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Helping Female and Nonbinary Identifying Students Grow Confidence in the Science Classroom

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HELPING FEMALE AND NONBINARY IDENTIFYING STUDENTS GROW CONFIDENCE IN THE SCIENCE CLASSROOM

by

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CHAPTER ONE

Introduction

When I ask my students to name famous scientists, they very rarely can think of a female scientist to name. If they can, they usually only know Marie Curie. This lack of examples for my female students leads to them not seeing themselves as scientists. The standards and curriculum typically used to teach high school biology do not help this matter. Scientists that are commonly mentioned in the curriculum include Charles Darwin, Gregor Mendel, Robert Hooke, and Antonie van Leeuwenhoek. These white, male, European scientists are not particularly inspiring to my students, as my students cannot identify much with them. The lack of role models leads to lower test scores, grades, confidence, and interest in science classes for female-identifying students. Women in scientific and research based careers face more barriers than men, leading to fewer women in those fields. By systemically keeping women out of scientific work, society is disadvantaged and discoveries cannot be made as quickly. A more diverse research workforce can lead to more efficient scientific discoveries and new creative ways of solving scientific problems. This is why I have chosen the research question: *What are the best practices for improving female-identifying students' science confidence in the classroom?* This chapter will explore why this topic is important to teachers, students, society, and me personally. Statistics will be included in the rationale. Data about confidence and interest in the classroom and how they affect success will be shared. This chapter will also discuss why a website is used to showcase the discoveries and share the resources.

Rationale

I was very lucky in my childhood to grow up with two parents who are very passionate about science education. My father is a high school physics teacher, and my mom is an elementary school STEM teacher. This allowed me to develop great science confidence and interest from an early age, which I prided myself on through elementary and middle school. During elementary and middle school, while I was encouraged in my science interest, I didn't have many role models to look to. None of my female relatives hold science positions, while many of my male relatives do. I wasn't exposed to children's books about female scientists, or shown examples of female scientists or scientists of color at school or at home. However, once I got to high school, I found myself lacking the confidence of my male classmates in my accelerated science classes. It was challenging for me to pick what to study in college because I had strong interest in the sciences, but lacked confidence to focus on a "hard" science major.

While I ended up focusing on environmental science, there were still many male students in my classes who had greater confidence. More male students also complete undergraduate research opportunities at the University of Minnesota, where I attended. After graduating, I entered a male-dominated field as an environmental consultant for factories and production companies. I did not thrive in this position, as I lacked female mentors. As a teacher, I have had success because of my wonderful female mentors who I had been able to look up to.

Now, through my three years of teaching high school biology, I noticed much more negative self-talk from my female identifying science students than from my other students. My female students also express less academic confidence in general. They do

not speak about themselves as people who are good at science, and don't volunteer to join science and engineering based clubs such as science olympiad or robotics at the same rate as the boys. I have also noticed that some of my female students have greater responsibilities at home, and their parents focus less on their daughters' academic successes than that of their sons. I have noticed this to be more common in my students of east African descent. There is, of course, a racial breakdown in the success of my students in class. This needs to be recognized and noted, but will not be explored further in this paper.

I have spent the last three years teaching high school biology in St. Paul. The first two years I taught with very little support while working to obtain my 9-12 Life Science License. During this time, I relied heavily on the internet to provide free and easy to access materials to teach with. The resources and curriculum that I have used have been wonderful, but they are lacking in their diversity. By compiling resources that can help science teachers keep the interest of their female students, more effective science teaching can take place, and teachers can save a lot of time while appealing more effectively to their students' interests. Most teachers are tight on time, and by having a website where science teachers can easily access materials to improve the gender diversity of their curriculum, many more female identifying students could be inspired to pursue science in class and in their future careers. Based on my experience as a student and a teacher, science teachers don't typically focus on people very much in their courses, and my hope is that this website can change that by including scientists and researchers who share multiple identities with our students, including gender. As noted above, many of the scientists discussed in a typical high school biology course are white, European

men. There are thousands of brilliant scientists whose work is applicable to the lessons being taught and learned in high school science courses. The challenge is applying complicated research to high-school level topics and curriculum, and having it meet state science standards. This site will focus on meeting the 2019 Minnesota Science Standards, which are very similar to the Next Generation Science Standards. This will allow the materials included to be applicable to all states. I hope to provide materials that are helpful to all the sciences that are typically taught in high school, including biology, chemistry, physics, and possibly earth science and astronomy. The best science curriculum and education encourages students to ask questions and explore what they are interested in. This is only becoming more important as science literacy is more valuable in the current era of "fake news" and COVID-19 misinformation. My goals are to help my students ask scientific questions and be excited to be scientists, and to help other teachers do the same.

All teachers know that their classroom management becomes easier when students are engaged in the topic. Female students do not see themselves in science lessons or when they learn about scientists. Lack of confidence and interest lead to students checking out and becoming less engaged in their studies. Lower engagement leads to more challenging behaviors among students. If we can increase engagement for half of our students (or more), that will lead to easier classroom management for teachers and school staff. Additionally, increasing engagement for some of our students leads to better learning outcomes for all students.

The website that will be developed will include lesson ideas, assignments, projects, and focus on pedagogy and classroom organizational techniques that will help

lift up female students to the level of science interest and confidence of their peers. As I am in the beginning of my teaching career, I would like this website to help me make my own classroom more diverse and accessible to all students, particularly as I move into teaching physical science. The physical sciences, physics and chemistry specifically, are historically less interesting to female students (Shi et. al, 2018). Biology translates well to healthcare careers, and those are typically more interesting to female students. Physics and chemistry, and the careers they lead to, are less popular with women. If women can be interested in these topics in high school, they may consider focusing on them after high school as well, increasing the gender diversity of those fields. Women tend to pursue scientific careers that are more giving, such as nursing, dentistry, and teaching, because of expectations of us. This keeps women away from doing other scientific pursuits. It also leads to women liking biology more than other sciences like physics and chemistry.

Many schools and districts have expressed diversity goals, including the district that I am joining in the fall. To quote, a north metro school district's equity promise states that "programs and services will be in place at all schools to ensure that race, gender, class and disability will not predict students' success in (the district)". Colleges and universities also have gender diversity goals for specific programs, and those goals can only be reached if female identifying students have interests in science careers, and those interests can and should be developed in middle and high school. More women pursuing science careers can help to reduce the pay gap between men and women.

A further focus that I would like to explore is how nonbinary students perform in science classes. There is not extensive research on this topic; however, there is information about how to help nonbinary students achieve in general. Nonbinary students

can often struggle in the classroom, and can benefit from different types of instruction than male students. There are also many nonbinary and queer scientists that can and should be learned about as good examples in the science classroom. As more students become comfortable sharing their true selves in the classroom, we as teachers need to be prepared to support and validate them through examples of scientists who share our students' identities. Studies show that all students do better when they can see themselves represented in the curriculum. This is true for gender identity as well as other factors.

Summary

In this chapter I have explored the personal and professional importance of the question: *What are the best practices for improving female-identifying students' science confidence in the classroom?* This chapter has given an overview of why this question is important, not only to me, but also to educators and students in general. As a high school science teacher, I focused on how students see themselves in science curriculum in my experience, and how that impacts their learning outcomes. Time was also spent justifying why a website is a good way to share this information with teachers, and how a website with these sources could be used for improving the science education of girls in the classroom.

Chapter Two is going to focus on the literature review that was completed for the project development. A lot of research has been done around gender, science, and school success. This research is important to discuss to ensure that the resources provided in the project are helpful to students and teachers. Chapter Three is a description of the project, including why a website was chosen, the specific resources included on the website, and

more about the context and audience. Finally, chapter Four summarizes the project and the information collected, including patterns and themes that were found in the resources.

CHAPTER TWO

Literature Review

Introduction

Girls lack confidence and interest in pursuing science subjects. This begins in grade school, and continues on into university and beyond. This paper is looking to answer the question "What are the best practices for improving female-identifying and non-binary students' science confidence in the classroom". The lack of women in the sciences is a well-documented issue, and has limited the potential of scientific research and discovery. According to a report completed by Beede et. al for the U.S. Department of Commerce in 2011:

> Our science, technology, engineering and math (STEM) workforce is crucial to America's innovative capacity and global competitiveness. Yet women are vastly underrepresented in STEM jobs and among STEM degree holders despite making up nearly half of the U.S. workforce and half of the college-educated workforce. That leaves an untapped opportunity to expand STEM employment in the United States, even as there is wide agreement that the nation must do more to improve its competitiveness. (p. 1)

It is essential to understand the history of women in science, before discussion of what can help this issue. This chapter will first explore the literature surrounding why this is a problem, specifically focusing on academics and research and how the historical exclusion of women in STEM hampers society. It is important to understand why society has this gendered divide, so that specific reasoning can be addressed through specific pedagogical techniques, and so that it is known when pedagogy isn't the issue. The

second section will discuss the confidence and interest of girls in science, specifically discussing why women and girls lack confidence and interest in pursuing STEM and how that affects the gender divide in those fields. The gender gap in STEM can't be narrowed without the desire and interest of girls and women to join these fields. Following will be the types of pedagogy that can help improve this issue, by focusing specifically on pedagogical techniques that have been proven to help women and girls excel in STEM topics. Finally, non-binary students and their experiences learning science in school will be discussed, as non-binary students have different struggles excelling in STEM and pursuing STEM careers than female students and thus require different answers to how to best include those students in STEM fields.

Why is this a problem?

The need for girls to study and enjoy studying science topics in school is multi-dimensional. More scientific interest from girls leads to more women studying science in college and graduate school, and can lead to more female scientists. Women are significantly underrepresented in science academia and STEM positions in general. This contributes greatly to the gender pay gap, as people who work in STEM earn more than those in other fields (Beede et. al, 2011). The majority of women who work in STEM careers work in the life and physical sciences, compared to men who are largely employed in engineering. Walker (2019) found that female authors in entomology journals are significantly underrepresented. This is consistent with other STEM journals, and shows that either women's articles are being published, or there aren't as many women as men in academia. Both of these instances are negative. If fewer women are being published, then their voices are being included in scientific research. If there are

fewer women in academia, then thoughts and ideas could be missed out on. Besides publications, women working in science departments at research institutions are underrepresented. This underrepresentation is even more prevalent if you consider the race of the women in question. Black, Latina, and Native American women have low percentages in science positions. While this intersectionality is strongly present in this topic, it will not be discussed further in this paper (Beede et. al, 2011).

We know there are fewer women employed in science academia (Mattheis et. al, 2022). Women who are included in academic science are traditionally employed in non-tenure-track positions. These positions typically have lower job satisfaction and salaries. Because of this, most women in academic science have lower job satisfaction and lower salaries than men in academic science (Rennane et. al, 2022). Rennane et. al discuss at length in their paper how the long, arduous path to tenured research positions is much less likely for women to achieve than men. This leads to less job security for women in academia overall, and makes science academia less attractive as a career path for women. As more women join academia, that increase generally leads to more women joining. Walker (2019) agrees with this fact, stating that increasing diversity causes more diversity. This fact should act as motivation for departments to increase their recruitment efforts to focus on hiring more women.

Devine et. al (2017) showed that most hiring interventions focused on hiring more women in STEMM (science, technology, engineering, mathematics, medicine) do not work as designed. This implies that more work needs to be done to attract women to work in the sciences, since what has been done before isn't effective, evidenced by the lack of women in these fields. Recruitment in these fields is a well-documented issue,

explored further by Macfarlane and Burg in their 2019 article. According to the article, "Women constitute 56 per cent of students in British higher education and almost 46 per cent of university academics but just 24 per cent of professors in the United Kingdom" (Macfarlane & Burg, 2019, pp. 262-274). This lack of role models does not encourage women to major in science. Even if women major in science in undergraduate studies, if they don't see any women like them in higher up positions those women will not be as encouraged to continue on in academic sciences in the future. It can be challenging to be the only woman in the room, or the only woman in the department. Without the support of other women, it is harder to achieve success.

Women have contributed greatly to the study of science, while routinely being ignored for those contributions. A famous example of a female scientist not receiving credit is in the story of Rosalind Franklin. It is well known now that Rosalind Franklin assisted in the determination of the structure of DNA, and that her notes were effectively stolen and used to assist Watson and Crick, who receive credit for this discovery. As Elster writes in her 2019 article for *History Today*, Franklin was routinely bullied in the lab. Watson's famous book, *The Double Helix*, portrays Franklin as an assistant. In reality, the X-ray crystallography image that Franklin took enabled Watson and Crick to confirm the structure of DNA. Without Franklin's work, the discovery could have taken much longer, or not happened at all (Elster, 2019). The story of Rosalind Franklin and the lack of credit she has received for her scientific contributions is a perfect example of how female scientists are treated and the lack of respect they still get, causing fewer women to enter the field (Rennane et. al, 2022). This is compounded by issues previously stated, including the lower pay levels and lack of role models for women studying sciences.

This section discussed why it is important to improve the number of women in science fields, including STEM industry careers and academics. It discussed how women are very strongly underrepresented in academic publishing, and also strongly underrepresented in the math-focused STEM fields, including engineering and computer science. Women are also underrepresented in higher academic careers, such as professorships and tenure-track careers. It also discussed how these gaps could be remedied, including how hiring more women leads to even more women being hired. Additionally, womens' contributions to research sciences are routinely ignored or miscredited to their male peers, such as with the case of Rosalind Franklin.

It is important to recognize that it is a problem that women are less represented in the sciences than men, and how society is hurt by the lack of gender diversity in the field. More women can be attracted to STEM fields by addressing the gender gaps, and investigating why women are less inclined to study STEM topics and pursue STEM careers. One of the most prominent issues is that girls and women lack the confidence and interest to study STEM fields. These differences will be discussed in the next section, along with how those gaps may be addressed.

Confidence and Interest

Grade School

Shi et. al (2018) researched the gender gap in engineering, focusing on women in high school and colleges in North Carolina, and around the country. They focused on engineering because it is the STEM (science, technology, engineering, and math) field with the largest gender gap. Shi found that this issue begins in high school, with 8% fewer girls focusing on engineering, which increases to an 11% gap by the end of the first

year of college. Interestingly, only 5-7% of the disparity can be attributed to grades achieved in high school or SAT test scores. There is also no direct correlation between courses taken in the first few years of high school and an engineering major. So what is the biggest predictor of this gap in participation? It appears, according to Shi's research, that 22% of the gender gap in engineering can be explained by female student confidence and interest. Miles and Naumann (2021) agree, claiming that science self-perception and how students view themselves as science students is possibly more important than external factors.

Women are often seen more in careers that are helpful to society and involve caring, such as nursing or teaching. Shi noted in 2018 that "female preferences for prosocial responsibilities and contributing to the arts over sciences explain over 14% of the gap" (Shi, 2018, p. 129). Much of the gendered gap in engineers can be explained by social roles which are reinforced by parents. This phenomenon is explored in great detail by Anaya et. al in their paper from 2021, entitled "Gender gaps in math performance, perceived mathematical ability and college STEM education: the role of parental occupation". They looked at two factors to see how they influenced a students' future participation in STEM careers: science-related parental occupation and self-perceived math ability. Beede et. al found, using data from a survey done in 2009 by the Census Bureau, that though women hold 48% of all jobs, they only hold 25% of STEM jobs. This gap is even larger when focusing on math related STEM jobs such as engineering or computer science, but is smaller when looking at careers in the Life, Physical, and Social Sciences. Anaya et. al found in 2021 that having a parent who works in a science job leads to better grade-school performance in math classes and on math tests for girls.

Interestingly, having a parent who works in a science career does not improve girls' self-perceived math ability. When controlling for math specifically, Anaya et. al found that the lack of self-perceived ability is specific to math and does not occur in reading. Math achievement, parental science job, and self-perceived math ability are all predictors of if any student studies STEM fields in college. Therefore, these should be considered when recommendations are made to improve participation in STEM fields by women and girls.

Specifically when reviewing high school classes and participation of girls in those classes, AP (Advanced Placement) classes are predictors of whether or not women will study STEM subjects in college. Girls are less likely to take AP mathematics and AP computer science classes than boys, while girls are more likely to take the other AP science classes than boys (Anaya et. al, 2021). One can conclude from this data that girls lack the math confidence to take these courses, and that the apparent lack of confidence in high school leads to a lower level of participation in STEM focused majors in college. According to Ganley et al. (2017), if a major such as computer science or engineering is seen as a male-dominanted field of study, women are less likely to pursue that field. Ceci et al. (2014) found that stereotypes of STEM careers and genders participating in those careers can begin as early as kindergarten. This reinforces the importance of educating students at a young age and developing their confidence in their STEM abilities. Cowgill et. al (2020) note that women feel a greater sense of belonging in STEM fields when they are exposed to role models. Therefore, it can be extrapolated that teachers who work with any age group should include examples of women in STEM in their curriculum in multiple ways.

Petričević et. al (2022) focus on physics education in grade school, and note that interest in physics declines steadily for every year of grade school. This leads to lower physics class enrollment which, as discussed previously, leads to fewer women studying math-based STEM subjects in college and beyond. Instructional methods can help increase student engagement and confidence. Some of the methods discussed by Petričević et. al include relating physics to everyday life and making it relevant to students. Active student participation along with student-focused lessons, instead of simply lecture-based lessons, were also noted as preferable for grade school students learning physics (Petričević et. al, 2022). Students' interest in physics was found to increase with more relevance and choice being provided to the students. This is corroborated by Simeon et. al (2022), who found that STEM engagement and learning increases when students are provided with lessons and curriculum that include design thinking aspects. Design thinking involves students applying learned physics concepts to real world situations and problem solving. Creativity is also an important aspect of design thinking, and this can lead to more interest and motivation for all students. This relates to what was mentioned on page eight. Shi noted that girls tend to desire career paths that will help people (Shi, 2018). Applying design thinking to physics teaching can show girls that physics and other STEM subjects can be applied in ways that can help service society.

Higher Education

Cowgill et. al (2020) discuss in their paper the fact that many efforts to increase higher education participation in STEM end up backfiring. When women are told of the statistics for women in STEM, including graduation rates and specific company’s gender

balance, the framing of the information was of the utmost importance. When statistics were framed as emphasizing women's enduring underrepresentation in STEM fields, women were less likely to show interest in the position. Women don't want to feel like the "*other*" in their career field, and don't want to have excess emphasis placed on their underrepresentation (Cowgill et. al, 2020).

Physical atmosphere is also important in STEM retention. Similarly to what was mentioned in Chapter One, women who are surrounded by other women in STEM are more likely to feel comfortable in their field and feel that they can be successful in STEM. As written by Cowgill et. al (2020), it really helps encourage women to have ambient reminders of successful women in science around them. This lends credence to common tips for teachers to encourage their female students to pursue STEM, including having female guest speakers, researching successful female scientists, and having posters of female scientists in their classrooms. Even having female science teachers can make female students feel as if they belong more in STEM fields (Cowgill et. al, 2020).

There is much work that needs to be done in higher education and research fields to promote greater retention of women in science. It has been mentioned previously in this paper that currently, the fields of life science and physical science have a more equal gender distribution than math-based sciences such as engineering and computer science. However, it is noted in the paper titled "Finding spider woman: the past and present role of women in arachnology" written in 2022 by Holmquist and Gillespie that the distribution of gender in the field of arachnology is still heavily skewed towards men. This distribution is more skewed towards men in the higher positions in the field, such as first authors and presenters. Holmquist and Gillespie found that technology can be used

to effectively increase the number of women involved in arachnology academic positions by connecting students to resources and mentors, increasing access to hiring practices and encouraging learning for all students. Technology can be used to include more female role models for women studying STEM, which has been confirmed previously in the chapter.

While there has been much discussion on how women do not feel included in STEM fields because of a lack of role models, Matthies et. al (2022) discuss how women in geosciences experience harassment and discrimination because of their gender. One of the biggest patterns that researchers found is that people who perpetrate harassment in the geosciences are not likely to experience consequences for their actions. This is further confirmed by the 2016 article by Sarah Scoles written for Wired magazine. Scoles summarized the year 2016 by noting gender discrimination and harassment incidents that happened each month; all involving celebrity professors and researchers. It is also noted by Scoles that these incidents lead to more active initiatives being implemented by scientific societies and universities. While these efforts are a good starting point, it is hopeful that bringing attention to this issue will allow for greater societal change, leading to more women involved in the sciences.

This section had two sub-sections. The first sub-section discussed how girls' confidence and interest in STEM subjects is already lower than that of their male peers by the time they are in grade school. Studies were cited that mention how confidence and interest are larger factors in a girls' decision to pursue STEM in high school than past academic success or class grades. Other factors discussed for the gender divide in STEM in grade school included parental job and student's math ability and interest. It was

mentioned that for girls in both grade school and higher education, girls factor in the societal impact that their careers can make, and find that social-focused roles such as education, or life-science focused roles such as nursing, are seen as more important and interesting for women. This leads to fewer women pursuing engineering and math roles. Other factors that were discussed as factors that push women out of higher education include gender-based discrimination and harassment in academic research sciences, and physical atmosphere of the job. It is important to understand these factors that decrease women and girl's interest and confidence in STEM, so that specific factors may be addressed and improved.

Women and girls are dissuaded from pursuing STEM fields starting in elementary school and continuing through higher education and academia (Petričević et. al, 2022). This lack of encouragement is furthered by a lack of confidence and interest in STEM fields expressed by girls and women. Specific pedagogical techniques can help women grow their confidence and interest in STEM, and those pedagogical techniques will be discussed in the next section

Pedagogy

There has been much discussion around how to better include women in the sciences. While the previous section discussed interest and confidence, this section will discuss specific pedagogical techniques that will help improve the number of women in the sciences by increasing academic success and engagement. As mentioned previously, the gender divide in STEM begins as early as kindergarten. One pedagogical technique that has been written about by Welty in *The Elementary STEM Journal* in 2021 involves teaching STEM to elementary school students by employing the use of children's

literature. This can encourage young girls and nonbinary students to see themselves as scientists and engineers through stories of scientists and engineers who look like them. Additionally, many of these children's books focus on the engineering and research design processes that were used to make discoveries and develop inventions. This helps directly with meeting the new Minnesota science standards, and the nationally used Next Generation Science Standards of Science and Engineering Practices.

The Thinking Science program, a type of teaching and learning technique that has been implemented in Australia, has seen success in encouraging girls to focus on and enjoy learning science. As written by Andrea Kerr in *The Journal of Australian Science Teachers Association* in 2016*,* Thinking Science encourages teachers to facilitate discussions between students, and guide students through their own thinking. This, in turn, leads to an increase in success and confidence. Kerr notes how the girls she teaches are typically more quiet and afraid to be wrong. This prevents them from speaking up, which in turn prevents them from learning as effectively. The Thinking Science program allows girls to make mistakes and be wrong in a lower-pressure, discussion-based environment. More confidence can be established once girls experience what it is like to be wrong.

According to a study written by Dweck et. al from 1978, women receive less negative feedback in schools, but they perceive it differently. Girls see any mistakes or errors they make as they learn to be a reflection of themselves and not their learning environments. This is different from what boys experience, and as a result boys are challenged more in the classroom. They are allowed to struggle and get things wrong more than girls are, and this limits learning that girls experience in the classroom. Barba

and Cardinale (1991) note that science teachers interact with male students more than female students, and ask male students more higher-order questions than they ask female students. Knowing and recognizing this data allows for all teachers to improve their classroom routines and pedagogy to improve learning for female students. Teachers could even audit their own teaching methods by recognizing which students they call on the most, and what type of questions they are asking their students.

One specific pedagogical practice that has been shown to help all students, and specifically girls and women, learn better is classroom discussion and student participation. Aguilera and Perales-Palacios found in 2020 that including employing participative teaching techniques in the geology and biology classrooms increased learning experiences for girls, leading to better grades and better attitudes towards the sciences. Allchin, in his article written in 2011, discusses how the Nature of Science standards can be best taught by having students work through real-life historical science mysteries. Historical mysteries are recommended because they have usually been solved with strong scientific reasoning by this point. Having students study historical scientific mysteries can be challenging, because real life is rarely as neat and clean as prepared labs and assignments. Part of Allchin's reasoning behind using real-life science in class is to implement more Problem-Based Learning into the classroom. Problem-Based Learning is shown to help students learn more effectively and Allchin believes that posing the proper problems can lead to the best learning and experiencing of the Nature of Science.

It has also been shown that college students do well with project-based learning strategies (Elsamanoudy et. al, 2021). When second-year pharmacy students were taught their molecular-biology course using student-centered, project-based learning methods,

they had more academic success in the course had better social emotional learnings as well. Students said that they were better at teamwork and project management. This study is another example of how student-centered learning is best for all students academically, and increases interest of students in the sciences. Therefore, student-centered learning is a good option to explore when attempting to encourage more women to explore careers in STEM fields.

By definition, from an Edutopia article written by John McCarthy in 2015, "student-centered classrooms include students in planning, implementation, and assessment" (Student-Centered Learning: It Starts With the Teacher, para. 4). Along with project- and problem- based learning, context-based and science-technology-society (STS) approaches to teaching have been increasing in use over the last few decades (Bennett et. al, 2007). These learning types all have the aspect of being student-centered learning. Bennett et. al found that context-based and STS learning reduce gender gaps in attitude towards science and gender gaps in science confidence. This is agreed upon by Moroni in her paper "Making science education through laboratory teaching" published in the journal *Geophysical Research Abstracts* in 2019. Interactive environments were shown to improve student communication and collaboration skills, which leads to more interest and enjoyment in science. Moroni also found that because laboratory and experience based learning are more applicable to real life, this type of learning helps students become adults who make more informed choices, which benefits society. Moroni mentions that students require sympathy and appreciation when working in this type of classroom, which calls back to Kerr's writing discussed at the beginning of the chapter. Girls are more afraid to be wrong at school, and thus would need more

encouragement in a STS structured classroom. Laboratory teaching in this context took about one third of the instructional time. Students were also able to utilize outdoor agronomy and indoor laboratory spaces to apply scientific hypotheses, which many teachers do not have access to. However, applying the techniques of allowing students to make mistakes and ask questions that interest them can be applied in all classroom settings, no matter the resources available.

Different types of pedagogical approaches to improve women's confidence and interest in STEM fields were discussed in this section. These included pedagogical techniques specific to all grades, from pre-kindergarten through college. One common theme amongst the discussed pedagogical approaches was classroom discussion. Women and girls are typically less willing to be wrong in the classroom than men and boys, and classroom discussions at many levels help girls build that confidence needed to be wrong. Other techniques discussed included introducing a variety of STEM figures through picture books. This can help students in the lower grades see themselves as scientists. Generally, student-based classrooms and learning experiences have been proven to help improve the confidence and interest of all students, and thus level the playing field for girls studying the sciences.

Pedagogical techniques that can improve girls' and womens' confidence in STEM were discussed in this section. While many of these techniques improve learning for all students, non-binary and transgender students typically face different obstacles when studying in school and pursuing STEM fields. This next section will discuss how to best support trans- and non-binary students in school and in STEM classes, specifically.

Non-binary Students

The definition of non-binary or genderqueer genders was given by Richards et. al in the "International Review of Psychiatry" in 2015:

> Some people have a gender which is neither male nor female and may identify as both male and female at one time, as different genders at different times, as no gender at all, or dispute the very idea of only two genders. The umbrella terms for such genders are 'genderqueer' or 'non-binary' genders. (pp. 95-102)

It is the job of educators to ensure that all of their students feel protected and affirmed in their classroom. This can be challenging when working with non-binary or gender non-conforming students, who experience more mental health challenges than their peers (Durbeej et. al, 2019). The non-binary youth in the study conducted by Durbeej et. al in 2019 were more likely to experience truancy and more likely to fail a class. In one student done in Sweden with over 8000 responses, 1.6% of those students were found to identify as gender non-conforming or nonbinary (Durbeej et. al, 2019). If secondary teachers have 150 students each year, they will then teach around 2 non-binary or gender non-conforming students each year. Multiply that by 25 years, and that is at least 50 students who share the nonbinary identity. The number of students with this identity is also expected to increase, as society becomes more accepting of various gender identities. This data was confirmed in 2021 by Long et. al, who found that 10.5% of high school aged teenagers identify as transgender and 27% of Americans know someone who is transgender. Schools are known as places where LGBTQ (lesbian, gay, bisexual, transgender, and queer) students experience much bullying and harassment. All of this

indicates that teachers need to be taught and prepared to help these students learn as best they can.

The above factors have generally led to an increase in interest from schools and teachers to improve their gender diversity in their schools and create more welcoming environments for all students by reducing gender-based harassment and recognizing gender diversity. This has also become more important as young people are feeling comfortable enough to fully express their genders in school. To fully welcome gender non-conforming students, schools must hire and support gender non-conforming teachers and staff. Iskander researched how to best support gender diverse teachers in 2021. Iskander found that the pre-service teachers who were interviewed for the study had more resistance to them being included in the education space by gatekeepers, including mentor teachers and professors. The study participants did not experience gender-based negativity from parents or students. These two studies together indicate that nonbinary students do better when they see themselves represented in the classroom, and that nonbinary teachers face resistance from gatekeepers. Therefore, hiring departments and administration should work to hire more gender nonconforming and nonbinary teachers and staff if they want to improve their school's culture around gender diversity. Schools also need to support those teachers and staff members to ensure that they do not feel pushed out of the school or profession.

Long et. al noted in 2021 that LGBTQ-inclusive curriculum is rarely implemented in science classes, even though including that curriculum really helps LGBTQ students experience less descrimination. Many transgender, gender nonconformity, and nonbinary topics come up in the biology classroom when discussing chromosomes or reproduction.

As discussed by Bird et. al in 2022, it is typical for biological reproduction to be taught separately from the social implications of reproduction and sexuality. Bird et. al claim that it is best for all students to include some of the social aspects of gender and sex while teaching the biological aspects. Native American cultural practices surrounding gender should also be included in this discussion of biological gender (Bird et. al, 2022). This can lead to increased understanding and acceptance of nonbinary identities. It also allows for the inclusion of native cultural practices, which are part of the new Minnesota science standards. As stated by Bird et. al, "an interdisciplinary approach is essential to integrate theories engaging with the non-binary nature of sex and gender with the largely binary process of reproduction" (Bird et. al, 2022, pp. 228-241). Long et. al agree with the interdisciplinary approach, as described in their 2021 article in *Science Teacher* magazine. Long et. al also emphasize the importance of proper language when discussing sexuality in an interdisciplinary context, such as social issues and biological issues. By starting the school year on a socially responsible first step, such as learning students preferred names and pronouns, you can set an expectation that your classroom will be accepting of everybody and their identities. This will make discussing social issues surrounding sexual and gender identities easier, as many gaps in understanding will have been bridged by that point.

Everyone is aware of how English and Social Studies classes are set up to address historical and current issues of discrimination. However, it is more rare that STEM subjects address these issues. Science has historically been harmful to marginalized groups, and many historical and even present scientific practices continue that discrimination. One example of gender-based discrimination that uses chromosomes as

an argument is what the state of Idaho has done banning transgender athletes from competing in sports that match their gender identity, as covered by Trudy Ring in her 2021 article for *Advocate,* "Run, Lindsay, Run". Examples such as this give teachers and students wonderful opportunities to discuss and address how science has added to discrimination. Long et. al (2021) give the example of an HHMI BioInteractive lesson which deals with Sex Verification of Athletes. This lesson can be used to address how gender is not simply a factor of chromosomes or expression, but is much more complicated and not as simple biologically as we may be taught.

Students who are non-binary or transgender experience discrimination in school, and in STEM classes specifically. This section discussed what can be done to help those students feel more comfortable and excel in school, especially as the number of students identifying as non-binary or gender nonconforming is expected to continue to increase. Gender diverse teachers are also becoming more common. The increase of gender diverse teachers is good for gender diverse students, as those students feel more seen and supported when there is a staff member or teacher who shares their identity. It can be very challenging for school employees to have positive experiences entering education, and combating those negative experiences is the first step to increasing the number of gender diverse school employees, which in turn will help gender diverse students succeed. Finally, specific subjects were discussed, and how to best teach them to increase understanding of gender diversity. Gender is a frequent topic in biology, and thus gender diversity needs to be addressed when discussing the biological aspects of sex and gender. All of these aspects of the school experience need to be addressed to help gender diverse students feel more confident and comfortable being themselves in academic settings.

Conclusion

This chapter looked to explore literature that can help answer the question "What are the best practices for improving female-identifying and non-binary students' science confidence in the classroom". The first section discussed the history of women in STEM fields, and why the gender gap in STEM fields is a problem. It was found that women and girls lack confidence and interest in STEM fields, which leads to the gender gap in participation in those fields. Math confidence was found to be one of the biggest culprits in this issue. It was also discussed that the gender gap in STEM hurts society, as more perspectives leads to better research. Section two explored how girls' confidence around math and science and interest in those fields prevent girls and women from entering STEM. It was discussed how this confidence and interest gap begins as early as kindergarten, and that it continues through grade school, college, and post-graduate academia. Specific pedagogical techniques to help address the gender gaps in STEM were discussed in section three, including student-focused classrooms and having role models present in various forms in the classroom. Many types of ideas were introduced, including techniques to encourage girls and women of all ages. Section four discussed gender diverse students in the classroom, and how to best encourage those students in school and in STEM specifically. Specific ideas of how to best teach these students, and how to teach biology in the context of multiple genders were introduced as well.

All of the topics discussed in the various sections previous are integral to figure out how to support female-identifying and non-binary students' confidence in the science classroom. Recognizing the history of the issue is necessary in order to address systemic practices which keep women out of the field. The core of the issue appears to be interest

and confidence for girls in STEM, and specific pedagogical techniques need to be used to address those issues, such as employing role models in science classrooms. Those specific pedagogical techniques were further explored in section three, to directly answer the question based on information found in sections one and two. Finally, non-binary students are an increasingly present population of students who need additional support to excel in school and in STEM specifically. This support was addressed directly in section four to answer the last part of the question.

Chapter Three will describe the project that will be completed based on the research found in chapter two. This research will be applied to answer the question "What are the best practices for improving female-identifying and non-binary students' science confidence in the classroom" through specific pedagogical techniques and assignments. These techniques, assignments, and lessons will be compiled into a website that will be free for educators to access and use, in order to reduce the gender gap in STEM fields.

CHAPTER THREE

Project Description

Overview

Chapter Three will describe the project to be completed. This project will seek to answer the following question: "What are the best practices for improving female-identifying and non-binary students' science confidence in the classroom". A website will be developed, which will include resources that are free for anyone to use in their classroom to help encourage girls' interest and confidence in science. A website was chosen for two reasons. First, that it will be free and easy for anyone to access. Many teachers spend much of their time and money on their classrooms and curriculum, and a free website with free resources will decrease some of the burden. Second, there are many resources that have already been developed by various teachers and institutions. These resources are available for free, but they are spread out around the internet and can be challenging to find. Compiling free resources with a shared goal in one place will save time and lead to more improved instruction.

Chapter Two of this paper focused on four research themes which will be used to assemble the website and resources included. Alarming statistics around why the gender divide in science is a problem were discussed, along with why it is important that the divide be remedied. Chapter Three will outline the website which will be developed. It will discuss the outline of the website, what will be included and the format. The expected users of the website and what sources will be included will be discussed as well. The effectiveness of those sources and the website will be measured and the timeline of the project will also be discussed.

Objective

Mattheis et. al discussed in their paper from 2022 that women are less represented in science academia, as well as less represented in tenure-track positions. This tallies with what was found by Walker in 2019, who states that women are underrepresented in published scientific journals. Much of this was shown by Shi et. al in 2018 to stem from the lack of confidence girls have in their math abilities and interest in STEM classes. This means that girls need to be encouraged to develop confidence in math classes. This is also agreed upon by Anaya et. al in 2021, who found that self-perceived math ability is a major factor in a girls' future STEM education and career. These findings add up to the fact that girls need to be encouraged to develop confidence and interest in math and science subjects in order to address the gender gap in STEM subjects.

Welty found in 2021 that the gender divide in STEM begins as early as early as kindergarten. Young learner activities and pedagogical techniques will need to be included in the developed website to address these early divides. It would be best to include early childhood pedagogy and lessons on the bestie to help assist early childhood teachers in encouraging their female and non-binary learners. One of the best ways to encourage women in science was shown by Kerr et. al in *The Journal of Australian Science Teachers Association.* All students, and especially students who are underrepresented in STEM fields learn best in discussion-based and hands-on classes. It is not enough, however, to employ more discussions in class. From my personal experience, girls are generally more afraid to be wrong in class, and thus less likely to speak their minds. This hinders their learning of the topics. Therefore, girls need to be

encouraged in their thinking and taught how to participate in discussions confidently and without fear.

Project-based learning strategies will also be included in the website, as those are shown to help all students succeed in science and math (Elsamanoudy et. al, 2021). Because of this, many projects and discoveries will be included on the website. Along with discussion-based learning, project-based learning is a student-centered classroom pedagogical technique. Student-centered classrooms will be the main focus of the website, meaning that students will be involved in planning, implementation, and assessment in the classroom. As found by Bennett et. al in 2007, student-centered classrooms and pedagogical techniques reduce gender gaps in attitude and confidence towards science. Laboratory techniques will be included extensively on the website as well.

Website Outline

One of the goals for the website is to make it easily accessible to teachers, and easy to use. It will be organized by grade and age group. There will be a section for early childhood education, a section for elementary school, a section for middle school, and a section for high school. Each of those sections will be divided by subject. Subjects that will have resources included for them will include the following: anatomy, astronomy, chemistry, computer science, earth science, engineering, environmental science, life science, math, and physics. It may be challenging to find resources for all of those topics for each of the listed grade levels, but some resources should be helpful for multiple grade levels and subjects. Some math resources will be included on the website because studies show that math confidence and interest holds students back from pursuing

subjects such as engineering, computer science, and physics. Once resources are divided by grade and subject, then they will be divided into types of pedagogy, such as labs, activities, discussions, and projects. There will also need to be a section for tips and tricks that don't fit into any subject category, such as general lab and discussion tips. It also might be helpful to include classroom decorations and environment tips that can help students feel comfortable.

Additionally, there will be a section of resources surrounding how to best help non-binary students feel comfortable and successful in the classroom and in the building. There are many educators that have done fantastic work sharing information around the queer community, and around transgender and non-binary people and students specifically. This website will not copy or steal the hard work of those educators, but will include links to access these educators' resources and links to support them. As a cisgendered, heterosexual woman it is not my place to speak on the experiences of non-binary people or students. However, I will ensure that I am providing access to those voices. One section of the website will also have resources for how to ensure that the entire school can be as welcoming as possible to non-binary and transgender students.

Evaluating Effectiveness

It is important to measure the success of the website and how teachers are utilizing the site. There will be two optional surveys that will be provided on the website for teachers to complete. The first will ask questions for teachers to answer before they use the resources. It will ask teachers where they work, what they teach, and how they are currently experiencing teaching STEM subjects. There will also be a survey at the end of the resources that will ask teachers how they experienced the website. If possible, the

website will send an email to those who have accessed any resources on the website. That survey will ask users which resources they looked at, which they used, and how effectively they used the resources.

This website will be compiled during the spring of 2023, during the capstone class. Half of the weeks will be spent collecting resources, and the other half will be used to organize and develop the website.

Perspective

The goal of this project is to develop a website that will be valuable to all types of STEM teachers, at many levels, and of many various identities. In order to properly develop this site, it is important to recognize the biases and experiences that I have as the developer and how those may impact the final product. I have experienced a lot of privilege in my life due to many of the identities that I possess. As a white woman, I have experienced and benefited from racial privilege. I am not treated with suspicion in public places, and many teachers I have had share my identities. I have always been able to see myself represented in the media, though have experienced not seeing many female scientists for me to look up to. I also did not have many female science teachers as role models. As a cis-gendered, heterosexual woman, I have never been in danger due to my sexuality or who I choose to marry. I also have experienced economic privilege which has helped me attend field trips, join sports and teams, and attend higher education. It is important to recognize that many of our students do not have the economic resources that I have, and to note as I develop the website that many of the teachers using the site may not have the same experiences as me, as well as the opportunities that I have had. The focus of this website will be helping girls and non-binary students develop interest and

confidence in science classes and subjects. Because of this focus, the resources included will be culturally relevant and culturally sustaining. They will need to be accessible to all students, and specifically chosen to sustain the various identities and cultures that our students hold. In order to do that, the identities of ourselves and our students need to be recognized.

Conclusion

Chapter Three began with an introduction to the chapter, and then an overview of the paper so far. It then discussed the objective of the paper, and the goal of the website. The website will be made public for all teachers to use across ages and levels. Female students are less interested in science historically, and have less confidence in their math and science abilities. The website that will be developed will provide resources for free to help teachers encourage their female and non-binary students in their math and science confidence, and encourage their interest in these topics. The organization of the website and how it would be laid out to make it most easily accessible were also discussed. The next section of chapter four discussed how the effectiveness of the website would be evaluated, which will be challenging. Since the website will be open for anyone to access, pop-up surveys will be used, and a survey will be encouraged before resources are downloaded or copied, and for after resources are used. Emails will also be collected to encourage educators to complete surveys. Finally, my perspective as the author of the paper and the person who will be compiling the resources on the website was discussed. It is important to recognize the privilege that I come with when compiling the website, and that many of our students and the educators who will use this resource will not share the same amount of privilege that I have, and that the resources that will be shared need

to be culturally affirming and accessible to all of our students. Chapter Four will discuss the website that was compiled, and review the effectiveness of the website.

CHAPTER FOUR

Overview

Female identifying students are less likely to have interest and confidence in science classes from Kindergarten to grade 12 and beyond. There are many reasons for this, including lack of role models and confidence in math. The interest and confidence in STEM (science, technology, engineering, and math) of female identifying students is harmful to those students and society by limiting who is successful in pursuing STEM careers and thus the forwarding of STEM research and knowledge. Due to these issues, this capstone project attempted to answer the question: *What are the best practices for improving female-identifying students' science confidence in the classroom?*

It can be challenging for teachers to find resources that encourage diverse female identifying students in STEM fields. Many resources that currently exist and are used in schools are outdated and focus on men and their contributions to STEM. It was the goal of this project to gather free materials for teachers of grades kindergarten through twelve to motivate their female students in STEM fields. Resources were collected and organized by grade, and focused on hands-on activities, introductions to STEM careers, and lessons on various diverse scientists from history and the present. There are also many different varieties of posters and decorations included on the site, especially focusing on women of color in STEM fields. A small portion of the site is also dedicated to introducing students to LGBTQ+ scientists and mathematicians. The philosophy of the posters and decorations section is that if students can see themselves in important and famous scientists and mathematicians, then they will be more inclined to be passionate about pursuing those fields.

Major Learnings

It was found in chapter two of this paper that female identifying students lack interest and confidence in STEM fields, which prevents them from pursuing those fields (Shi et. al, 2018). One of the biggest things that has been found to help motivate underrepresented students in STEM fields is seeing themselves represented in those fields. There are many free classroom decorations and posters that can be found online and have been linked on the website. These resources show historical and modern scientists and mathematicians that are of various races, ethnicities, and gender identities. Decorating with those resources is an easy first step to encouraging students in STEM fields.

The most common type of resources found were lessons for all grade levels that involve students researching and learning more about different mathematicians and scientists. Eight of the resources gathered are like this, including multiple resources about the women of "Hidden Figures". There were also multiple elementary level resources that involve the teacher reading a picture book to their students, and students responding with a worksheet that has them reflect. The high school and middle school assignments similar to this include guided research papers on various Black scientists and STEM pioneers, such as Katherine Johnson and Marie Maynard Daly.

A majority of the elementary resources are focused on students having fun and creating things by hand. There is an activity that has students build a rocket while they learn about Mary G Ross, the first known female Native American engineer in the US. Activities such as this help students empathize with the person they are learning about and practice engineering skills as they learn. They also can reflect on their own

preferences and interests, and possibly realize that engineering work is interesting to them. Another large section included on the elementary portion of the website is online coding games from scratch.org and code.org. Code.org specifically has games targeted at common interests of young girls to encourage them to engage in the process of computer coding, including games from specific pieces of media such as Star Wars, Moana, and Frozen. By incorporating characters and stories that students are already familiar with and excited about, students may feel more motivated to choose these games and work hard on them when they get challenging.

Many resources help students imagine themselves in their future careers as mathematicians, scientists, or engineers. Some of these are suited to middle schoolers, while many more are focused on helping high school students figure out their passions. Some of the resources allow students to learn about other students of similar ages who have experience in these fields. There are also many lessons about what it is like to be involved in STEM, what careers could be, and what you might need to study to be involved in those fields. More context helps students who may not be familiar with these careers.

One thing that surprised me in my research and project experience was how math interest and confidence limits girls from pursuing STEM fields. Math classes are vital requirements for many engineering and science courses, and those classes dissuade many students. It was challenging in my search for free resources to find games, activities, and lessons that are focused on encouraging girls in math. From the literature review I know that girls and all students learn more effectively with hands-on activities. Those are

increasing in popularity in math classes in recent years. Besides hands-on work, there were no specific resources that would help girls get more interested or confident in math.

Limitations

It has been discussed previously in this paper that non-binary people are also underrepresented in STEM fields. That lack of representation led to a similar lack of resources available to motivate those students in STEM. The resources that could easily be freely found were generally outlining LGBTQ+ scientists and mathematicians, and their contributions to their fields. It was challenging to find resources on how to specifically support non-binary students in STEM classes. It appears that very little research and information on supporting LGBTQ+ students in STEM has been done at all, and any research or data collection that can be done in the future would be helpful. This would be more challenging to study than other identities that students have, because they are not identities that are reported at school registration. Address, race, home language, and other data pieces are included when each student is registered in schools but gender diversity and sexuality routinely isn't. Because of this, any studies done would require surveys to be done with students self-identifying, and there could be ethical implications, however I am not well-versed in classroom study ethics.

As mentioned previously, multiple of the resources compiled reference the book and movie "Hidden Figures" which is about a team of Black mathematicians who worked for NASA at the beginning of the space program. Resources focused on this piece of media are more common than others because of the recency of the book and film, and because they have a very inspiring story. More engaging resources need to be developed

that focus on STEM pioneers of many diverse backgrounds. This would help students feel inspired to pursue those fields that they may not see themselves in.

One people group that was very underrepresented in the resources found was the LGBTQ+ community. There were no free lessons or activities found that explore being an LGBTQ+ scientist, mathematician, or engineer, or that focus on learning about a specific scientist, mathematician, or engineer in the LGBTQ+ community. One reason for this could be that people who share those identities have historically been private or secretive about their identities to avoid potential discrimination. It is my hope that as societies become more supportive of other identities, more LGBTQ+ scientists will share about their lives and careers.

Where from Here?

The research found in the literature review chapter of this project supports the idea that students need to see themselves represented in various fields in professions if they will consider pursuing those fields. This finding and potential successes from use of the website resources would provide encouragement to policymakers to add inclusion of diverse voices to future state and national science standards. Minnesota's new 2019 science standards include specifications on including Native American perspectives on science, ecology, and climate change in Minnesota to most courses.

One of the major limitations to this project is that the resources compiled were all free, and found on the internet. The website Teachers Pay Teachers was where most of the resources were found. Other sites that were helpful were linked on the developed site. It was overall fairly challenging to find many free resources that are helpful. A large

number of free resources were printable posters, leading to the posters and decoration section of the site.

More research needs to be done on how to support non-binary students in STEM fields specifically. While some, though minimal, research exists on how to support non-binary students in schools, it is nowhere near enough. This is especially important as more transgender and nonbinary youth and teens are experiencing mental health distress in recent years. Students who can see themselves represented as successful adults in STEM worker role models might feel more comfortable and confident in their identities and futures.

A survey has been added to the website to allow for user recommendations. There are many amazing teachers who have amazing resources that they might be willing to add to the site for others to use. Crowdsourcing information gathering for the site would help diversify the resources available and improve the quality of resources, especially if they are resources that have been used in classrooms and found to be useful by experienced educators.

Summary

The website developed includes many resources to help encourage and motivate non-binary and female identifying students to pursue STEM fields. I am hoping to share this site and resources with teachers around the country and the world. Specifically, many of the resources are aligned with NGSS, and thus would be more applicable to classrooms in the United States. A majority of the scientists, mathematicians, and other STEM professionals discussed on the site are from the United States as well, though not all of them.

Teachers are very busy and have a lot going on in their careers, and providing free and easy-to-use resources can increase students' access to lessons and activities that could help improve their interest and confidence in STEM fields. Many of these lessons require very little preparation and supplies, and are easy to set up and use. For these reasons, the site is a benefit to the profession as a whole.

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