goggles standing in front of test tubes. However, this is only a set of stereotypes, not the truth. Science is an interdisciplinary field where students should be encouraged to think creatively, but people often do not recognize that science and scientists look different for many people. In order for scientists of any age to feel as though they are a "scientist," they need to feel as though they are a part of an environment in which science is performed. For students, this is most likely a science classroom, but it is also the world around them. Engaging and participating in science, no matter the setting, can help to develop the identity of "scientist" in students, and has been shown to help women and minorities in science, technology, engineering, and mathematics (STEM) develop their identities (*1*). When a person identifies as a scientist, or more specifically a physicist, their motivations for science, their career aspirations, their self-awareness as a student, as well as their perceived place in the physics community can be impacted in positive ways (*2*). To encourage students to develop their identities and increase their sense of belonging in the classroom, targeted interventions and lessons centered around physics have been implemented as a way for students to engage with complex topics in a hands-on manner, which can help entice students to study physics (*3*).

Though these interventions have been seen to be effective in educating students, they are not the realities for most educational systems due most prominently to the resources available to students and faculty. These interventions are most often tied to positive outcomes for students' sense of belonging and identity as a scientist, which are tied to persistence in physics, regardless of a person's academic performance (*4*). This goes to show that even when students do perform well in academic situations, they still can feel the need to switch their area of study when they do

not feel as though they belong in their community. This is more often the case for students who identify with minority populations. Only 20% of physics graduates in the United States are women, which only further goes to show educators that they need to support women and minority populations in physics (*4*). Therefore, the goal of the present study was to create and implement a set of lessons in a college setting centered around discoveries in astrophysics made by women and minorities to examine the impact of these lessons on the development of identity, sense of belonging, and interest in physics as well as comprehension and retention of physics topics. Subject areas of the lessons include overviews of pulsars, black holes, sonification, Hertzsprung-Russel diagrams, escape velocity, and planetary movements. Lessons also mentioned computer programming, software engineering, and theoretical physics concepts. The lessons will serve as a hands-on way for students to interact with physics topics while they are at the introductory stage of their physics education in their undergraduate careers, and the intention is to design these interventions in a way where they can be adapted to be used at any level of education. The goal of the study is to increase students' sense of belonging as well as help them to develop their identity as a scientist. Finally, these lessons are also designed to increase student interest in studying physics further as well as debunk many of the stereotypes centered around physics as a whole. To begin, background information will be presented on astrophysical topics as well as women and minorities in physics. Then, psychological and pedagogical motivations will be presented as foundations for the lessons.

THEORETICAL BACKGROUND

2.1 Astrophysics and Notable Astrophysicists

Astrophysics, most broadly, is a branch of physics research which involves astronomy and physics along with other natural sciences to look at space and the relationship between humans and the environment on a universal scale. When speaking about astrophysics, it is important to recognize that it is an interdisciplinary science which brings together physics, chemistry, computer science, and many other fields to make determinations and learn about the universe. Historically, many people know of the National Aeronautics and Space Administration (NASA), and many people know names like Stephen Hawking (famous for research on black holes and Hawking radiation), Edwin Hubble (famous for Hubble's Law and observational work in astronomy, also the Hubble Space Telescope is named after him), and even Johannes Kepler (famous for Kepler's laws, and has a telescope named after him). However, many people are not knowledgeable about the women and people of color who have been involved in many aspects of astronomy and astrophysics from the beginning and continue to make progress in the field today.

The life and work of eight physicists are presented for this project, but there are many other extraordinary women and people of color making groundbreaking discoveries today. All the women presented here have faced adversary, sexism, and push back from people because of who they are. Jocelyn Bell Burnell worked on the discovery of pulsars and still works on them today. Andrea Ghez works on black holes and recently won the Nobel prize in physics for her work. Katherine Johnson worked on John Glenn's historic launch as well as many other projects at the National Aeronautics and Space Administration (NASA). Mae Jemison was the first Black woman to go to space. Annie Easley worked on many projects for NASA, most notably the Centaur project and the Cassini mission. Margaret Hamilton worked on and coined the term

software engineering in her work at NASA and wrote code to ensure the moon landing went smoothy. Wanda Díaz-Merced works with gravitational waves and sonification. Chanda Prescod-Weinstein is a theoretical physicist who works on combining particle physics and astronomy in her work on dark matter and spacetime. These women have done remarkable things to advance astrophysics and many more women and minorities will continue to break ground, but only if we are able to educate them about the foundations first.

2.1.1 Hertzsprung-Russell Diagrams

To educate others on stars, scientists have used Hertzsprung-Russell Diagrams, or H-R Diagrams, to show how different stars compare to one another in luminosity and temperature as well as other integral features of stars (lifetime, brightness, color, etc.) (*5*). Scientists Henry Norris Russel and Enjar Hertzsprung laid the groundwork for the creation of the modern HR diagram (*5*). Russel plotted stars on a graph, creating what would later evolve into the H-R diagram, and allowing for many different components that could be observed to be shown on his graph such as absolute magnitude, brightness, spectral type, and temperature (*5*). An observational H-R diagram is shown in Figure 1.

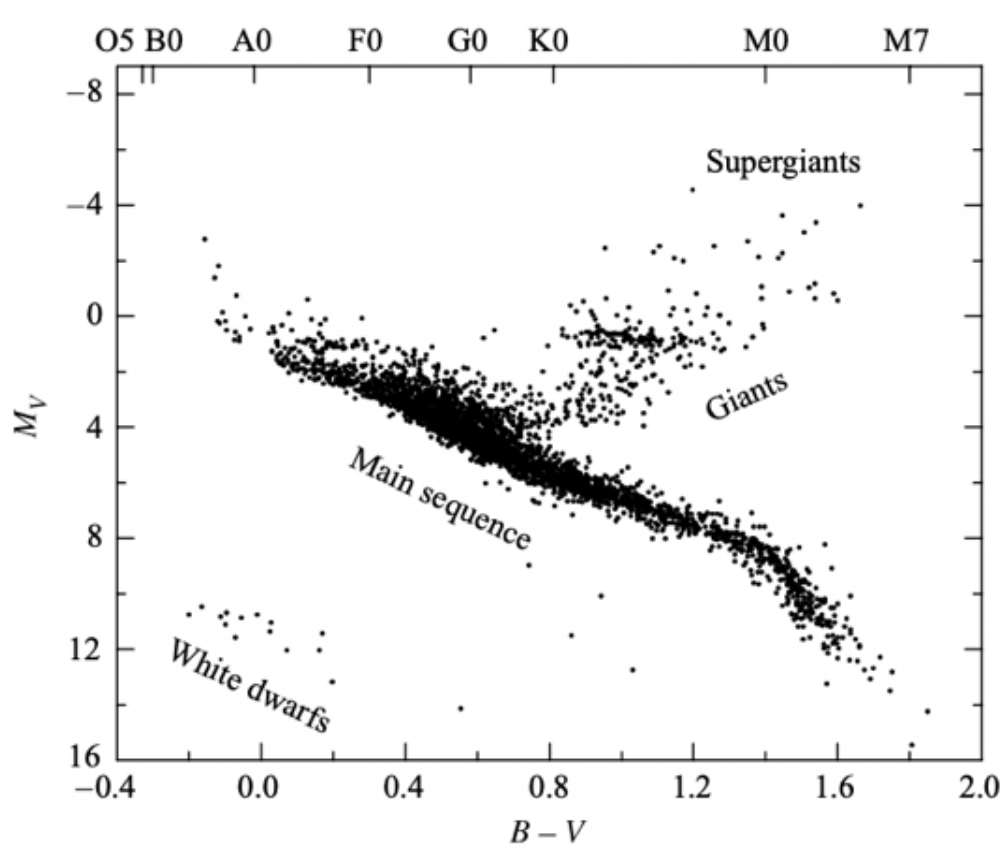

Figure 1: An observational H-R Diagram (*5*). There are more than 3700 stars graphed on this diagram, all from data provided by the European Space Agency. Many stars exist on the main sequence which spans the middle of the graph, spanning from hotter stars to the left of the graph (classified as O for spectral type along the top of the graph) to cooler stars (classified as M). The conventional x-axis shows the color index for each star and the conventional y-axis shows the absolute visual magnitude.

Theorists have also created version of H-R diagrams in order to better explain and predict lifetimes of stars. An example of this can be found in Figure 2. When creating H-R diagrams, traditionally the log scale of luminosity is on what is conventionally the y-axis and temperature is on the x axis and increases in value as the graph moves to the left (*5*). These diagrams also show lifetimes of stars and how stars move through the main sequence (*5*). Stars also exist in

clusters of white dwarfs, giants, and supergiants on these diagrams (*5*). White dwarfs are below the main sequence and typically have the lowest luminosity ratio but the highest temperature (*5*). Giants are above the lower-middle portion of the main sequence and have lower temperatures and log luminosity ratios around two and three in magnitude (*5*). Supergiants are above the giants and are less clustered together (*5*). They also have lower temperatures like giants but have higher log luminosity ratios (*5*).

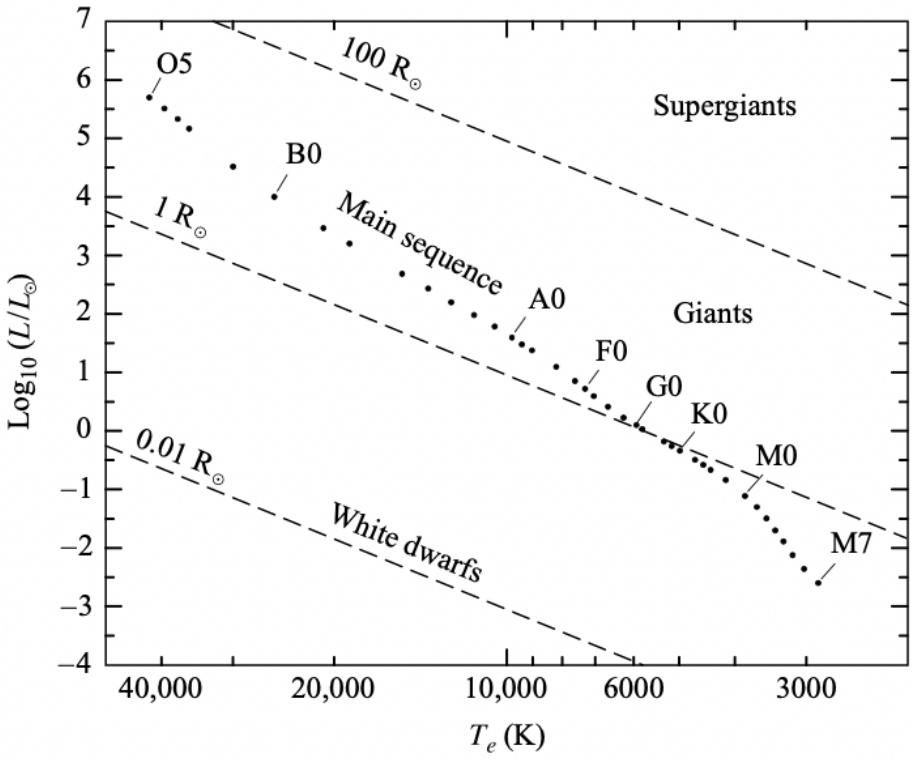

Figure 2: Theoretical H-R Diagram (*5*). This diagram shows a theoretical framework for H-R Diagrams and has the conventional horizontal and vertical axes of the log of the ratio of luminosity on the vertical axis and the temperature on the horizontal axis so that temperature increases as you go to the left of the graph. Dashed lines on the graph show different radii and are constant across the graph.

2.1.2 Pulsars

Pulsars are stars in the galaxy that emit pulses of radio waves that have a regular period of oscillation (*5*). The regular period of oscillation for a pulsar is between 0.25 and 2 seconds (*5*). On average, the pules that are emitted have about 0.795 seconds between them (*5*). These stars were discovered by Jocelyn Bell Burnell, as was already mentioned in Section 2.1. In order to observe pulsars, scientists can detect the pulses they emit, which is how Bell Burnell was able to see them with her radio telescope (*6*). These stars are neutron stars that are rotating at a rapid pace, which is why the period of oscillation is extremely short (*7*). Because of their rapid rotation and regular period, they can be used in order to keep time with accuracy that is on the level, if not better, than atomic clocks (*7*, *5*). A simplified diagram of a pulsar can be found in Figure 3. These stars also are, on average, as dense as the nucleus of an atom, and they have magnetic fields that have been seen to be as strong as 10^{10} Tesla (*6*).

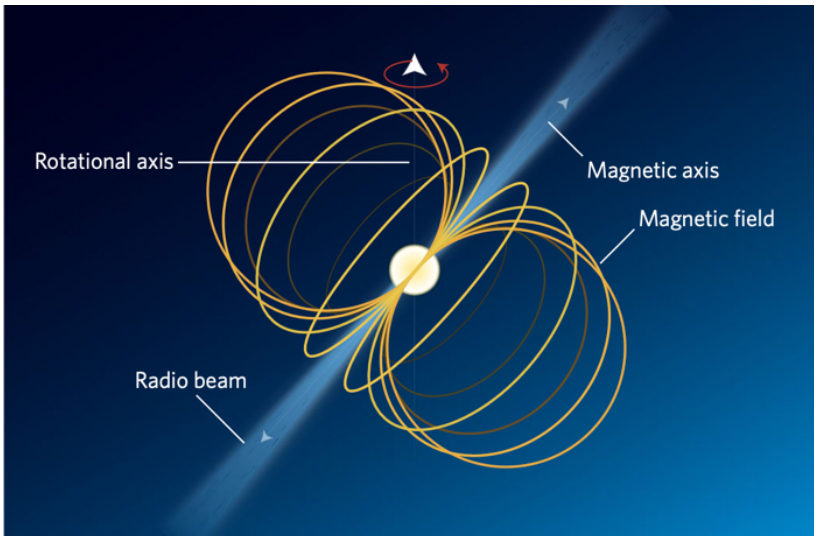

Figure 3: Pulsar Components (*6*). The diagram shows the components of a pulsar (rapidly rotating neutron star. The radio beams are shown and highlighted as well as the magnetic axis which they exist along. Magnetic field lines are drawn similar to a conventional bar magnet (coming out of one side and entering the other).

2.1.3 Black Holes

Black holes are objects in spacetime that are immensely dense, and because of this, no light can escape them (*8*). The gravitational pull from the black hole becomes inescapable once objects pass what is called the event horizon. Figure 4 shows the first image taken of a black hole, showing the black hole itself and its shadow as well (*8*). The structure of a black hole that is not rotating contains the singularity at the center, a point that has no volume but does have an infinite density, making it the place where the entirety of the black hole's mass resides (*5*). There is now evidence from work done by Roger Penrose, Andrea Ghez, and Reinhard Genzel that there is a black hole at the center of the Milky Way named Sagittarius A* (*9*).



Figure 4: First Image of a Black Hole (*8*). This image of a black hole was taken using the Event Horizon Telescope. This black hole is at the center of galaxy M87. The ring around the black hole is that of hot gasses and the gravitational pull at the black hole's event horizon.

The work that led to the conclusion that Sagittarius A* is a black hole came from theory around black holes, but also through observations of the galaxy around that point (*10*). These scientists looked at many different types of emissions, from gamma rays to radio waves to infrared to observe that part of the galaxy (*10*). Through the mapping of these stars, astronomers concluded that a black hole was the invisible object governing the movements of the stars near the center of the Milky Way (*9*). These projects tracked the motion of stars for decades as they orbited around the center of the galaxy to determine certain properties about the stars themselves (*10*). From there, scientists were able to look at a cluster of stars and map out their orbits.

2.1.4 Escape Velocity

For an object, say a spaceship, to break free of an orbit around a planet, it must achieve a certain speed in order to break out of that orbit (*5*). To derive the expression for escape speed, it begins with the ideas of work and energy. In order to find how much energy, it would take to raise an object away from the earth against gravity, the change in potential energy needs to be calculated, and since the gravitational force is directed inward and the infinitesimal length of the distance the object is traveling, that means the potential energy can be written as:

$$\Delta U = \int_{r_i}^{r_f} G\frac{Mm}{r^2}\,dr \tag{2}$$

where G is the gravitational constant, M is the mass of the planet, m is the mass of the object, and r is the distance from the center of the planet (*5*). After evaluation of the integral, the equation reached considers the initial and final positions of the object (*5*).

$$U_f - U_i = -GMm\left(\frac{1}{r_f} - \frac{1}{r_i}\right) \tag{3}$$

From here, by choosing a reference as to where the potential energy is zero (typically, when the distance between the object and the planet becomes infinite, the equation can be rewritten as an equation only considering the relative changes in potential energy (*5*).

$$U = -G\frac{Mm}{r} \tag{4}$$

In order to continue, the kinetic energy needs to be found for the object, and this can be found by integrating the change in potential energy, or in other words, by integrating the work. By integrating the force over the distance, the object has traveled, the integral can then be changed to include momentum (defined as the mass multiplied by the speed) and integrated over the time. Then, the integration can continue and by substitution (lines four and five below), we can follow the steps below to finish the integration (*5*).

$$W \equiv -\Delta U$$

$$= \int_{r_i}^{r_f} \boldsymbol{F} \cdot d\boldsymbol{r}$$

$$= \int_{t_i}^{t_f} \frac{d\boldsymbol{p}}{dt} \cdot (\boldsymbol{v} \cdot dt)$$

$$= \int_{t_i}^{t_f} m\frac{d\boldsymbol{v}}{dt} \cdot (\boldsymbol{v} \cdot dt)$$

$$\int_{t_i}^{t_f} m\left(\boldsymbol{v} \cdot \frac{d\boldsymbol{v}}{dt}\right) dt$$

$$\int_{t_i}^{t_f} m\,\frac{d\left(\frac{1}{2}v^2\right)}{dt} dt$$

$$\int_{t_i}^{t_f} m\, d\left(\frac{1}{2}v^2\right)$$

$$= \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2 \tag{5}$$

The quantity of kinetic energy can then be defined generally as:

$$K = \tfrac{1}{2}mv^2 \tag{6}$$

where m is the mass of the object and v is the speed at which the object is traveling (*5*).

By using the conservation of energy, the change in potential energy can be used and set equal to the change in kinetic energy, the final velocity of the object equals zero at an infinitely far distance from the planet, meaning both the kinetic and potential energy will be zero at that point (*5*). Then, the equation changes to this form:

$$\frac{1}{2}mv^2 = G\frac{Mm}{r} \tag{7}$$

and by solving this equation for v, the speed, the escape speed matches the equation below (*5*).

$$v_{esc} = \sqrt{\frac{2GM}{r}} \tag{8}$$

2.1.5 Planetary Motion

The solar system humans reside in is heliocentric, meaning that the sun is at the center of the system and planets orbit around it (*5*). Planets that reside in orbits between the earth and the sun are inferior planets and those with orbits where the earth is between the planet and the sun are considered superior planets (*5*). Inferior planets, when in between the earth and the sun, are said to be in inferior conjunction, and they are said to be in superior conjunction when the sun is between the earth and the planet (*5*). For inferior planets, when their angular separations from the sun are the greatest, planets are said to be at the greatest eastern elongation (to the east of the sun) and the greatest western elongation (to the west of the sun) (*5*).

Superior planets are said to be in opposition when the earth is between the planet and the sun and said to be in conjunction when the sun is in between the earth and the sun (*5*). When superior planets are at ninety-degree angles with the sun, planets are said to be in eastern quadrature (when it is to the east of the sun) or western quadrature (when it is west of the sun) (*5*). A diagram of these components can be found in Figure 5.

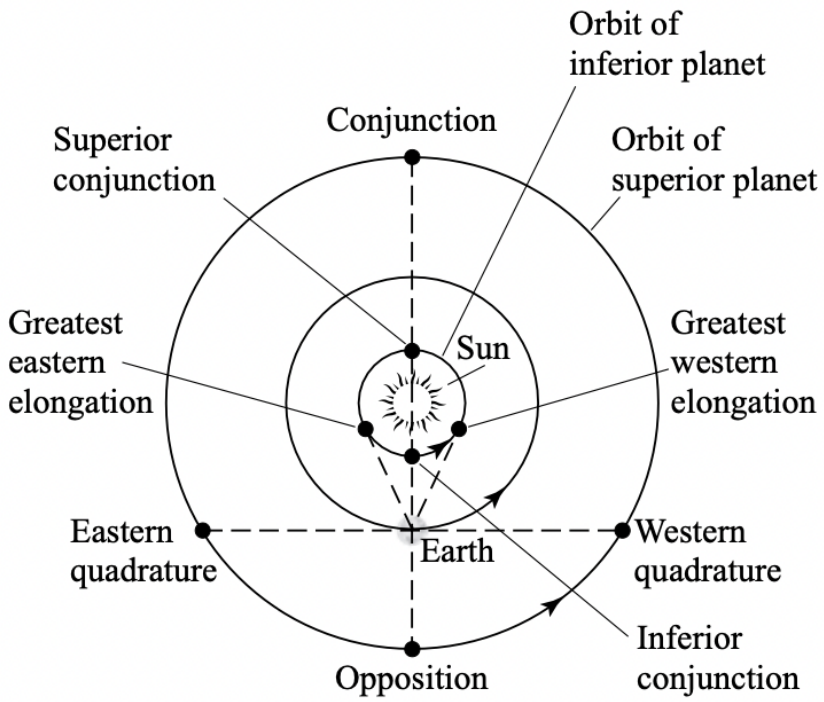

Figure 5: Conjunction, Opposition, and Planetary Motion (*5*). The diagram above shows the different components of inferior and superior planetary motion. Directionality of orbits is shown with arrows.

2.1.6 Sonification

In studying many physical phenomena in the universe, scientists are often guided by their sight as the primary source of information. However, it is not the only way we can analyze and distinguish data. Sonification is the process of using sounds to represent physical data, and this allows for people who are sight-impaired to be able to analyze data by listening to different pitches, rhythms, and volumes of sound to distinguish the data (*11*). This process of sonification is done through computer programs that then convert the physical data into sounds which scientists can use to identify different things in their data such as noise in the data, peaks, or pulses from different sources in the galaxy (*11*). Díaz-Merced, as spoken about earlier, used this technique when working at Virgo (a gravitational wave observatory located in Italy) to look at

gravitational wave data (*12*). Díaz-Merced, when asked about her work, said that when black holes are colliding, a "chirp" represents their collision when converted into sounds (*12*). This technique can also be used combined with traditional visual displays of data to better identify and classify numerical data (*11*).

2.2 Notable Astrophysicists

Not only are astrophysicists scientists, but they are also people who impact and inspire generations of future scientists. Each of these women have made groundbreaking strides in the physics community and many of them continue to shape science as it is known today, both based in physics and in other realms entirely. Many of these women have won awards, however only one has won a Nobel prize. Throughout history, only four women have won the Nobel prize in physics for their discoveries, and many go unnoticed for their contributions to groundbreaking work, which is ultimately what this section serves to do: notice and give voice to each of these women and their current and past work. All of these women can be found in Figure 6.



Figure 6: Notable Astrophysicists. These photos show the eight astrophysicists spoken about in this section. Each has made notable contributions to the field of astrophysics. Six of these eight women are continuting to make strides in physics and related fields still today.

2.2.1 Jocelyn Bell Burnell

When Jocelyn Bell Burnell was a graduate student at the University of Cambridge, she discovered pulsars, which are a type of star, after picking up a reading in the middle of the night off a radio transmission (*21*). Before knowing it was a pulsar, Bell Burnell dubbed the signal LGM for "little green men" (*7*). This did not last long, as they detected more signals and eventually reaching the conclusion that they were observing pulsars (*7*). She, however, was not given credit for her discovery and her PhD advisor, Antony Hewish and another researcher Martian Ryle won the Nobel Prize in physics for her work (*22*). Despite this, in recent years Bell Burnell has won numerous awards, served as the president of the Royal Astronomical Society, and became the first woman to serve as the president of the Institute of Physics (*22*). Bell Burnell continues to research stars and black holes to this day (*7*). Her advice to women in science is "to do the very best work you can" (*22*).

2.2.2 Andrea Ghez

Andrea Ghez is an astronomer at the University of California, Los Angeles, and she studies black holes, often using new technology like detectors and optical techniques (*10*). She also recently won the Nobel Prize in physics with Roger Penrose and Reinhard Genzel for their work on black holes (*9*). She is only the fourth woman in history to win the Nobel Prize in Physics (*9*). Her work began in the 1990s and continues today, and she uses technology to analyze star movements near Sagittarius A*, which is the object at the center of our galaxy (*9*). Because of her work, there is now evidence that Sagittarius A* is a black hole at the center of the Milky Way (*9*). When asked about her work with stars that are tens to hundreds of years in age, she was asked how long she planned on living, to which she responded, "I don't know. I figure the more fun I have the longer I'll live" (*10*).

2.2.3 Katherine Johnson

Katherine Johnson started out as a computer with NASA, working to do calculations for space missions and to fight against segregation (*23*). Johnson was instrumental in the space race during the time of the Cold War and helped John Glenn orbit the Earth during Project Mercury (*24*). After this she continued to work for NASA and contributed to the Apollo 11 mission to land people on the moon, not only in her own calculations, but also in checking the calculations of the mechanical computers at NASA (*21*). Recently, there has been both a group biography and movie made about her time at NASA, both titled *Hidden Figures* (*24*). They explore her experiences at NASA being a woman of color in the 1950s and 1960s along with the experiences of Mary Jackson and Dorothy Vaughn, who were also instrumental figures in their times at NASA (*24*). Johnson was honored with many awards including the NASA Lunar Orbiter Award, Mathematician of the Year in 1997, and the Presidential Medal of Freedom when Barack Obama was in office (*25*).

2.2.4 Mae Jemison

Mae Jemison, as a child, followed the Apollo missions and dreamt of being an astronaut (*21*). She began her work as a chemical engineer, then became a medical doctor before becoming an astronaut with NASA. From there, she became the first African American woman in space, and was part of the first set of astronauts at NASA after the *Challenger* explosion (*26*). After her work at NASA, she went on to teach at Dartmouth College and was an advocate in teaching her students how to increase science literacy in the world (*26*). She went on to become the principal for the 100 Year Starship project and help to found science camps for future scientists (*21*). The 100 Year Starship project is multidisciplinary and based around creating opportunities for future generations to participate in interstellar travel (*26*).

2.2.5 Annie Easley

Annie Easley began her work in astrophysics as a human computer like Katherine Johnson, and eventually worked with the mechanical computers at NASA, which kick-started her work in programming (*21*). Easley worked primarily with the International Business Machine (IBM) computer and writing programming for space navigation systems (*27*). Formula Translating System (Fortran) and Simple Object Access Protocol (SOAP) were the two languages she was well-versed in and used them to implement her code into NASA's projects (*25*). She went on to work on the Centaur project, which would go on to be an important part of many space missions, especially with satellites and exploratory spacecraft and the Cassini mission to Saturn in 1997 (*25*). Easley also advocated for underrepresented voices in physics and computer science by doing volunteer work, and while she was still at NASA, she protested dress codes and was active in the Business and Professional Women's Association even after her retirement (*25*).

2.2.6 Margaret Hamilton

Margaret Hamilton was a self-taught programmer, who began her work at the Massachusetts Institute of Technology (MIT), where she began doing software development and engineering, before that was even a field of study (*25*). The software programs she began designing at MIT involved hexadecimal and binary code and then went on to create platforms/operating systems for her codes (*25*). She began her work at NASA soon after and began her work in leading a team for Software Engineering Division in the Apollo team (*25*). She worked on the Apollo program by writing the computer program to help land Neil Armstrong and Buzz Aldrin on the moon (*25*). This code has since been adapted for many other space missions at NASA (*25*). Hamilton won many awards, but the most notable include the

2003 Exceptional Space Act Award and the Presidential Medal of Freedom from Barack Obama (*25*). She made sure her daughter, Lauren came with her on nights and weekends to work and when asked about her work, she emphasized that “the greater the challenge, the more fun [they] had" (*25*).

2.2.7 Wanda Díaz-Merced

Wanda Díaz-Merced works currently on using computer software to convert data into sounds at Virgo, which is a gravitational-wave observatory, so she can analyze data from black holes (*12*). She also works to make science more accessible to people with disabilities like her so they can contribute to research as well (*12*). When Díaz-Merced was in her early twenties, she lost her sight so to analyze data from gravitational waves, she used sonification (*11*). Sonification, as was already touched on, converts data into sounds so it can be analyzed (*11*). However, other studies are being done on how to use sonification in combination with physical data in order to become more precise about data redouts and simply aid in identification of data (*11*). Díaz-Merced has also used her work with sonification as outreach to schools, teaching children about radio astronomy and giving them viable opportunities to analyze and observe radio emission data (*11*). She is excited about science outreach and keeping science accessible to all from scientists to parents to children (*11*).

2.2.8. Chanda Prescod-Weinstein

Chanda Prescod-Weinstein works to break barriers for women of color in physics, using her position to not only do theoretical research which ties together astronomy and particle physics, but also bring her research to people outside of academia (*20*). She works on answering questions about our expanding universe, dark matter, and what it means to make education in these topics more equitable and accessible for all (*28*). Currently, she is an assistant professor of

physics and a core faculty member at the University of New Hampshire in the women's and gender studies department there (*20*). She recently wrote a book entitled *The Disordered Cosmos: A Journey into Dark Matter, Spacetime, and Dreams Deferred,* and it explores both dark matter and more astrophysical concepts while also addressing topics of social justice (*28*). Her work with diversifying the field of physics touches on intersectionality of identity and how different sets of problems exist for those who have multiple intersecting minoritized identities (*30*). Prescod-Weinstein won the 2017 LGBT+ Physics Acknowledgement of Excellence Award because of her work on intersecting and minoritized identities (*20*).

2.3 Identity

In the most basic terms, identity is a changing portion of one's sense of self and how that relates to a person's definition of who they are. When looking at prior research that concerns the topics of identity, researchers have mainly looked at gender, race, culture, sexual orientation, and religion as the major pillars to one's personal identity. However, researchers have also looked at how jobs and different terms like "scientist" interact with identity and how that portion of a person's identity is formed. In a study done by Irving and Sayre (*2*), they looked at the levels of identity that students go through when they are forming the scientist part of their identity. These students were a part of undergraduate upper-level physics classes studying electromagnetism and mechanics (*2*). The researchers conducted semi-structured interviews centered around career paths after undergraduate studies, their level of interest in physics, and their metacognitive level (*2*). They found that the more defined a student's career aspirations are, their self-awareness of their place in the scientific community, and their definition of who a physicist is influenced their level of identity (*2*). To help students identify more as scientists, students should be given adequate access to career services and education throughout middle and high school. The earlier role models and career options are shown to students, the more likely students will identify with being a scientist and in turn, the more defined their career aspirations and intentions.

The most common way for identity to be assessed is in doing interview techniques like those done in the previous study, and many are done on students in upper-level physics classes or those who have careers and degrees in physics. For instance, in a case study done by Eren (*1*) on women studying physics and physical science in higher education, interviews of 29 different women who attend universities around Dublin, Ireland were conducted. All the participants were working towards a bachelors, masters, or Ph.D. in physics, and this was done to achieve a cross

sectional view of how the development of gender and science (one's ability to see oneself as a scientist) intersect (*1*). Eren (*1*) used an in-depth interview with each of the participants to gather the data about their experiences and then coded all the responses to see patterns in the responses to different prompts. The results of this case study centered around the development of the science portion of a woman's identity, and the responses show that often engaging and participating in science can help to develop interest in pursuing physics and physical sciences further (*1*). They also concluded that there were community factors that influenced the development of the participants' identity as well (*1*). There is often tension between the portions of identity that are related to being a scientist and the portions that are associated with femininity because of stereotypes that have persisted over long periods of time centered around physics, exemplifying it as a male-dominated field (*1*). The interview style research done by both Irving and Sayre (*2*) and Eren (*1*) form the basis of looking at identity progression in people who are already interested in physics and these interviews are often done in a retrospective manner.

As stated before, much of the identity research is done on students who are already invested in doing physics at the level of higher education. However, for people to even begin developing an association with science, they need to be introduced and exposed to it, which is easy to do in high school settings and in introductory classes at the undergraduate level. These students may develop their identity as scientists in a different way or at a different pace in comparison to those who are invested in studying physics for a prolonged period of time, as they may be just starting to see themselves as scientists once they start taking lab classes that are standard across high school education and introductory classes at the college level in the United States. Identity development, though, does not come without also fostering a sense of belonging in the spaces where science skills are relevant, like lab classes and science classes in general. It

stands to reason that students who feel as though they belong to a community will identify themselves with that community. However, there are complex implications for how different stereotypes and portions of identity interact with one another and impact identification with terms like “scientist” and physicist”.

2.3.1 Intersectionality

The term intersectionality was coined by Kimberlé Crenshaw in 1989 (*31*) and refers to how aspects of a person’s identity intersect and impact one another. In order to accurately assess identity in any realm, it is important to recognize that everyone has many aspects of identity which interact with each other. Crenshaw’s work centers around specifically looking at how race and gender intersect with one another with the lens of multidimensionality, which means giving voice to each part of a person’s identity while also recognizing how those components intersect with each other (*31*). When people do not recognize the intersectionality of identity, they often disregard entire groups of marginalized people who have multiple intersecting and minoritized identities. For example, by only looking at gender, there is a complete disregard of how race interacts with gender identity, or how sexual orientation interacts with gender, or how sexual orientation and race interact with each other and how those identities combined interact with gender. By not recognizing this in research, oftentimes participants have to choose race over gender or sexual orientation, which can cause research studies and situations in the real world to ignore intersectionality and diverse experiences, or disregard people who share aspects of one identity but not another (*31*). Crenshaw (*31*) brings to light many experiences where Black women were marginalized and erased from many legal rulings because they did not have the same experiences as White women or Black men, when their identity is neither that of a White woman or Black man. Black women experience both racial and gender discriminations, while

White women and Black men only endure gender discrimination or racial discrimination (*31*). In order to facilitate any research based on identity, intersectionality must be considered so participants who have intersecting identities are recognized and valued in research studies.

Studies in the past have focused on intersectionality of race and gender, but there are other aspects of identity that many people do not often think about, especially in educational settings. People not only identify with certain genders or racial groups, but they also can identify with terms like "scientist" and "physicist". In a study done by Hyater-Adams et al. (*32*), researchers used qualitative coding to examine the concept of a critical physics identity, which combines and recognizes a person's science identity and how it coincides with their racial identity. They looked specifically at the different types of resources offered to students: relational resources (how relationships with others impacted the student's connection to physics), ideational resources (how ideas impact one's connection to physics), and material resources (how physical things can connect students with other aspects of their identities) (*32*). They also looked at recognition (being recognized/lack of recognition as a physicist), interest in physics, as well as performance and competence (whether there was a belief that one could understand and perform tasks connected to physics) (*32*). Their preliminary model can be found in Figure 1, which describes how the components of their analysis illustrate the concept of a critical physics identity (*32*). They speak to how resources encompass, impact, and relate to each of the pieces of the critical physics identity.

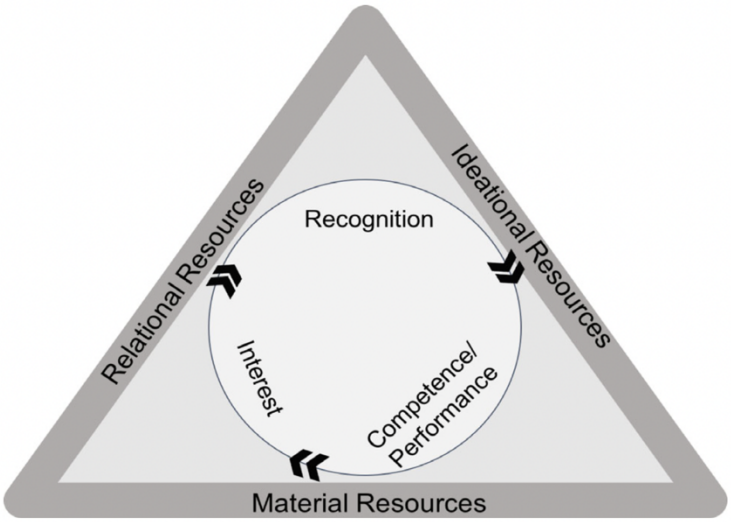

Figure 7: Critical Physics Identity (*32*). The critical physics identity focuses on the relationships between different kinds of resources and how that impacts interest (how much the student enjoys physics), recognition(being recognized by others as a "physics person"), and competence/performance (exam performance/grades).

By looking at how students identify as a scientist and which racial groups they identify with, researchers were able to see how those identities intersect and impact one another. This is vitally important in science education and more specifically physics education because there are many stereotypes about women and minorities in physics that hinder people who identify with those minoritized groups from identifying as a scientist. Therefore, it is important to create environments where students feel like they belong, so their identities can be validated, and they can grow in their relationship with their science identity.

2.4 Sense of Belonging

A strong association with science as a part of one's identity can be attributed to the environment in which the identity is fostered and whether they feel like they belong in that environment. When people are in supportive environments where they feel they can be

themselves, they feel more comfortable sharing parts of themselves with others. This, in turn, will help to foster a sense of identity with different groups, science-based or otherwise, and this can help students feel more comfortable being themselves. In a two-part study done by Chen et al. (*33*), participants were asked about how they identify as a scientist, and they looked at how science identity impacted performance. They also implemented a randomized intervention for each of the students where some were given an affirmation task (speaking about a value they have and why it is important) while others were a part of the control group (which asked them to speak about a value that was not important to them, but why it might be to others) (*33*). They found that science identity had a larger impact on minority students than on majority students, showing that science identity can impact grades (*33*). This implies that students who identify more with the term "scientist" often achieve better grades in places where their science identity is being brought to light. If students do not identify themselves as scientists, they can experience drops in their performance in class (*33*).

At the end of the first study, they were still left with the question of why this was the case, and they wanted to look more into how sense of belonging impacted identity. In the second study done by Chen et al. (*33*), they looked more into how science identity and sense of belonging interact with each other, and they theorized that science identity should influence students' sense of belonging and foster those feelings of belonging as well. They manipulated belonging by creating two separate interventions for the students, one being the social belonging condition where students were put into groups and asked to write about their experiences and difficulties transitioning to college; students were then shown examples of upper-classmen students who share the same feelings and experiences to foster a sense of belonging (*33*). The control condition participants were also put into groups, but their communications with each

other as a team were more oriented towards icebreaker activities rather than personal experiences like in the social belonging condition.

Chen et al. (*33*) found that science identity level was a predictor of belonging for minority students, and the social belonging condition boosted self-reported belonging for minority students. This study goes to show that identity and sense of belonging often intersect and interact in the classroom and that they can both play a role in the performance of students. This engagement with belonging interventions has also been shown to decrease and counteract the stereotypes that minority students experience in the classroom as well (*33*). The integration of groups that share common experiences in the classroom can encourage sense of belonging as exemplified with the social belonging condition. By giving students the chance to develop a sense of belonging in group settings with hands-on learning, they are more likely to feel as though they belong in spaces where science is being done. Also, allowing students to engage with each other at early stages of their physics education will allow them to foster not only a sense of belonging, but a sense that they are a scientist, both in and outside of the classroom.

Sense of belonging or academic belonging can be defined as feelings of being valued and accepted in the places where the person was doing academics (*4*). For students, this is often, but not always, the science classrooms in which students are enrolled. In the review article by Lewis et al. (*4*), the researchers looked at many different studies concerning women in physics and STEM and how different aspects of classroom settings can affect sense of belonging in women (*4*). Most often, sense of belonging in students was correlated with higher academic performance, feelings of competency in their discipline, persistence in studying STEM, motivation, and self-efficacy (*4*). Factors that can influence sense of belonging most often include how many role models and peers are introduced to them in the context of physics,

interventions in STEM settings, and outside influences can change a students' sense of belonging in their academic discipline (*4*). They also found that the person presented as their role model in certain situations affected their sense of belonging, in the sense that when a "geeky" scientist stereotype was presented, that resulted in lower belonging than when representation was given more generally (*4*).

Lewis et al. (*4*) includes a list of recommendations to physics educators at the end which include being aware of stereotypes, emphasizing effort and hard work, sending messages about sense of belonging and how it can change overtime, and being aware of the social environments that students experience in and outside of the classroom. By integrating these ideas into the classroom and out of the classroom, teachers can help to create an environment that students feel comfortable in, which can help them feel more comfortable learning science, and therefore identifying as a scientist. Increasing the amount of discussion centered around sense of belonging, identity, and common stereotypes in the science, and more specifically physics, community can also help students become more aware of stereotypes and how to combat them because oftentimes, negative stereotypes are what stands in the way of women and minority students identifying as scientists and feeling like they belong in spaces where science is done.

2.4.1 Stereotype Threat

While considering sense of belonging as a factor that influences academic performance, researchers have also looked at how negative stereotypes can influence sense of belonging in the classroom. In a three-part study done by Good et al. (*35*), researchers defined stereotype threat as negative stereotypes that can influence and change academic performance, sense of belonging, and cause people to feel they are not valued or accepted in their discipline. They developed a psychometrically sound measure of sense of belonging using a sample of undergraduate

mathematics students (*35*). They also examined how sense of belonging was related to the intent to pursue mathematics in the future and specifically at how academic performance influenced sense of belonging (*35*). They found that sense of belonging can predict the desire to study mathematics in the future and hearing stereotypical messages about women in STEM (for example, math ability is a fixed trait about someone) tend to impact a woman's sense of belonging in math (*35*). Good et al. (*35*) also found that the higher the degree of stereotyping, the lower the sense of belonging.

Since stereotypical messaging can be linked to impacts women's sense of belonging, teachers and professors should be thinking of ways to combat stereotypes so this does not happen. In order to encourage more women and minorities to work in STEM and related fields, current teachers and professors need to work to create units where students can see role models who look like them, especially when they are the minority in the classroom. When students feel as though they do not belong, they are more likely to leave the field they are studying, even if they perform well in that area (*4*). This only perpetuates the creation of stereotypes centered around women and minorities not belonging in fields like physics, which will only cause less and less individuals who identify with minoritized groups to study STEM, which creates an endless cycle of stereotypes and underrepresentation. Researchers have also looked specifically at how minoritized students learn and how teachers and professors can help make their learning a more positive experience.

2.5 Physics Education Research (PER)

Physics education research (PER) began with scientists who wanted to know about how students were learning physics. PER has historically encompassed pedagogical practices, learning theory, and how to apply different critical theories in classrooms which study physics.

Much of this has historically been done with qualitative and quantitative methods combined; by using both methods, researchers are able to capture a clearer picture of what is going on in the classroom, and it also gives educators access to diverse ways in which they can assess the learning of their students. Using both methods also allows us to focus on aspects of education that can impact student performance. PER is meant to improve the way physics is taught, and it can also be used to improve education for groups that have been underrepresented in the physics community (*36*).

Many standardized materials used by physics educators were standardized without regard for the groups with which students identify. The Force Concept Inventory (FCI, *37*), which is a standardized material for looking at student learning gains qualitatively, shows a strong performance gap favoring men and there have been little to no studies done on how other underrepresented groups perform on the FCI (*36*). By incorporating PER and teachers employing an active pedagogy, researchers have seen student performance increase, but the fact remains that it is unknown whether these methods can combat gender stereotypes (*36*). It is important to recognize the different aspects of pedagogy and how to apply them in the classroom to meet the needs of students and make learning environments which can support both their academic and personal growth.

2.5.1 Pedagogical Studies in PER

Though physics education is a broad area of research, applying different pedagogical methods is one way of looking at things which affect student learning. Many researchers employ an active pedagogical approach, which is where instructors alter their teaching methods to engage more with the students. Whether with flipped classroom styles, more teaching assistant interactions, or peer-lead instruction, many of these aspects are used in combination with each

other to help engage students and create more community-based learning. In a study done by Robinson et al. (*38*), researchers looked at college students and their performance on concept inventories like the FCI (*37*) and the Force and Motion Conceptual Evaluation (FMCE; *39*) because of the prevalent gender gap in achievement, despite interactive engagement techniques in other studies. Many studies cited by Robinson et al. (*38*) show that students perform better on the concept inventories, but the gender gap is not reduced. As such, a blended pedagogical model was used in combination with a first-year, one credit, physics class centered around problem solving skills commonly used in the field of physics (*38*). The blended pedagogical model included direct instruction, group-problem solving, and peer instruction, which this study also hopes to emulate in high school classrooms with lessons centered around women and minorities in physics (*38*). The researchers did observe positive shifts in students' attitudes and the gender gap narrow on standardized concept inventories, which they did attribute to their alterations to their pedagogical approach, but they also attributed the shift to the classroom culture which was built from this (*38*). They worked as researchers and educators to create the classroom environment which allowed for the students to engage in collaboration with their peers which helped to lead to better understanding of the material as well as encourage the students to adopt a growth mindset when it comes to physics (*38*).

The contributions from this article show that educators have a lot of influence when it comes to classroom culture. Robinson et al. (*38*) suggests that instructors should encourage and explain the value of making mistakes, allow students to recognize they are not struggling alone, and encourage participation in and outside of class by creating a good environment for relationships among students as well as relationships with students and teachers. This model is also useful in showing women and minoritized students that they are valued in the classroom and

has been shown here to change views in a positive way, regardless of gender (*38*). PER does not only serve to better the learning of minoritized students, but it also makes learning better for everyone, regardless of how they identify. Introducing collaborative environments and other aspects like Robinson et al. (*38*) speaks to does not diminish learning for anyone, it only serves to lift up minoritized students and it allows them to grow just as majoritized students have been since the beginning.

2.5.2 Learning Gains in PER

To gain knowledge about how students learn and retain knowledge overtime, scientists can use tests and surveys to assess how lessons and interventions impact student learning with something called a learning gain. Learning gains or normalized gains are common in PER and are used to see if students were able to grasp conceptual material taught to them (*40*). The idea of normalized gain was introduced by Hake (*37*) in a study done on student populations from high school, colleges, and universities centering around the Force Concept Inventory (FCI; *37*). Since then, it has become the standard for communicating how much students have learned in relation to the amount they could have learned in the class. Hake's (*37*) equation for normalized gain is:

$$< g > = \frac{<post> - <pre>}{100 - <pre>} \tag{9}$$

A normalized gain below 0.3 is low, between 0.3 and 0.7 is medium, and above 0.7 is high, and the brackets denote an average is normally taken of the sample's post and pre scores (*37*). Researchers can also choose to calculate individual learning gains and average them together, which was done by Robinson et al. (*38*) with matched data of student performance on the FCI (*37*). Robinson et al. (*38*) notes that their strategy is different from the first method, which is more generally done, but when normalized gains are calculated on samples above twenty students, both ways of calculation produce similar results (within 5%). When Hake (*37*) spoke to

this idea early on, he described how using learning gains can help PER have more standards in measurement, especially for the continuation of research, which can be seen as it is still being used today in research like Robinson et al. (*38*). In a recent study done by Pleskovitch and Guy at Washington State University (*41*), learning gains were assessed for students taking the Physics and Your World course, meant to educate future teachers about the areas of physics typically covered in middle school and high school classes. The Mechanical Waves Conceptual Survey 2 (MWCS2; *42*) was used by the researchers to assess student learning on mechanical waves, and it is similar to the FCI (*37*), in that both are used by physics teachers and professors to assess student learning because of their reliability and validity (*41*). Guy also has used the FCI (*37*) in the past to assess student learning on introductory level mechanics and used normalized gain to calculate student learning gains (*41*).

2.5.3 Interest Level in Physics and Motivation to Continue

Interest and engagement in physics is also often a part of many of the studies done by physics education researchers. This often manifests in questions about whether students want or intend to continue studying physics (either from high school to college, continuing from introductory classes to upper-level classes in college, or from undergraduate programs to graduate school programs), and it can also be assessed as generally as asking students if they enjoy science classes and activities. In a study done by Bottia et al. (*43*), researchers examined how students' experiences in high school impacted whether they were interested or intending on majoring in a science in college. They also wanted to look specifically about how traditionally minority populations in STEM fields are influenced in comparison to majority populations in STEM because of the trend of proficient women and minority students tend to leave science fields despite their achievements (*43*). The researchers also point out that most research in this

area is about retention of students once they already have declared their major and less about how and why students declare or start in the sciences (*43*). They found from their sample of high school students, 24.5% of students identifying as women intended on majoring in a STEM field compared to 58.0% of students identifying as men, and physical sciences are much more popular among students who identify as men (20.4%) versus students who identify as women (6.6%) (*43*).

Bottia et al. (*43*) also looked at the breakdowns of African American students in comparison to White students. They found that White students historically are enrolled in more STEM related classes in high school in comparison to African American students, which influences the amount of exposure students receive to science activities and their interest in pursuing STEM majors in college (*43*). In relation to this, they found that if more courses were taken at the advanced level, students were more likely to declare a STEM major (*43*). Physics classes being taken in high school were the greatest indicators of students' intent to major in a science for all gender and racial groups, though that does not mean they declare physics as a major, they are only more likely to broadly intend to major in a STEM field (*43*).

This study shows how important it can be for students to take STEM courses in high school, but also have good experiences in science classes in general. Instructors at all levels of schooling, especially at the introductory level, should create more lessons aimed at introducing students to the broader research areas across STEM education, not just only teaching them the basics. Obviously, the answer is not to give elementary school students astrophysics problems, but the goal is to take upper-level science concepts and format them for different levels of education while still offering them enough challenge to intrigue them. Achieving this also involves creating collaborative spaces where students can feel comfortable talking through

wrong answers to get to the correct one, spaces where they can truly bounce ideas off each other and learn from each other. By exposing students to these environments and concepts early on, they can have more time to understand and experience science, which as Bottia et al. (*43*) points out, is the largest indicator of intent to major/continue learning in the STEM fields.

There have also been studies which look at how students' motivation and interest level progress over time while in traditional lecture-based settings. Li and Singh (*44*) conducted a survey of undergraduates in an introductory physics course which was calculus-based, asking them to reflect on their interest level, their motivation in studying physics, their self-efficacy, and demographic questions so they could compare their results based on gender (*44*). The class was lecture-based and included a recitation period once a week where collaboration on homework problems was common (*44*). Both women's and men's interest and self-efficacy dropped from the beginning of the semester to the end, but the women's interest and self-efficacy scores had an even bigger gap than the men's scores (*44*). They also found that women had lower motivations over time, and they attributed this partially to the learning environment (*44*). Li and Singh (*44*) spoke about how their lecture-based learning environment did nothing to alleviate stereotypes and biases centered around gender and successes in physics. Because of this, it is important to create environments that are inclusive and equitable for students. This can occur with different pedagogical methods, which were discussed in previous sections. Also, interventions can be implemented in and out of class on topics concerning diversity, equity, and inclusion. Many times, these lessons are also able to be given in group settings, where students are free to collaborate with each other, fostering a sense of community and giving students motivation and support in classrooms from their peers.

2.6 Targeted Interventions

Most often in STEM-based classes at the undergraduate level, there is a need to get through an exuberant amount of material in a semester to prepare students for their future classes, especially at the introductory level and even more so with lecture-based classes. In this case, it can be difficult for professors to see the value in targeted interventions, which would take up time in the classroom. However, when these types of interventions are integrated into the environment where students are learning physics, there are often positive impacts. There are not many interventions done at the college level, but it stands to reason that people who are studying physics at the introductory level in undergrad would react similarly to younger students who are also at the introductory level in their physics education. In any case, there seem to be many positive implications for hands-on targeted interventions in school classrooms and for interventions done outside of the classroom to supplement education as well.

For example, Kersting et al. (*3*) looked at groups of middle school girls aged 14 to 15 who attended a boarding school in Australia and how presenting Einsteinian physics in classrooms can influence their perceptions and orientations towards physics (*3*). These lessons took place during regular lessons in the classroom and featured a collaborative group setting for instruction in order to foster a hands-on learning environment (*3*). The importance here is the integration of the intervention into the classroom, as it gives the students easy access to the intervention, and does not require staying after school, or commitments outside of their regular school day, which is ideal, but not the only option. The researchers also conducted interviews with some of the students along with questionnaires to hear more about the topics they learned about, how their experience was in the program, their motivations, and attitudes towards physics (*3*). Groups were allowed to collaborate on responses, which is both a limitation and strength for

the research because it fostered communication but also limited the number of responses collected (*3*). The lessons were shown to correlate with increased interest in physics, they were able to challenge traditional stereotypes in physics, and show clear career paths later in life concerning physics (*3*). Kersting et al. (*3*) highlights that targeted interventions concerning topics in physics can have positive effects on students' perceptions of physics while also addressing things like stereotype threat for students. These instructors did not decide to give up teaching portions of physics in favor of speaking about stereotypes though, they integrated this conversation into their lessons, showing that it is possible to talk about equity and inclusion without compromising on content.

In a different study done by Wulff et al. (*45*), researchers looked at a Physics Olympiad program as the backdrop for their intervention. This intervention did not take place in the classroom, but as a part of a science enrichment program where they were able to alter the social environments during the program in order to foster a sense of identity around physics (*45*). The researchers wanted to create an environment where women could see themselves as a part of a supportive physics community, and they did this also without compromising on the content of the program (*45*). The researchers looked at how interest, recognition, and competence change with identity as well as how participation in the events of the Physics Olympiad changed overtime (*45*). The intervention implemented by the researchers was done in one day and involved group discussions and filling out pre and post surveys involving identity related questions (*45*). They also divided their participants at times into same-sex groups in order to avoid domination of one gender over another, and there were many instances of hands-on work through the intervention as well as reporting out to a larger group what was found (*45*). Thirty students took part in the intervention (13 women and 16 men), and they were all aged from 15 to

17 (*45*). From this intervention, women were positively impacted in terms of their identity, and there were no harmful effects for the men who participated in the intervention, who were not experiencing any issues with identity development (*45*). When the content of the discussions involved the debunking of stereotypes that are often associated with women in STEM, women were interested in looking at those topics, which speaks to how targeted interventions can affect a target group without causing any adverse effects for members of other groups (*45*). They also looked at the percentage of group members that came back to participate in the Olympiad again the next year, and overall, from their small pool of data, more women than average came back after receiving the intervention (*45*). This study implies that similar interventions that are designed for certain minority groups in physics can be effective in identity development and change as well as participation in physics related projects and fields later in life.

2.7 The Present Study

The present study will investigate how a set of interactive lessons about upper level physics topics centered around the representation of diverse voices in physics influences four domains: (1) the formation of a student's identity as a scientist, (2) students' sense of belonging in physics spaces/classrooms, (3) the interest that students have in studying physics later on in their academic careers, and (4) the students' knowledge on specific concepts and people in physics. The three outcome variables include identity, sense of belonging, as well as comprehension and retention of physics knowledge. Each variable will be assessed before and after the set of physics lessons. Both upper-level physics topics and psychology topics will be integrated into the design and implementation of the lessons being created. Once the lessons are developed, they will be implemented at Allegheny College in a physics classroom where assessment will happen before and after the lessons.

For Domain 1, I expect students to progress through different levels of identity concerning their identity as a scientist because of the work by Irving and Sayer (*2*), which looked at different levels of a student's identity as a physicist and how they were influenced by the preconceived notions students have about who scientists are. In giving the students role models to help them modify and redefine the terms "scientist" and "physicist", I expect students will alter their views about who a scientist is in general, as well as their identity as a scientist. For Domain 2, I hypothesize that students will experience an increase in sense of belonging because they will feel as though they are a part of a classroom community in which they are accepted. This is supported by research by Chen et al. (*33*), which showed a positive relationship between hands-on interventions and student's sense of belonging in their classrooms, and by Lewis et al. (*4*), who found that the presence of role models and education involving role models can influence sense of belonging for students. For Domain 3, I expect there to be an increase in interest concerning physics because of research from Bottia et al. (*43*) suggests that the more exposure that students get to science, the more likely students are to show interest in declaring a STEM related major in college. For Domain 4, I expect students to be able to comprehend and retain the information taught to them during the lessons done because of the research done by Pleskovitch and Guy (*41*), which showed positive learning gains in classes at Washington State University. Also, due to the work by Robinson et al. (*38*), who also saw positive learning gains after incorporating a blended pedagogical model which encompassed interactive engagement of students, which this study will emulate.

METHODOLOGY

3.1 Participants

The sample that was collected consisted of introductory-level astronomy students (PHYS*121) and first year seminar students (FS*101), both classes were taught by Dr. James Lombardi and were based in space science and introductory astronomy/astrophysics. There was a total of eight participants from the two classes aged from 18 to 24, and the sample consisted of three people identifying as women and five identifying as men. Five of the students identified as White, two identified as Asian, and one identified as multiracial. Demographics are further detailed in Table 1. The students participated in two lessons spanning ninety minutes each day, and these lessons were administered outside of class time. Students received specialized lesson plans, and they were given a 2% increase in their overall course grade for participating in the study. Students were also able to enter a drawing for five-dollar gift cards to French Creek Coffee. Students used both their phones and laptops to complete data collection and participate in activities.

Table 1: Participant Demographics by Gender

Age	**Woman**	**Man**
18	2	2
21	0	2
24	1	1
Race	**Woman**	**Man**
White	2	3
Asian	1	1
Multiracial	0	1

3.2 Procedure

Participants were recruited for the study through Dr. Lombardi's introductory astronomy class and first year seminar courses using the recruitment script in Appendix 1. Participants were all over the age of 18 and were able to fill out the informed consent form listed in Appendix 2. Participants filled out the informed consent during the first day of intervention before the lessons were administered and data was collected. Once informed consent was gathered, participants proceeded to fill out surveys and questionnaires concerning sense of belonging (Appendix 3), identity, and interest in physics (Appendix 4). They were given open-ended questions to supplement the quantitative measures concerning sense of belonging, identity, and interest in physics (Appendix 5). Participants were also given a pre-test centering around the scientists, discoveries, and physics that will be talked about during the hands-on lessons (Appendix 6). All measures were used to gauge a baseline and were then compared to the post-test data collected at the end of the intervention and took the participants about thirty to forty minutes to complete.

After initial data was collected, participants engaged in two hands-on lessons. One was given after pre-test data was collected and the other was given during the next session before post-test data was collected. Both lessons were centered around women and underrepresented minorities in STEM and consisted of a lecture-based portion, a hands-on activity, and a discussion portion. Further outlines of these lessons can be found in Appendices 7. The lecture-based portion of each lesson highlighted four people who have made significant contributions to astrophysics and astronomy. The first lesson was designed around Jocelyn Bell Burnell, Wanda Díaz-Merced, Chanda Prescod-Weinstein, and Andrea Ghez, which was made to give an overview of the interdisciplinary nature of astrophysics. The second lesson was designed around

Katherine Johnson, Mae Jemison, Annie Easley, and Margaret Hamilton, which focuses on space travel as well as computer programming in astrophysics.

Participants were then able to participate in a hands-on demonstration of a physics concept talked about during the lecture. The first activity centered around creating a Hertzsprung-Russell diagram by clicking and dragging pieces of a diagram to create a representation of the lives of stars. The second activity involved participants picking a planet to call their "home" planet (from planets that have a known mass and radius) and a "destination" planet to visit. They calculated the distances they would need to travel when the planets were in different positions in their orbits as well as their escape velocities for each planet. Participants worked in groups to determine this and were able to discuss their approaches for both activities. After the hands-on portion, participants engaged in a discussion of the activities and how they could apply these concepts to astrophysics. Then, they were able to discuss how learning about women and minorities in physics impacted them and why it was important to educate people on these topics.

After the second lesson was given, participants engaged in post-data collection. The post-tests/surveys were the same as the pre-tests/surveys, but demographic questions were only asked during the pre-data collection as they are constant factors that would not change overtime. After the data was collected, participants were given a debriefing form (Appendix 8) allowing them to opt into receiving the results of the study and allowing them to opt into the gift card raffle. They were asked if their open-ended responses could be quoted in this narrative as well as in future posters/publications. During the debriefing, participants were able to ask questions and give feedback on the intervention. Approval forms from Dr. Lombardi for this research project can be

found in Appendix 9. Table 2 gives a description of the order of events for teaching and data collection. Further details can be found in lesson plans in Appendix 7.

Table 2: Administration of Data Collection and Lessons for Day 1 and Day 2 of Intervention

Order	DAY 1	DAY 2
Beginning of Intervention	**Data Collection Pre-tests:** **Students will fill out four different measures for data collection:** • Sense of Belonging (SB) Instrument • Student Science Identity Questionnaire (SSI) • Open Ended Response Items and Demographics Questionnaire • Physics Quiz/Assessment	**Lesson Plan Instruction:** **Physicists:** Mae Jemison, Katherine Johnson, Annie Easley, and Margaret Hamilton **Content:** Astronauts, The Space Race, Coding and Astrophysics, Escape Velocity, and Planetary Motion
End of Intervention	**Lesson Plan Instruction:** **Physicists:** Jocelyn Bell Burnell, Wanda Díaz-Merced, Chanda Prescod-Weinstein, and Andrea Ghez **Content:** Pulsars, Sonification and Gravitational Waves, Theoretical Physics, Hertzsprung-Russell Diagrams, and Black Holes	**Data Collection Post-tests:** **Students will fill out four different measures for data collection:** • Sense of Belonging (SB) Instrument • Student Science Identity Questionnaire (SSI) • Open Ended Response Items • Physics Quiz/Assessment

3.3 Materials

3.3.1 Sense of Belonging (SB) Instrument

Sense of belonging was assessed using the Sense of Belonging Instrument (SB; *46*), which is a 26 item self-report questionnaire measuring four factors that interact with sense of belonging in the classroom: "perceived peer support ($\alpha_{pre} = .78, \alpha_{post} = .66$) perceived class comfort ($\alpha_{pre} = .26, \alpha_{post} = .99$), perceived isolation ($\alpha_{pre} = .94, \alpha_{post} = .94$), and perceived faculty support ($\alpha_{pre} = .74, \alpha_{post} = .97$)." This measure can be found in Appendix 3. This measure was designed for first-year college students, and the language of the measure was adapted slightly for future use and consistency by changing language centering around college-dependent settings (i.e., office hours) and deleting item 20 about speaking to faculty outside of class. Student responses are given on a five-point scale (1 = completely true, 2 = mostly true,

3 = equally true and untrue, 4 = mostly untrue, and 5 = completely untrue). Means were calculated for each of the five factors, where lower numbers were associated with more perceived social support, faculty support, classroom comfort, and empathetic faculty understanding, and less perceived isolation. Item examples include, "If I miss class, I know students who I could get notes from." and "Speaking in class is easy because I feel comfortable." Reliability was shown both in the Hoffman et al. (*46*) study when the survey was created and shown by Solanki et al. (*47*) which used the measure to examine belonging in the discipline of biology ($\alpha = .85$).

3.3.2 Student Science Identity Questionnaire

Identity and interest in physics were evaluated with the Student Science Identity (SSI; *48*), which is a 24-item questionnaire which assesses the construct of identity development in a science context as well as interest in studying science in the future. This measure can be found in Appendix 4. This measure identifies four different scales in the definition of identity: performance ($\alpha_{pre} = .85, \alpha_{post} = .86$), competence ($\alpha_{pre} = .83, \alpha_{post} = .87$), recognition ($\alpha_{pre} = .96, \alpha_{post} = .95$), and interest ($\alpha_{pre} = .69, \alpha_{post} = .85$). Due to a technological error, item 17 of this measure was not included in data collection, which is a part of the interest subscale. This measure was designed and tested on students in grades 8, 10, and 11, and consists of a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). Item examples include, "I think I am good at science" and "I plan to pursue science careers in the future." Means of each of the four components of the questionnaire were calculated. Higher scores on each of the four components indicated higher perceived performance in science settings, higher science competence, higher levels of science recognition, (recognizing oneself a scientist), and higher interest in science. Reliability and validity were both tested in the study done by Chen and Wei

(*48*) in the development of the survey (science learning confidence $\alpha = .88$, science class interest and performance $\alpha = .83$, science career interest $\alpha = .86$, science recognition $\alpha = .89$, and total $\alpha = .95$).

3.3.3 Open Ended Items for Sense of Belonging, Identity, and Interest

For the qualitative portion of the study, questions will be asked of the students in an open-ended way where they can write down their thoughts about the questions asked, and these can be found in Appendix 5. There will be three questions in this portion of the survey: "Do you feel as though you as a student belong in your physics class? Why?", "Do you see yourself as a scientist? Why or why not?" and "Are you interested in studying physics in the future? Why or why not?" Students will complete these questions in approximately fifteen minutes. After students submit their written questions, responses will be transcribed by typing them. Responses to these questions will be coded with thematic analysis using the framework outlined by Braun and Clarke (*49*). Questions will be used to get a better understanding of student responses for the concepts of sense of belonging, identity development, and interest in physics.

3.3.4 Conceptual and Mathematical Physics Knowledge Assessment

In order to assess conceptual and mathematical understanding of physics topics, a multiple-choice test will be administered to students both before and after the interactive lessons. Students will be asked three types of questions about each of the four scientists: questions about conceptual and mathematical physics concepts, questions about the significance of the discoveries made by the scientist, and questions about the scientists themselves. Each of the questions will pertain to the information spoken about during the lesson as well as the interactive portion of the lessons. Each question is weighted equally at one point and a mean score will be calculated. These scores will be calculated at baseline and at the end of the study and compared

to see growth across the six weeks in their education. This will be done by calculating the learning gains for each student as well as the average learning gains across the class (*37*).

3.4 Design & Data Analysis Plan

This longitudinal and correlational study will use quantitative and qualitative methods to examine associations between interactive lessons in physics and how they affect sense of belonging, the development of the label scientist as an identity, and interest in physics. The structure of the study is within groups, as there will only be one group of students receiving the lessons, and there is no control group. Paired samples T-Tests will be used to look at the differences in pre and post test scores. Learning gains will also be calculated, following the framework outlined by Hake (*10*). Each of the mean scores from the surveys will be compared from pre and posttests. For the qualitative portion of the study, a thematic analysis will be performed on the written portion of the student responses. To perform the thematic analysis, the framework described by Braun and Clarke (*49*) will be used. The six step framework involves (1) reading, rereading, and annotating data, (2) producing an initial code to label features in the data, (3) identifying themes and patterns in the responses of the data, (4) quality checking the themes and codes for meaning and diversity in content, (5) defining and naming themes so they are related, but do not overlap, and (6) reporting the data to show the analysis (*22*).

RESULTS

4.1 Descriptive Statistics

A series of Pearson's correlations were conducted on each quantitative measure completed by the students to get a holistic picture of how the variables could be impacting each other. Both pre- and post-performance scales on the identity questionnaire (which indicate students' perceptions of their abilities to perform on scientific tasks) were significantly and positively correlated with higher scores on the physics assessment ($pre\ r = .84,\ pre\ p = .009,$ $post\ r = .71, post\ p = .05$). Recognition and interest scales on the identity scale were also significantly and positively correlated with each other, meaning the more recognition students were feeling the higher they rated their interest in physics (pre recognition and pre interest: $r = .84, p = .009$, pre recognition and post interest: $r = .83, p = .01$, post recognition and pre interest: $r = .81, p = .01$, and post recognition and post interest $r = .89, p = .002$). Many pre and post scores for the same subscales were also correlated together, for example pre and post recognition scores were significantly and positively correlated, meaning students who rated their initial recognition highly also rated their recognition highly after the intervention ($r = .95, p < .001$). The extended table of correlations between pre and post scores for the same subscales can be found in Table 3. All significant correlations can be found in Table 4.

4.2 Sense of Belonging

A paired-samples t-test was conducted on each subscale in the sense of belonging measure to see how each of the variables changed following the intervention. There was no significant change in sense of belonging scores from pre- to post-intervention. Perceived peer support decreased slightly from pre ($m = 2.69$), to post ($m = 2.42$), though not significantly ($t(7) = 1.51, p = .91, Cohen's\ d = .53$). Perceived class comfort increased slightly from pre

($m = 1.91$), to post ($m = 2.09$),, but not significantly, ($t(7) = -.43, p = .34,\ Cohen's\ d = .15$). Perceived isolation increased slightly, but not significantly from pre ($m = 2.94$), to post ($m = 3.09$), ($t(7) = -1.11, p = .15,\ Cohen's\ d = .39$). Perceived faculty support increased slightly, but not significantly from pre ($m = 1.54$), to post ($m = 1.85$), ($t(7) = -1.02, p = .17,\ Cohen's\ d = .36$). Table 5 details the paired-samples t-test run for sense of belonging and Table 6 details the descriptive statistics for sense of belonging.

4.3 Science Identity

A paired-samples t-test was conducted on each subscale in the student science identity measure to see how each of the variables changed overtime. The recognition subscale did increase significantly from pre ($m = 2.47$), to post ($m = 2.84$), meaning students were better able to recognize themselves as scientists after the intervention, and the effect size was medium to large ($t(7) = -2.05,\ p = .04,\ Cohen's\ d = .72$). The performance subscale had a slight increase in scores from pre ($m = 3.10$), to post ($m = 3.35$), but was not significant ($t(7) = -1.12,\ p = .15,\ Cohen's\ d = .40$). The competence subscale also had a slight increase on scores from pre ($m = 3.65$), to post ($m = 3.75$), but was not significant, and ($t(7) = -.59,\ p = .29,\ Cohen's\ d = .21$). The interest subscale decreased from pre ($m = 3.71$), to post ($m = 3.50$) but not significantly, ($t(7) = 1.44,\ p = .90,\ Cohen's\ d = .51$). Table 7 details the paired-samples t-test run for identity and Table 8 details the descriptive statistics for identity.

4.4 Open Ended Items

Themes were derived from student responses to three questions about sense of belonging, identity, and interest in physics. All themes emerged within each question; however, the themes were more prominent in certain questions, which spoke to the differences in student responses across questions and across participant demographics. Each student indicated 'yes' or 'no' to each question and was asked to elaborate.

4.4.1 Sense of Belonging

By doing a frequency analysis on the codes, most participants stated they do feel as though they belong in their classes, both before and after the intervention. Most students who cited they did not feel as though they belong in their physics classes spoke about understanding the content as well as their peers. Student 7 stated that they "see others doing much better than [them] in the course," and brought up struggling with the content of the class as well. Those who did feel a sense of belonging in their classes referenced the classroom atmosphere and their professor as the main reasons for their belonging in the classroom. Student 2 said "[the classroom atmosphere] makes it really easy to speak up and express questions," and they stated they felt comfortable asking questions both during class and outside of class. Students most often cited aspects of their classroom and peers in general when talking about their sense of belonging as well, whether they had positive or negative feelings about their own sense of belonging. For example, student 4 stated they did not feel as though they belong in their physics class and cited that they "did not understand the topics as well as others in the class," though they also spoke to making friends in the class. On the other hand, student 8 said they did have a sense of belonging in their class and said they "enjoy working with their classmates."

4.4.2 Identity

Most students answered definitively on both pre and post questionnaires that they do not see themselves as scientists. Students cited many struggles and stereotypes of scientists when they were answering about whether they felt they were a scientist. Student 6 explicitly stated a stereotype by saying that "[they] picture the stereotypical scientists in a lab coat surrounded by data and super stressful." Many other students cited that they did not have the dedication, passion, or the knowledge to call themselves scientists. Students also brought up many aspects of physics, stereotypical or otherwise, to talk about what they thought were the main aspects of what a scientist does (i.e., math, coding, experimentation, and answering scientific questions related to the world). Though many students brought up content areas of physics and topics from their astronomy-based classes, many had varying interest and dedication to those topics. Student 3 said "[they] love thinking about planets, stars, and galaxies, but [they] do not wish to be a scientist" because they felt science was a rapid process and there was pressure to perform in science settings. From a different perspective, student 8 said they "strive to understand the world as we currently know it and apply reason wherever possible."

4.4.3 Interest in Physics

Students were asked if they had an interest in studying physics in the future and many students answered with uncertainty. Students answered that they had difficulties or reservations about continuing their education in physics because of language gaps, feeling physics is not for them, and their struggles with physics content. Some students expressed a desire to continue, but in a more relaxed setting. Student 3 stated they would like to continue studying physics but "during [their] free time on a much more low-key basis." Student 6 also said "if [they] get a chance to learn about physics in the future, [they] would love to, but only if it [was] for leisure." Other students were considering becoming physics majors, but most were, again, on the fence

about continuing, like student 1 who said "[they are] not sure if [they are] going to major in physics, but learning the subject is super fun to [them]." Student 7 also said:

> "[They are] interested in studying physics in the future. [They are] very interested in astrophysics and space. [They are] not dead set on if it will be [their] major, for [they] would still like to explore other areas as a first-year student, but that doesn't mean [they] don't have interest in physics."

4.5 Physics Assessment

The paired samples t-test run for the physics assessment was used to gauge whether students learned about the topics taught during the lessons. There was a statistically significant difference in the scores for students from pre ($m = 0.64, 64\%$), to post ($m = 0.79, 79\%$) intervention, and the effect size was large ($t(7) = -2.59, p = .02,\ Cohen's\ d = .92$). This shows that students had a statistically significant increase in their knowledge about physics after participating in the lessons. Students' knowledge overtime was also examined using learning gains, comparing pre and post intervention scores to determine the amount of knowledge gained in comparison to what they already knew. By averaging student's pre and post intervention scores, there was an overall learning gain of .36, which is in the small to medium range from Hake's initial work on the measure (*10*). Table 9 details the paired-samples t-test run for identity and Table 10 details the descriptive statistics for identity.

DISCUSSION

The present study was designed to show how a set of interactive lessons on eight diverse women across the field of astrophysics influenced students' identity as a scientist, sense of belonging, and interest in physics while also teaching them about content concerning eight astrophysicists and introductory astrophysics concepts. It was hypothesized that identifying with the term "scientist", sense of belonging in the students' physics classrooms, students' interest in physics, and their knowledge of diverse voices in physics would all increase over the course of the intervention. These hypotheses were largely unsupported by the results and data collected from the participants. However, students were able to gain knowledge about the physics concepts taught to them, and there were mixed results on how students identify as scientists. Most subscales of both measures of sense of belonging and identity were not statistically significant. Qualitative analysis showed overall that students' ideas about sense of belonging, identity, and interest did not change over the course of the intervention, though were influenced by many concepts that are seen in prior literature.

5.1 Experimental Results

Of the correlations that were run, the performance subscale of the identity questionnaire was significantly correlated with higher scores on the physics assessments. This means that students who are confident in their abilities to perform on academic and scientific tasks are more likely to score higher on physics assessments. This is shown also in prior literature by Testa et al. (*50*) by researchers looking at introductory chemistry and physics classes attended by biology students and engineering students respectively. They looked at students' self-evaluations concerning their academic abilities and compared them to assessments on physics and chemistry to see how the two variables were related (*50*). They found that students' evaluation of their own

self-efficacy and self-confidence were indicators of performance on exams based on class content (*50*).

Recognition and interest, as measured by the identity questionnaire, were also significantly and positively correlated together. This shows that people who are recognized for the work that they do in physics are more likely to take an interest in physics. Research done by Jackson et al. (*51*) also looked at how interest is cultivated in STEM fields through the experiences of first-year undergraduate students after their first semester as science majors. They looked at how students' interest developed over their first semester and found that talking more about interests in science led students to have higher aspirations for science careers in the future (*51*). Social recognition from others was related to interest in science and career interests, but only for women, and not statistically significantly for men (*51*). In the future, it would be interesting to look at gender differences in studies like this, but due to small sample size, using demographic variables to find trends was not feasible or reliable. Jackson et al. also found in looking more at their demographic data that men with low initial science identity, similar to the majority of their participants who identified as women, also could benefit from social recognition as related to interest in science and career interests, though they did not have statistically significant findings for men (*51*).

In terms of sense of belonging overall, there was no support for a significant positive change in students' sense of belonging. Each subscale represented a different aspect of sense of belonging including perceived peer support, perceived class comfort, perceived isolation, and perceived faculty support. Perceived peer support decreased and perceived isolation increased, which seem to make sense together. However, faculty support increased and so did class comfort. These increases and decreases overtime were not significant and shows that two days of

intervention is not enough to alter students' sense of belonging in a significant way. Many students on their qualitative self-reflection said that they do feel as though they belong in their physics class, though the lessons did nothing to alter those feelings. It is reassuring to see that most students are feeling as though they belong in their classes already, which can be attributed to many factors already existing in their classroom. Many students said they felt like they belong because of their peers and the relationships they had formed in class which is supported by research by Lewis et al. (*4*), who looked at different factors for student belonging and how they related to gender as well. They found that many students look to see others like them and form relationships with them, so therefore students who have less peer support and less people who look like them in their classrooms would have less of a sense of belonging (*4*). Though these positive implications are there, students still mentioned struggling with the content of the class, which both contributes to their sense of belonging and impacts their identity as a scientist.

Another possible reason for a lack of significant results is the reliability found for certain subscales of the sense of belonging measure used. The reliability for the pre subscale of perceived class comfort was extremely low with a value of 0.2. This could be due to the sample size of the study as well as the measure design itself. In the future, using multiple or another measure for sense of belonging may be more reliable as well as gathering information from a larger sample size.

In terms of identity overall, there was little support for significant positive change in students' identification with the terms "scientist" and "physicist", and the support that was shown with quantitative data was not the same with the qualitative. On the quantitative measure of identity, there was a statistically significant increase in students feeling recognized as scientists, which reflects those students at least feel on some level that they are scientists.

However, on the qualitative measure, almost all students reported both pre and post that they did not identify as scientists and no students altered their stance from pre to post. Students said they did not feel a connection to the material and lacked motivation to learn the topic, which explains their lack of identification with the term "scientist." Students mentioned stereotypes they had of scientists, and if they feel they do not fit the mold they have in their heads, they will often say they are not scientists. If there are also negative stereotypes that are associated with parts of their identity, they also can have a more difficult time putting those aside and choosing to identify as a scientist. This is supported also by research collected by Lewis et al. (*4*) that reviewed many articles that showed salient stereotypes about the performance of women in academic settings in comparison to men can negatively impact women and their identification as scientists. They also found from their literature review that sense of belonging and identity were lowest for women when others in their community expressed that they thought men were better at math than women with the caveat that math ability was also a fixed trait (*4*). This research and findings show how important it is to recognize students as scientists and for stereotypes about abilities in STEM that focus on degrading women and minorities in physics as well as STEM fields in general need to be demolished.

The integration of diverse role models was meant to loosen any stereotypes associated with what a scientist looks like, but it seems as if the presentation of these role models did not fully work as intended. In the future, integrating more about the role models into the content of lessons and a prolonged set of lessons over the course of a set of weeks may help to increase identification with the term scientist. Also, having students do more self-driven portions or hands-on group work can also help to show students that they can do science. Teachers and instructors though must be careful to create activities which challenge students but are not overly

difficult such that students feel they cannot perform the task and then become even more separated from the terms “scientist” and “physicist”. Mauch of the literature reviewed for this project involved targeted interventions with hands-on portions designed to allow for students to take charge of their learning and education, which can help create a stronger bond between a student and their science identity.

Students had mixed reactions to studying physics in the future and seemed to be disinterested in interacting with physics concepts in a rigid setting like academia. Many students expressed a dislike for exams and struggles with the structure of assessment in their classes. Some students, on the other hand, were considering physics as a major or minor in their academic path. Students were diverse in ages and therefore were also diverse in class year and many who were farther along in their education expressed less of an interest in studying physics than students who were younger or at an earlier time in their academics. This intervention was intended to target students who were at the beginning of their physics education, but it still shows that future research should be done on different populations of students and for longer periods of time to see how interest develops and changes based on the content and pedagogy of their classrooms.

Many students cited that they enjoyed the conceptual content of their astrophysics classes, but did not like the timeline and assessment, as already stated. Students did not express much dedication in their interest, stating they liked the content, but lacking the motivation to continue with their interests, especially those who were older and therefore closer to anticipated graduation. Students were looking for a more low-key way of engaging with science that has less pressure to perform than a traditional college classroom. Creating programs in museums, articles which people without a science background can read, programs at community centers, and other

outreach activities can promote the de-stigmatization of physics related to both intimidation and who does science while also fostering interest. This can also allow students and people in general to have access to scientific information, which is the first part of being interested in anything: access and exposure. The research done by Bottia et al. (*43*) shows that the longer you expose high schoolers to science and physics, the more likely they will be to declare their major as science in the future. Their research looked at demographic breakdowns, as spoken about in the introduction, but found the largest factor in students continuing to study STEM related fields was their exposure to them prior to college (*43*).

Students were able to gain knowledge from the lessons about women and minorities in physics as well as physics concepts associated with their areas of research. Both the t-test and learning gains showed positive and significant gains in knowledge for students from pre to post. This leads to the conclusion that interventions like this can lead to comprehension and retention of physics topics. Just like the study done by Pleskovitch and Guy (*41*), there were positive learning gains from hands-on lessons and interactive classes.

5.2 Limitations

The most prominent limitation from this study is the population in diversity and in number. The low number of participants did not give an accurate representation of the target population (students early on in their undergraduate careers who are enrolled in introductory physics classes). Though that was the population pool for this research, many students were enrolled in introductory physics courses were in their later academic years and had decided their majors already. In the future, more populations (high school students, introductory physics at the college level (PHYS*110 instead of the introductory astronomy and first-year seminar courses), and even middle and elementary school students) can be looked at and compared to one another

to get a better picture of the different impact of these types of interventions. Many studies reviewed for this project were done on high schoolers and not many were done on college students, which means there is not much to directly compare this study with now, regardless of the sample not representing the target population. Many studies which involve college students either just assess learning gains (*41*) or are designed as case studies to gain knowledge about the population without implementing any type of intervention (*1*).

Due to logistical constraints, the present study was only able to offer two, one-hour lessons. This set of lessons could be expanded upon and be delivered over the course of weeks, creating an entire class period spanning about forty to fifty minutes for each woman in physics mentioned, their area of research, and a hands-on activity students could complete to learn more about the topic and about how scientists do research. There are great opportunities to create hands-on components to integrate computer programming, data readings, etc. Many of the present findings were not significant and very little changed over the course of the intervention. Allowing for the content and intervention to span over a longer period allows for stereotypes to have more time to be broken and students to progress through the different stages of development of sense of belonging and identity, while that is less feasible over the course of two ninety-minute periods. The lesson delivery was concise and condensed, and they were given outside of class time. Students have many barriers to attending programs outside of their classes (sports, homework, prior commitments, etc.), and future studies should allow for integration of the material into class time to encourage participation in the lessons themselves, but also give students easier access if they would like to participate in the research study as well.

At the end of each lesson, students were asked a series of discussion questions based on the physics content of the lessons as well as discussion questions centering around why it is

important to talk about women and minorities in physics. Many students were not responsive to these questions and did not want to answer in small groups or to the rest of the class of only eight students. It was extremely difficult to create a classroom atmosphere in two ninety-minute periods where students felt as though they could share their ideas out to others, even when doing the hands-on portions of the lessons. As already talked about, giving the intervention in the classroom over the course of weeks would be a better format for this material, but also give students the chance to form connections between their classmates, instead of working with students from two different classes which cover different topics and contain very different populations of students.

5.3 Future Work

Creating content about physics for a wider audience and allowing people to see physics in a less formal setting than in a classroom can help to gain interest in topics. Science and children's museums are great examples of this, but this can also include community centers and after-school programs. Allowing for content to be widely available to the public also reduces the stereotype that physics is difficult and if one is not a physicist working in a lab, it is inaccessible and not able to be understood. Creating more spaces for people to ask questions and be curious about science without the pressure or consequence of assessment also allows for a stress-free environment for learning to happen, which many students in this research stated they wanted. Even creating posters or flyers that are available for science teachers and professors around the world to show the diverse perspectives science holds.

Hands-on content allows students to engage in being the leaders in their own education and engage in doing science, which is arguably the best way to get students interested in anything: let them get creative with it and engage in it themselves. Allowing students to design

experiments, participate in gathering materials, choosing how to best display what they have learned, and allowing them to run wild with all the possibilities of science lets them explore and learn from their mistakes. These lessons served as a base to create more hands-on components for students to engage in when it comes to more abstract and larger systems that are not as easily hands-on as others. Allowing students to participate in demonstrations, not just the instructor performing them, allows students to discover things for themselves. Giving students a knowledge base to pull from prior to exploration also allows them to scaffold and use prior knowledge to create new associations to their experiments. It allows them to learn in an organic way, not one that is structured and forceful, but one driven by curiosity and a want to discover something new.

5.4 Conclusions

Though it did not have many significant findings, this project still has important educational implications for physics classes both at the undergraduate level and findings that can be applicable to other populations as well. In terms of how to format lessons and how to incorporate them into curriculum, it is best to create lessons that can be implemented into existing classes instead of outside of class. Giving students access to knowledge in a hands-on way, when they are already required to be in class, allows them to engage in the material with students they have already formed relationships with throughout class time while also not requiring them to attend set sessions outside of class that they may not be able to attend. In order to get students interested in research and science, they must also be exposed to diverse science as soon as possible. This requires teachers, professors, and administrators to be committed to the preparation required to provide students with hands-on lessons that also have connections to students' identities and cultures.

This imperative requires faculty to be committed to finding a balance between content and diversifying student experiences in the classroom. Making learning something that students can be in control of allows them to pick subjects and people in science that they are passionate about while still providing them with diverse learning opportunities. Oftentimes, tests are not the only way students are capable of showing their knowledge, and sometimes they are not the best ways to assess student learning. Being able to have activities that are student-led where they share findings with the class and collaborate with others also allows them to have experiences working in team settings, which are abundant in science and in innumerable other positions. Not only are they leaders in their own education, they can be champions of others, encouraging their group members to also explore science and think of themselves as scientists. The ultimate goal of this project was to make students feel they belong, feel they are scientists, and get them interested in not only physics but creating inclusive environments in and outside of their classrooms. All instructors should thrive to create diverse settings by getting their hands dirty, so to speak, in research about scientists and content which will excite students and help them to feel as though they are scientists because they are. They are the future of science. It's time teachers, faculty, and staff start emphasizing the importance of the future of science by seeing students for who they are: scientists.

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TABLES

Table 3: Pre and Post Mean for Quantitative Measures Correlations				
Variable 1	**Variable 2**	**Pearson's r**	**Lower CI**	**Upper CI**
PRE SB PS MEAN	POST SB PS MEAN	0.8*	0.22	0.96
PRE SB CC MEAN	POST SB CC MEAN	0.46	-0.36	0.88
PRE SB PI MEAN	POST SB PI MEAN	0.93***	0.66	0.99
PRE SB FS MEAN	POST SB FS MEAN	0.74*	0.08	0.95
PRE P SSI	POST P SSI	0.77*	0.15	0.96
PRE C SSI	POST C SSI	0.86**	0.39	0.97
PRE R SSI	POST R SSI	0.95***	0.74	0.99
PRE I SSI	POST I SSI	0.95***	0.73	0.99
PRE Physics Mean	POST Physics Mean	0.5	-0.31	0.89

PRE and POST denote which test was done, CI = Confidence Interval (95%), SB = Sense of Belonging Measure, PS = Perceived Peer Support, CC = Perceived Class Comfort, PI = Perceived Isolation, FS = Perceived Faculty Support, SSI = Student Science Identity Measure, P = Performance, C = Competence, R = Recognition, I = Interest, Physics = Quantitative Physics Assessment

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 4: Significant Correlations Excluding Matched Quantitative Correlations				
Variable 1	**Variable 2**	**Pearson's r**	**Lower CI**	**Upper CI**
PRE SB PI MEAN	POST SB PS MEAN	-0.82*	-0.97	-0.27
PRE SB PI MEAN	POST SB FS MEAN	-0.83*	-0.97	-0.29
POST SB PS MEAN	POST SB CC MEAN	0.77*	0.13	0.95
POST SB PS MEAN	POST SB PI MEAN	-0.78*	-0.96	-0.16
POST SB PS MEAN	POST SB FS MEAN	0.76*	0.12	0.95
POST SB CC MEAN	POST SB FS MEAN	0.75*	0.1	0.95
POST SB PI MEAN	POST SB FS MEAN	-0.83*	-0.97	-0.3
PRE P SSI	PRE C SSI	0.92**	0.63	0.99
PRE P SSI	POST C SSI	0.83*	0.31	0.97
PRE P SSI	PRE R SSI	0.78*	0.16	0.96
PRE P SSI	POST Physics Mean	0.84**	0.32	0.97
POST P SSI	PRE C SSI	0.87**	0.44	0.98
POST P SSI	POST C SSI	0.96***	0.8	0.99
POST P SSI	PRE R SSI	0.88**	0.45	0.98
POST P SSI	POST R SSI	0.88**	0.48	0.98
POST P SSI	PRE I SSI	0.73*	0.04	0.95
POST P SSI	POST I SSI	0.74*	0.07	0.95
POST P SSI	POST Physics Mean	0.71*	0.01	0.94
PRE C SSI	PRE R SSI	0.87**	0.41	0.98
PRE C SSI	POST R SSI	0.79*	0.18	0.96
PRE C SSI	POST Physics Mean	0.79*	0.2	0.96
POST C SSI	PRE R SSI	0.93***	0.66	0.99
POST C SSI	POST R SSI	0.91**	0.58	0.98
POST C SSI	PRE I SSI	0.79*	0.19	0.96
POST C SSI	POST I SSI	0.78*	0.17	0.96
PRE R SSI	PRE I SSI	0.84**	0.32	0.97
PRE R SSI	POST I SSI	0.83*	0.3	0.97
POST R SSI	PRE I SSI	0.81*	0.25	0.96
POST R SSI	POST I SSI	0.89**	0.51	0.98

PRE and POST denote which test was done, CI = Confidence Interval (95%), SB = Sense of Belonging Measure, PS = Perceived Peer Support, CC = Perceived Class Comfort, PI = Perceived Isolation, FS = Perceived Faculty Support, SSI = Student Science Identity Measure, P = Performance, C = Competence, R = Recognition, I = Interest, Physics = Quantitative Physics Assessment

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 5: Sense of Belonging Paired Samples t-test						
					95% CI for Cohen's d	
Measure 1	**Measure 2**	**t**	**df**	**Cohen's d**	**Lower**	**Upper**
PRE SB PS Mean	POST SB PS Mean	1.51	7	0.53	-∞	1.14
PRE SB CC Mean	POST SB CC Mean	-0.43	7	-0.15	-∞	0.44
PRE SB PI Mean	POST SB PI Mean	-1.11	7	-0.39	-∞	0.23
PRE SB FS Mean	POST SB FS Mean	-1.02	7	-0.36	-∞	0.25

PRE and POST denote which test was done, CI = Confidence Interval (95%), SB = Sense of Belonging Measure, PS = Perceived Peer Support, CC = Perceived Class Comfort, PI = Perceived Isolation, FS = Perceived Faculty Support

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 6: Sense of Belonging Descriptive Statistics					
Measure	**N**	**Mean**	**SD**	**SE**	**Coefficient of Variation**
PRE SB PS Mean	8	2.69	0.83	0.29	0.31
PRE SB CC Mean	8	2.42	0.64	0.23	0.27
PRE SB PI Mean	8	1.91	0.55	0.19	0.29
PRE SB FS Mean	8	2.09	1.38	0.49	0.66
POST SB PS Mean	8	2.94	1.09	0.39	0.37
POST SB CC Mean	8	3.09	0.98	0.35	0.32
POST SB PI Mean	8	1.54	0.45	0.16	0.29
POST SB FS Mean	8	1.85	1.13	0.4	0.61

PRE and POST denote which test was done, CI = Confidence Interval (95%), SB = Sense of Belonging Measure, PS = Perceived Peer Support, CC = Perceived Class Comfort, PI = Perceived Isolation, FS = Perceived Faculty Support

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 7: Paired Samples t-test for Student Science Identity						
					95% CI for Cohen's d	
Measure 1	**Measure 2**	**t**	**df**	**Cohen's d**	**Lower**	**Upper**
PRE P SSI	POST P SSI	-1.12	7	-0.4	-∞	0.22
PRE C SSI	POST C SSI	-0.59	7	-0.21	-∞	0.39
PRE R SSI	POST R SSI	-2.05	7	-0.72**	-∞	-0.04
PRE I SSI	POST I SSI	1.44	7	0.51	-∞	1.11

PRE and POST denote which test was done, CI = Confidence Interval (95%),
SSI = Student Science Identity Measure,
P = Performance, C = Competence, R = Recognition, I = Interest,
* $p < .05$, ** $p < .01$, *** $p < .001$

Table 8: Descriptive Statistics for Student Science Identity					
Measure	**N**	**Mean**	**SD**	**SE**	**Coefficient of Variation**
PRE P SSI	8	3.1	0.92	0.32	0.3
POST P SSI	8	3.35	0.96	0.34	0.29
PRE C SSI	8	3.65	0.91	0.32	0.25
POST C SSI	8	3.75	0.96	0.34	0.25
PRE R SSI	8	2.47	1.45	0.51	0.59
POST R SSI	8	2.84	1.61	0.57	0.57
PRE I SSI	8	3.71	0.67	0.24	0.18
POST I SSI	8	3.5	0.99	0.35	0.28

PRE and POST denote which test was done, CI = Confidence Interval (95%),
SSI = Student Science Identity Measure,
P = Performance, C = Competence, R = Recognition, I = Interest,
* $p < .05$, ** $p < .01$, *** $p < .001$

Table 9: Paired Samples t-test for Physics Assessment						
					95% CI for Cohen's d	
Measure 1	**Measure 2**	**t**	**df**	**Cohen's d**	**Lower**	**Upper**
PRE Physics Mean	POST Physics Mean	-2.59	7	0.02	-∞	-0.19
PRE Physics Percent	POST Physics Percent	-2.59	7	0.02	-∞	-0.19

PRE and POST denote which test was done, CI = Confidence Interval (95%),
Physics = Quantitative Physics Assessment
Physics Percent: Quantitative Scores as Percentages
* $p < .05$, ** $p < .01$, *** $p < .001$

Table 10: Descriptive Statistics for Pre and Post Physics Assessment					
Measure	**N**	**Mean**	**SD**	**SE**	**Coefficient of variation**
PRE Physics Mean	8	0.64	0.19	0.07	0.3
POST Physics Mean	8	0.79	0.14	0.05	0.18
PRE Physics Percent	8	63.63	19.09	6.75	0.3
POST Physics Percent	8	79.35	14.28	5.05	0.18

PRE and POST denote which test was done, CI = Confidence Interval (95%),
Physics = Quantitative Physics Assessment
Physics Percent: Quantitative Scores as Percentages
* $p < .05$, ** $p < .01$, *** $p < .001$

APPENDICES

8.1 Recruitment Speech and Email

The same script will be used as sent in the email to students.

Hello everyone,

My name is Alexis Pleskovitch, and I am a senior here at Allegheny. I am a physics and psychology double major, and I am doing a project on physics education where I teach students about cool women and minorities in physics. I am asking your class to consider participating in my study. My study has been approved by the Institutional Review Board (IRB) of Allegheny college and participation in this study is completely voluntary. In order to participate in the study, you would come to two sessions, each spanning 80-90 minutes. Again, participation in this study is voluntary.

If you are interested in participating, data collection will take place on [insert date and time] and we will be in [insert room and building here]. There will also be a set of sessions on [insert data and time] and we will be in [insert room and building here]. Please complete the interest form here with your date/time preference: [insert link].

If you have any questions, you can email me (pleaskovitcha@allegheny.edu), my advisors (sstanger@allegheny.edu) and (apoynor@allegheny.edu), or the institutional review board (IRB@allegheny.edu.)

Thank you, and I hope you all have a great rest of your day!

8.2 Informed Consent

Informed Consent Form

Modification of "Scientist": The Intersection Between Physics Education and Sense of Belonging

Allegheny College

Departments of Physics and Psychology

Purpose of Research: The purpose of this study is to examine how interactive lessons on minorities in physics can influence sense of belonging, identity development, and interest along with comprehension and retention of astrophysics and astronomy-based lessons.

Method/Procedure: I understand that I will be asked to participate in a set of interactive lessons about women and minorities in physics or asked to read resources based on women in physics and construct a response to those readings. I will also be asked to answer questions on quizzes about the lessons/readings being taught. I will also be asked to fill out surveys and answer open ended questions about sense of belonging, identity, and interest in physics.

Length of Participation: I understand that the lessons and all other parts of the study will take place outside of the classroom. The study will take place over two ninety-minute periods. Data collection will take up 30 minutes of each period. Lessons will take up 40 minutes of the allotted time. 10 minutes will be set aside each day for questions about content, the research study, and any other topics that may arise. These periods will take place across two days, and I will be asked to complete surveys before and after I participate in the lessons.

Risks to the Individual: I understand that there will be no more risk other than what is normally experienced in everyday life. Because this is in-person research, the student researcher will follow the current Allegheny College COVID-19 policies.

Benefits of the Research: Research is designed to benefit society by gaining new knowledge. This research will give insight into physics education and help students feel more comfortable in science classrooms. By participating in this research study, you may learn new things about physics in a hands-on manner.

Compensation: I understand that by participating in both sessions of this study, I will receive compensation by way of extra credit in my FS or Introductory Astronomy class that equates to a 2% increase in my overall course grade. I will also be able to opt into a raffle for $5 gift cards from local Meadville businesses at the end of the study.

Confidentiality, Recording Information, and Data Security: I understand that responses to all of the portions of this research will be kept confidential. I will be given an ID number at random for the duration of the study in order to keep the data for each student together. Data collection will be done through Google Forms. If needed, paper copies will be provided. Hard copies will be collected in a secure case, transported, and stored in a locked filing cabinet in a locked office in Carnegie Hall at Allegheny College. Data collected through Google Forms will be kept in a password protected Google Drive on a password protected computer. The only people who will

have access to the data will be Alexis Pleskovitch (the student researcher) and Dr. Sarah Stanger (research advisor). The data may be used in reports, publications, and presentations of the research project, but the association of your child to the data will be kept confidential. No names or any identifiers will be shared on any publication or report.

Voluntary Nature of Participation: I understand that I do NOT have to participate in this research project. Furthermore, I may choose to withdraw my participation at any time without penalty and without impact on my performance in my physics course. I understand that I may skip any individual questions that I do not wish to answer, and they may choose not to participate in any part of the study without being questioned.

Results of Research Project: I understand that I am entitled to a copy of the results once this study is completed. Once the study is completed, the students will be given a debriefing form that will outline how to receive the results of the project by email.

Contact Information: If I have any questions about this research project, I can contact Alexis Pleskovitch at pleskovitcha@allegheny.edu or the research advisor, Dr. Sarah Stanger at sstanger@allegheny.edu. If I have questions or concerns about the treatment of research participants in this IRB-approved project, I can contact the Chair of the Allegheny Institutional Review Board (IRB) at IRB@allegheny.edu.

I understand that my signature(s) below indicate(s) that I am of 18 years of age, and I have received a copy of this informed consent form. I have carefully read and understood the information on this form and all of my questions thus far have been answered.

Name: _____

Signature: _____ Date: _____

8.3 Sense of Belonging (SB) Instrument

Directions: Read each underlined statement and reflect on whether that item is true or untrue for you and your experience in <u>your physics class this year.</u> You are able to skip any question you are not comfortable with answering. Circle only one answer for each statement.

<u>I could contact another student from class if I had a question about an assignment</u>

completely true mostly true equally true and untrue mostly untrue completely untrue

<u>Other students are helpful in reminding me when assignments are due or when tests are approaching</u>

completely true mostly true equally true and untrue mostly untrue completely untrue

<u>If I miss class, I know students who I could get the notes from</u>

completely true mostly true equally true and untrue mostly untrue completely untrue

<u>I have met with classmates outside of class to study for an exam</u>

completely true mostly true equally true and untrue mostly untrue completely untrue

<u>I discuss events which happen outside of class with my classmates</u>

completely true mostly true equally true and untrue mostly untrue completely untrue

<u>I invite people I know from class to do things socially</u>

completely true mostly true equally true and untrue mostly untrue completely untrue

<u>I have developed personal relationships with other students in class</u>

completely true mostly true equally true and untrue mostly untrue completely untrue

<u>I have discussed personal matters with students who I met in class</u>

completely true mostly true equally true and untrue mostly untrue completely untrue

<u>I feel comfortable seeking help from a teacher before or after class</u>

completely true mostly true equally true and untrue mostly untrue completely untrue

I feel comfortable asking a teacher for help if I do not understand the course-related material

completely true mostly true equally true and untrue mostly untrue completely untrue

If I had a reason, I would feel comfortable seeking help from a teacher outside of class time

completely true mostly true equally true and untrue mostly untrue completely untrue

I feel comfortable talking about a problem with faculty

completely true mostly true equally true and untrue mostly untrue completely untrue

I feel comfortable asking a teacher for help with a personal problem

completely true mostly true equally true and untrue mostly untrue completely untrue

Speaking in class is easy because I feel comfortable

completely true mostly true equally true and untrue mostly untrue completely untrue

I feel comfortable volunteering ideas or opinions in class

completely true mostly true equally true and untrue mostly untrue completely untrue

I feel comfortable contributing to class discussions

completely true mostly true equally true and untrue mostly untrue completely untrue

I feel comfortable asking a question in class

completely true mostly true equally true and untrue mostly untrue completely untrue

It is difficult to meet other students in class

completely true mostly true equally true and untrue mostly untrue completely untrue

No one in my classes knows anything personal about me

completely true mostly true equally true and untrue mostly untrue completely untrue

I rarely talk to other students in my classes

completely true mostly true equally true and untrue mostly untrue completely untrue

I know very few people in my classes

completely true mostly true equally true and untrue mostly untrue completely untrue

I feel that a faculty member would take the time to talk to me if I needed help

completely true mostly true equally true and untrue mostly untrue completely untrue

I feel that a faculty member would be sympathetic if I was upset

completely true mostly true equally true and untrue mostly untrue completely untrue

I feel that a faculty member would be sensitive to my difficulties of I shared them

completely true mostly true equally true and untrue mostly untrue completely untrue

I feel that a faculty member really tried to understand my problem when I talked about it

completely true mostly true equally true and untrue mostly untrue completely untrue

8.4 Student Science Identity Questionnaire (SSI)

Directions: read each underlined statement and reflect on whether you agree or disagree with that statement based on <u>your experience in your physics class this year.</u> You are able to skip any question you are not comfortable with answering. Circle only one answer for each statement.

<u>I think I did well in science classes.</u>

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

<u>I am able to get a good grade in science subjects.</u>

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

<u>I am able to complete my science homework.</u>

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

<u>I am proficient in using tools and operating apparatus in experiments.</u>

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

<u>I can smoothly conduct a science inquiry activity.</u>

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

<u>I can get a good grade in science and technology competitions.</u>

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

<u>I think I am good at science.</u>

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

<u>I can understand scientific laws and principles well.</u>

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

<u>I am able to use science to explain the nature phenomena in daily life.</u>

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I believe I can learn a lot of knowledge in science classes.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I believe I will do well in science.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I believe I can learn even the hardest parts of scientific knowledge if I try.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I think of myself as a science person.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

My classmates recognize me as a science person.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

My science teachers recognize me as a science person.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

My family and friends recognize me as a science person.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I will learn more about science knowledge through a variety of sources.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I like to participate in various scientific activities.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I think the science knowledge taught in my classes is important in the real world.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I like the science equipment in my science classes.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I like to attend classes that are related to science.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I am interested in careers that are related to science.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I plan to pursue science careers in the future.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

I would feel comfortable talking to people who work in science careers.

Strongly Disagree Somewhat Disagree Neutral Somewhat Agree Agree Strongly

8.5 Open Ended Response Items and Demographics
Demographics Questions:

Age:_____

Race:_____

Gender Identity: _____

Directions: Answer the open-ended questions with full sentences in order to reflect on your experiences in <u>your physics class this year.</u>

Do you feel as though you as a student belong in your physics class? Why?

Do you see yourself as a scientist? Why or why not?

Are you interested in studying physics in the future? Why or why not?

8.6 Physics Quiz/Assessment

Describe astrophysics in your own words:

Name 3 things that astrophysicists study:

Who was the scientist we talked about who worked at VIRGO?

A. Annie Easley
B. Wanda Díaz Merced
C. Katherine Johnson
D. Chanda Prescod-Weinstein

What are VIRGO and LIGO? What are they used for?

What is a pulsar?

A. Pulsating signals from black holes
B. A type of planet that emits radio waves in the form of pulses we can detect
C. Sound waves that are emitted from stars which "pulse"
D. Type of star that emits pulses like a lighthouse and we can detect the beams when it rotates

Who was the first woman to serve as president of the institute of physics?

A. Katherine Johnson
B. Mae Jemison
C. Jocelyn Bell Burnell
D. Andrea Ghez

Which of these scientists uses sonification for her gravitational wave research?

A. Wanda Díaz Merced
B. Margaret Hamilton
C. Jocelyn Bell Burnell
D. Mae Jemison

What is sonification?

A. A data packet which is transferred through the use of sound to other computers
B. Using software which converts physical data into sounds which can then be analyzed
C. A process which converts sounds into physical data which can be analyzed
D. Collecting data with the use of an ultra-sensitive microphone which picks up noise

When the big bang happened, how fast did the universe expand?

A. Faster than the speed of light
B. The universe has always been the same size, it never expanded
C. The speed of light
D. Slower than the speed of light

Why can spacetime travel/expand faster than the speed of light?

A. Because the limit of the speed of light only applies to things which are in spacetime, not spacetime itself
B. Because everything can travel faster than the speed of light, there is no rule that states something cannot
C. Spacetime cannot expand at any rate, it has always been the same size
D. Because time is a construct that only exists on Earth

Which of these scientists wrote *The Disordered Cosmos*?

A. Annie Easley
B. Wanda Díaz Merced
C. Margaret Hamilton
D. Chanda Prescod-Weinstein

Who was the first African American woman to go to space?

A. Mae Jemison
B. Katherine Johnson
C. Andrea Ghez
D. Jocelyn Bell Burnell

Name one thing astronauts get training in before they go to space:

What can be used to simulate zero gravity for astronauts?

A. Planes at very high speeds
B. We cannot reliably simulate zero gravity
C. Chairs which spin at very high speeds
D. Wind tunnels

Who helped to calculate John Glenn's launch and landing during the space race?

A. Margaret Hamilton
B. Katherine Johnson
C. Chanda Prescod-Weinstein
D. Annie Easley

What does a HR or Hertzsprung-Russell Diagram show? What are the axes?

What is the classification spectrum for stars?

A. MKOBFAG
B. GKFMOBA
C. OBGKMAF
D. OBAFGKM

If Mercury is in between Earth and the Sun, it is said to be in:

A. Inferior conjunction
B. Superposition
C. Superior conjunction
D. Opposition

Which one of these scientists did NOT work on the Apollo mission?

A. Chanda Prescod-Weinstien
B. Margaret Hamilton
C. Katherine Johnson
D. Annie Easley

Given that the distance between the Sun and the Earth is 1 AU (astronomical unit) and the distance between the sun and Jupiter is 5.2 AU, what is the distance between the earth and Jupiter when Jupiter is in superior conjunction? Draw a picture and show your work.

Name two different coding languages:

Which scientist worked to develop a rocket launcher for the Centaur project?

A. Andrea Ghez
B. Katherine Johnson
C. Chanda Prescod-Weinstein
D. Annie Easley

Which scientist coined the term software engineering?

A. Margaret Hamilton
B. Jocelyn Bell Burnell
C. Wanda Díaz Merced
D. Mae Jemison

8.7 Lesson Plans

8.7.1 Lesson Plans # 1 and 2

Total Time for Lesson: 80-90 minutes
Topic: #1 Consent, Surveys, Introduction
Topic: #2 Astrophysics Overview

Lesson Plan # 1

Part of Lesson Plan	Components and Details
Physics Concepts:	N/A
Women Physicist for the Lesson:	N/A
Expectations for the Lesson:	Students will ● Complete psychological surveys for sense of belonging, interest, and identity, and answer open ended questions about the topics listed. ● Listen to criteria for the study and ask questions about the consent process if needed
Learning Goals:	SWBAT: ● Identify and answer questions about sense of belonging, identity, and interest in physics ● Fill out a pre-test about physics concepts to the best of their ability ● Ask questions about the research process and fill out consent forms
NGSS Standards:	N/A
Core Questions to ask:	N/A
Supplies and Materials:	● Technology-based surveys ● Pens and pencils
Groups and Individual Activities:	● Fill out questionnaires individually ● Be able to hold a discussion about important concepts if we have time ● Engage with the researcher on questions regarding consent process and other questions about the surveys and questionnaires and the research process

Lesson Plan # 2

Part of Lesson Plan	Components and Details
Physics Concepts:	Astrophysics ● Pulsars, Black Holes, Cosmology ● Simple calculations with Newton's Laws ● Conceptual astrophysics questions
Women Physicist for the Lesson:	● Jocelyn Bell Burnell ● Wanda Díaz-Merced ● Chanda Prescod-Weinstein ● Andrea Ghez
Expectations for the Lesson:	● Participate in group discussions of pulsars, black hole and gravitational observatory detection, and theoretical astrophysics ● Complete hands-on activity for pulsar identification/Virgo data simulation ● Actively listen and participate in lecture ● Retain information and learn about women in physics
Learning Goals:	SWBAT: ● Identify astrophysical concepts concerning pulsars, black hole and gravitational observatory detection, and theoretical astrophysics ● Apply conventional mechanics to math problems involving astrophysics (plug and chug, on the level of high school mathematics) ● Discuss concepts relating to space and representation of women and minorities in astrophysics
NGSS Standards:	HS standards for: ● Forces and interactions ● Energy ● Space systems
Core Questions to ask:	● Accomplishments of Jocelyn Bell Burnell, Wanda Díaz-Merced, Chanda Prescod-Weinstein ● Basics about astrophysics broadly ● Interdisciplinary aspects of astrophysics ● Conceptual questions about pulsars, black holes, and theoretical cosmology ● Mathematical plug and chug calculations which relate to astrophysics
Supplies and Materials:	● Materials for demo ○ Pulsar and gravitational wave detection simulation

	○ Graph paper/printouts of gravitational wave data/pulsars ○ Have students work together to identify and discuss ● Worksheets for discussions ○ Guided notes based off of lecture ● pens/paper or laptops depending on the school's resources
Groups and Individual Activities:	● Group discussions about black holes ● Group discussions on cosmology ● Group discussions about pulsars ● Individual listening to lecture component about astrophysics and women in physics ● Work in groups or individually on the hands-on demonstration

Timeline for Class Instruction:

Time Interval:	Activity:	Notes:
5 minutes-7 minutes	Introduction to Research and Consent	● Explain consent process ● Explain overview of research ● Have students complete consent forms ● **Consent forms should be given at least a week in advance to parents
15-20 minutes	Physics Test	● Have students' complete physics test individually
15 minutes	Psychological evaluations	● SB instrument ● SSI instrument ● Open ended questions
5 minutes	Wrap up	● Wrap up, ask questions, short group discussions on topics of sense of belonging and identity in physics
2 minutes	Introduction to Lessons	● Go over expectations ● Group students together ● Introduce broad topics
15 minutes	Lecture	● Traditional lecture component about women in physics and basic concepts ● Overview of pulsars, cosmology, and gravitational waves as well as astrophysics as a whole

15 minutes	Hands-On Demo	● Students examine space concepts with hands-on activities which look at gravitational waves and pulsars ● Learning about how we identify pulsars and gravitational waves in an activity with real data that they have to pick out the important data which shows pulsars/grav. waves
15 minutes	Group Discussion	● Talk with group members about hands-on portion of the lesson ○ What was enjoyable about picking out data? Did you struggle to identify the different data points? Why? ● Group discussion worksheet questions to look at comprehension of topics and also to think abstractly about physics concepts and implications of astrophysics in the future ● Share out with to other groups to create community among students and shared knowledge

8.7.2 Lesson Plans 3 and 4

Total Time for Lesson: 80-90 minutes
Topic: #3 Space Race
Topic: #4 Debriefing, Post-Test, Wrap Up

Lesson Plan # 3

Part of Lesson Plan	Components and Details
Physics Concepts:	Astrophysics ● Space travel and the space race ● Conceptual astrophysics questions on space travel
Women Physicist for the Lesson:	● Katherine Johnson ● Mae Jemison ● Annie Easley ● Margaret Hamilton
Expectations for the Lesson:	● Participate in group discussions of space travel and the history of humans going into space ● Complete hands-on activity of HR Diagram Creation ● Discuss computer programming related to physics and science in general ● Also, hands on graphing of main sequence stars ● Actively listen and participate in lecture ● Retain information and learn about women in physics
Learning Goals:	SWBAT: ● Identify astrophysical concepts concerning space travel and the mathematics behind launch and landing ● Apply conventional mechanics to math problems involving astrophysics (plug and chug, on the level of high school mathematics), more about space travel/escape velocity of planets ● Discuss concepts relating to space and representation of women and minorities in astrophysics
NGSS Standards:	HS standards for: ● Forces and interactions ● Energy ● Space systems ● Waves and Electromagnetic Radiation ● Engineering Design
Core Questions to ask:	● Accomplishments of Katherine Johnson and Mae Jemison ● Basics about astrophysics broadly, but also as they are

	integrated into the space race ● Interdisciplinary aspects of astrophysics ● Conceptual questions about space travel ● Mathematical plug and chug calculations which relate to astrophysics/space travel ● Benefits to computer science and programming in physics and implications of interdisciplinary science ● Applications to physics ○ Space missions!
Supplies and Materials:	● Materials for demo ○ Print outs, glue sticks, graphing stars on the main sequence ○ Note cards with groups to assign roles for space mission think through ● Worksheets for discussions ● pens/paper or laptops depending on the school's resources
Groups and Individual Activities:	● Group discussions about space travel and space missions ● Group discussion on computer science applications to physics ● Individual listening to lecture component about astrophysics and women in physics ● Work in groups or individually on the hands-on demonstration

Lesson Plan # 4

Part of Lesson Plan	Components and Details
Physics Concepts:	N/A
Women Physicist for the Lesson:	N/A
Expectations for the Lesson:	Students will ● Complete psychological surveys for sense of belonging, interest, and identity, and answer open ended questions about the topics listed. ● Listen to debriefing and ask questions about research and resources for after interventions
Learning Goals:	SWBAT: ● Identify and answer questions about sense of belonging, identity, and interest in physics ● Fill out a post-test about physics concepts to the best of their ability ● Ask questions about debriefing process and research
NGSS Standards:	N/A
Core Questions to ask:	N/A
Supplies and Materials:	● Paper or technology-based surveys depending on classroom resources ● Pens and pencils
Groups and Individual Activities:	● Fill out questionnaires individually ● Be able to hold a discussion about important concepts if we have time ● Engage with the researcher on questions regarding debriefing process and other questions about the surveys and questionnaires if applicable

Timeline for Class Instruction:

Time Interval:	Activity:	Notes:
2 minutes	Introduction	● Go over expectations ● Group students together ● Introduce broad topics
15 minutes	Lecture	● Traditional lecture component about women in physics and basic concepts ● Overview of space travel and history of the space race ● Mathematical concept of escape velocity ● Integration of main sequence and lifetimes of stars ● Planets in conjunction and opposition and how orbits of planets work ● Overview of computer programming and applications in physics
15 minutes	Hands-On Demo	● Students examine space travel and the space race with a simulation of a space mission/space travel ● Students also graph out star placement on a main sequence to understand the lifetimes of stars
15 minutes	Group Discussion	● Talk with group members about hands-on portion of the lesson/lecture ○ Reflect on the components of a successful space mission ○ What are the most important roles and aspects of creating a successful mission? ○ How does coding interact with physics? ○ What are the possible interactions you can see? ● Group discussion worksheet questions to look at comprehension of topics and also to think abstractly about physics concepts and implications of space travel in the future ● Share out with to other groups to create community among students and shared knowledge
2 minutes	Introduction	● Transition to Data Collection

15 minutes	Physics Test	● Have students' complete physics test individually (posttest and pretest are the same)
15 minutes	Psychological evaluations	● SB instrument ● SSI instrument ● Open ended questions
15 minutes	Wrap up	● Debriefing form ● Ask questions about debriefing ● Fill out consent to be interviewed? ● Pull some kids aside afterward to answer a few extra questions about sense of belonging, interest, and identity

8.8 Debriefing Form

Research Participation Debriefing Form

Modification of "Scientist": The Intersection Between Physics Education and Sense of Belonging

Allegheny College

Departments of Physics and Psychology

Thank you for participating in this research, for welcoming me into your classroom, and allowing me to teach you about the work of women and minorities in physics. Please read this form and fill out the attached page once you have finished reading it and have asked any clarifying questions you may have.

Purpose of Research:

There aren't many people who go into physics in higher education, and only a small portion of people who do go on to study physics in college are women and minorities. The lack of representation in the field of physics is part of this problem. These lessons were designed to give you role models who don't fit society's definition of who a physicist is and show you a bit about how they made their discoveries and show you that you yourself are a scientist (even if you don't feel like one).

A lot of times, because people don't see role models in the fields they want to pursue, they assume that it isn't a place for them. This, however, is not the case. People also normally assume that "physics is difficult" and while this can be true at times, all things that you learn are difficult at times. This stereotype often stops people from pursuing physics even when they are interested in it. The same idea holds true for other science and math courses.

This research wanted to look at how seeing positive role models and learning about their discoveries in a hands-on way could change your feelings of belonging in the classroom (whether or not you feel welcomed, accepted, and appreciated when you are doing science). It also was designed to look at how your identity as a scientist changed after the lessons (whether you feel like you are a scientist right now when you are in class). Lastly, you were asked questions about how much you enjoy physics, and the research was designed to see if that changed after the lessons were taught.

You also took quizzes as a part of this research to gauge how much you learned about the people and the science that was taught. These scores show us how much you learned and how having hands-on projects helped you learn.

Confidentiality:

Everything that you wrote down for this research project will be kept secure and confidential. The copies of your responses will be kept in a locked cabinet in a locked office in Carnegie Hall (the psychology building on Allegheny College's campus) if they were done on paper, and if they were done on Google Forms, they are on a password protected Google Drive on a password protected computer. The only people who will ever see your responses are Alexis Pleskovitch (the researcher) and her advisor, Dr. Sarah Stanger in the psychology department. You were given an ID number at the beginning of this research to keep your name and any identifying information off of your responses, that way I won't even know specifically who

wrote what in response to the questions I asked. This ID number was just to keep track of each document and make sure your papers stay with your papers and don't get mixed up with everyone else's in the class. This ID number is assigned at random, so I don't know whose number is whose.

Important Information:

If you want to learn more about different really cool scientists, sense of belonging, or identity, these are a few really great books and websites that you can visit to learn more.

Books:

- Women in Science: 50 Fearless Pioneers Who Changed the World by Rachel Ignotofsky
    - 50 different stories about women who have done really cool science throughout their lives. Each story has nice illustrations, fun facts, and different science facts as well as information about the lives of these amazing women

Websites:

- https://obamawhitehouse.archives.gov/women-in-stem
    - A list of really cool women in STEM fields who have done groundbreaking research in their fields
- https://daily.jstor.org/forgotten-and-famous-women-of-stem/
    - A bunch of really short articles about different women in STEM and their accomplishments
- https://www.womenshistory.org/education-resources/topics/stem
    - Another big, long list of short articles about women in STEM that you can scroll through and have a lot of pictures with them

Contact Information:

If I have any questions about this research project, I can contact Alexis Pleskovitch at pleskovitcha@allegheny.edu or the research advisor, Dr. Sarah Stanger at sstanger@allegheny.edu. If I have questions or concerns about the treatment of research participants in this IRB-approved project, I can contact the Chair of the Allegheny Institutional Review Board (IRB) at IRB@allegheny.edu.

Consent to Use Quotes:

After thinking about everything you've written for this study, if you are okay with your response being quoted in my research (my senior project, posters, or future publications), you can sign the first statement on the next page. Your name has not been on any of the data we have collected, but you were given an ID number. That ID number and any other identifying information will not be included in quotations. Whether you say yes or no has no bearing on my research, my results, or your participation in the study. This is completely voluntary and your choice.

By signing this form, I know that

1. My responses that I gave to any of the research questions could appear as a direct quote in a scientific paper, on a poster, or in other academic publications.
2. I understand that my name, ID number, and any identifying information will not be present in this quote.
3. My decision to be quoted in the research documents was my choice and my choice alone.
4. No matter if I sign below or not, my participation in the study is not affected. My grades are not affected, and there will be no consequences or rewards for signing below.

Name: _____

Signature: _____ Date: _____

By providing my email address below, I am indicating that I would like to participate in the raffle for $5 gift cards for local businesses in Meadville. My email address will only be used to notify me that I have received a prize, if I win the raffle. My email address will not be shared with anyone.

Email: _____

By providing my email address below, I am signifying that I would like to receive the results of this study when they are finished being collected. No matter if I list my email below, my participation in the study is not affected. My grades are not affected, and there will be no consequences or rewards for signing below. My email address will not be shared with anyone and will only be used to send the results of the study once they are finalized.

Email: _____

8.9 Approval Form

myALLEGHENY POWERED BY GOOGLE

Alexis Pleskovitch <pleskovitcha@allegheny.edu>

Permission to Run Study
2 messages

Alexis Pleskovitch <pleskovitcha@allegheny.edu> Mon, Nov 14, 2022 at 8:03 AM
To: Jamie Lombardi <jalombar@allegheny.edu>

Hi Dr. Lombardi,

In order for me to do data collection and submit my IRB, I just need confirmation from you about what we've talked about to give to the IRB board so it's in writing. We are planning to ask your section of Physics 021 and your section on FS 101 to participate in data collection. For compensation for participation, students will be given 2% of extra credit. They will also be able to opt into a raffle for $5 gift cards to local businesses. If they do not want to participate in data collection, but they still would like to receive extra credit, they can do the alternative assignment of readings and a paper, which will be equitable to the time for students to participate in the study. Students who do not participate in data collection, but do the alternative assignment will not be entered into the raffle or included in the study in any way.

Let me know if you have any questions about what I've outlined, and I'll just need confirmation that is all okay with you.

Thank you, have a great rest of your day!
--
Alexis Pleskovitch (she/her/hers)
pleskovitcha@allegheny.edu | Class of 2023
Physics & Psychology Double Major
President of Society of Physics Students | 2021-2023
Vice President of Dimensions (Math Club) | 2022-2023
Gator Guide | 2021-2023
Orchesis Choreographer | 2022

Jamie Lombardi <jalombar@allegheny.edu> Mon, Nov 14, 2022 at 10:04 AM
To: Alexis Pleskovitch <pleskovitcha@allegheny.edu>

Hi Alexis,

Yes, that is correct, and please let this email serve as confirmation. In Physics 021, students will receive 15 bonus points to their overall grade, which is calculated out of 660 points. So this equates to about a 2% increase in their overall course percentage. In FS101, the compensation would be a 2% boost applied to their overall course percentage.

Regards,
JCL
[Quoted text hidden]
--
James Lombardi
Professor of Physics

Pronouns: he/him/his
YouTube Channel: Astronomy not Astrology
Office Hours:
Mondays 2:30 - 3 pm in Carr 117
Tuesdays 1 - 3 pm in Carr 117
Wednesdays 7 - 8 pm over Zoom
Thursdays 1 - 3 pm in Carr 117
Fridays 2:30 - 3 pm in Carr 117