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The Causes and Ramifications of the Lack of Women in the STEM (Science, Technology, Engineering, Mathematics) Fields

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Abstract

Women consist of only 27% of workers within the STEM fields while men make up the remaining 73% (Martinez). Several causes contribute to this drastic difference, with one of the main reasons being the lack of confidence that women have in these subject areas. Their lack of confidence often begins in the elementary and middle school grades as a result of teacher bias, fixed mindsets, and a lack of role models, causing young girls to shy away from STEM and turn toward other interests. However, there are ways to fix this problem and if teachers are willing to put the energy into it, classrooms can become places that encourage young girls to pursue STEM careers later in life, rather than discourage them.

Introduction

As long as humans have been around, they have wondered about the world around them and tried to improve life through invention. This remains true today, as inventions are the heart of the Science, Technology, Engineering, and Mathematics, also known as STEM, fields. STEM fields have been around since the invention of the light bulb and the articulation of the law of gravity, but in this technological age, they are becoming even more prominent. More recent inventions include the iPhone, solar panels, and mRNA technology. All these new STEM inventions are some of the largest signs that our society is advancing. But, looking into it on a deeper level we can see that it is not advancing in all aspects, especially in terms of gender equity. Women consist of only 27% of workers within the STEM fields while men make up the remaining 73% (Martinez).

In young children, this gap is essentially nonexistent with both genders wanting to be scientists, astronauts, or doctors when they grow up. However, between the ages of 13 and 15,

there is a large drop in the percentage of girls who are interested in pursuing STEM (AAUW). In these early adolescent years girls' confidence plummets, particularly in science and math, and stereotypes about who can do what jobs start to corrupt their thinking. Therefore, in this thesis, I will argue that one of the reasons why there are so few women in STEM is because of problems that originate in elementary and middle school classrooms, including teacher bias, fixed mindsets, and a lack of role models that contribute to girls having a lack of confidence in the science disciplines.

Teacher bias is made up of the unintentional messages teachers convey through their words and actions in lessons that signify that boys are better at STEM subjects than girls (Sharp-Grier). This idea gets ingrained into girls' memories, and they begin to believe it themselves. Then, once those girls become teachers, these biases come out and are passed along to the next generation.

A fixed mindset is the belief that intelligence is based on natural talent, rather than hard work. Those who have a fixed mindset are more likely to give up when they face challenges and attribute it to them being "stupid". Meanwhile, a growth mindset allows students to persist through challenges because they know if they work at it long and hard enough, they will be able to figure it out. Studies have found that most people have a fixed mindset when it comes to STEM subjects, which is detrimental to everyone (Clark). It is worse for girls though, because almost everyone also has the belief that men are naturally better at STEM than women. Therefore, when girls face a challenge in STEM, they reason that it is because they are not as naturally talented as their male counterparts, erasing any confidence they previously had in the subject (Clark).

There is an extreme lack of female STEM role models since there are so few females in these fields. When young girls do not see females in these fields, they assume that they do not belong there, which erases their confidence that they could get there one day. So instead, they start to dream about going into other fields that they see females in every day.

It is evident that a girl's lack of confidence is one factor that contributes to women's lack of representation in the STEM fields. Now the question remains, why does that matter? Why is it not ideal to have a lack of women in STEM? Well, imagine driving down the highway in a torrential downpour with rain slamming down on your windshield. Only you don't have windshield wipers, so you just aimlessly drive straight, preparing to crash into the car in front of you or to get rear-ended by the one behind you who is in the same position as you are. Now, imagine it is the 1960's and you are looking at newspaper articles of American citizens fearfully staring up at the sky as Russia beats the United States in the Space Race, ultimately leading to their victory in the Cold War. Lastly, imagine throwing someone you love out on the street because they got infected with the highly contagious leprosy and you cannot risk getting it yourself. You could be doing any number of these things today if it were not for female STEM inventors. Females like Mary Anderson, who created windshield wipers, Mary Jackson, Katherine Johnson, and Dorothy Vaughan, who helped get The United States to the moon, and Jean Watson who cured leprosy (Leeper, "Leprosy"). Without women like them in STEM, we would be far behind where we are today. But now, imagine how much further along we could be if we had even more women working in STEM. STEM is a highly creative field where you need a diversity of ideas, meaning you need a diverse background of people to create those ideas. If we only ever have the male viewpoint, we will come nowhere close to the potential we have for the creation of new inventions and advancements. That is why we need to get more women into

the STEM field. One way to do that is to start at the elementary grades and invoke interest in young children about science, technology, engineering, and mathematics. The next step is to assist them through middle and high school so they can keep up their confidence in these subjects, encouraging them to pursue science and technology in college and their careers.

As a future elementary teacher, this subject is intriguing to me because I am a person who will have a direct impact on girls' perceptions of STEM subjects and encourage them to enter the field. By understanding where their lack of confidence comes from, I will know what to do, and what not to do, in my own classroom one day.

Evidence

As mentioned in the introduction, there is a significant lack of women within STEM fields today. This lack of women is seen at all levels of expertise from high school AP test takers all the way to Nobel Prize winners. Within the past 18 years, only two women have won the Nobel Prize in Physics, compared to the 47 men, only four women have won the Nobel Prize in Chemistry, compared to the 41 men, and only three women have won the Nobel Prize in Physiology and Medicine, compared to the 44 men ("All Nobel Prizes."). Although these differences in numbers appear striking at first, it is logical as only 27% of the entire workforce in all of the STEM fields are female (Martinez).

Breaking that overall statistic down further, it can be seen that there are certain fields within the overarching category of STEM fields that are less represented than others. In Lily Jiang's article, "Why Are Some Stem Fields More Gender Balanced Than Others?" she found that the percentage of biological science, chemistry, and mathematics degrees earned by women was 40% or greater, while computer science, engineering, and physics were 20% or fewer

(Cheryan S). Strengthening her argument, the American Association of University Women found that women occupy 46% of the biological science fields, which is nearly equal to men, and women occupy 40% of Chemists and Materials Scientists. They noted that the gap began to widen with Computer Science and Math where women consist of only 25% of the workers, and it peaks with engineering where women consist of only 16% of the workers (Labuda). These findings prove that although all of the STEM fields are slightly underrepresented by females, some fields are closer to being equal than others. These drastically underrepresented fields are the ones that bring the whole average down to 27%. Although every field needs to be worked with, since they are at least slightly underrepresented, the real priority needs to be getting women into physics, engineering, and computer science, especially since computer science is the only field that has fewer women working in it now than it did in the 1990s (Labuda). Also, it is imperative to focus on these specific fields because even if a woman is part of the low percentage that does get a degree in engineering or physics, it is not likely they will continue to pursue a career in that area. Only 38% of women with a computer science degree go on to work in that field and only 24% of women with an engineering degree work in that field ("Women with College Degrees"). The rest go into various fields, mostly ones that are completely unrelated to what they spent their lives studying.

Again, these statistics appear striking, but it is logical that so few women work in those fields because so few go to college and earn degrees in them. Some universities, such as Massachusetts Institute of Technology, which is argued by many to be the most elite STEM-centered school, especially focusing on engineering, are making necessary adjustments so that their enrollment is about 50/50 for men and women. MIT's female enrollment has almost doubled in the past ten years, now representing 48% of students (L. Huang). However, most

colleges are not as advanced in this area as MIT. Other top-rated STEM-centered schools such as Georgia Tech and Worcester Polytechnic Institute have a 60:40 ratio of men to women (Duffy, "Georgia Institute"). On the other hand, smaller liberal arts schools that focus primarily on the humanities typically have the opposite ratio of 40:60 men to women. It is clear that by the age of eighteen when students are deciding what college to go to and what to major in, there is already a large distinction between men who choose to prepare to go into STEM fields and women who prepare to go into the humanities.

Eighteen is not the youngest age that shows evidence of this gap existing though. According to College Board, which runs the AP program for high schools across The United States, these trends are very similar in high school, since the numbers of females taking the AP exam in certain subjects such as physics and computer science are extremely low, whereas other subjects, like English Language and Composition or Biology, have a majority of women test takers. In 2021, AP Physics 1 had 84,330 males taking the exam and only 52,619 females, a difference of over 20,000 students. AP computer science A had 55,577 males take the exam and only 18,918 females, a difference of about 35,000 students. Meanwhile, Biology had only 86,033 males compared to 143,932 females and English Language and Composition had only 195,421 males compared to 321,490 females ("2021 AP Program Summary Report"). This data proves the idea that some subjects within STEM are more prominent for women than others since Biology had even more females take the test than males. Biology is so popular for females because it often leads to jobs that directly help people, such as nursing. Women are more likely to go into jobs like teaching or nursing, where they can help others since they feel that is their purpose in life (Towns). Overall though, these AP tests show that women are more inclined to focus on humanities whereas men are more inclined to focus on the sciences. This trend is visible

from young students all the way through college, and into the workforce, with women weaning out more and more as the levels get higher compared to men who have a solid representation in the STEM fields at all levels.

To find one of the reasons why these striking statistics exist in the workplace today, one can look all the way back to elementary school. At the start of school, boys and girls tend to have the same levels of confidence in STEM subjects, but by upper elementary and middle school, particularly around the ages 13-17, girls' confidence plummets in these subjects (AAUW). There is no practical reason for this drop in confidence, as boys and girls are still performing at almost exactly the same ability levels, but it occurs nonetheless (Cimpian). This lack of confidence in girls often leads to disengagement and disinterest in pursuing those subjects any further, and many give up the idea of ever pursuing a STEM career one day. There are many factors that lead to this plummet of confidence in young girls, including internalizing teacher bias, having a fixed mindset, and having a lack of role models. These three things that occur in grades 1-8, directly impact girls' confidence in their STEM abilities, which contributes to their disinterest in entering the STEM field later in life.

Teacher Bias

Teacher bias is when a teacher "decides a student's ability based on a factor external to their work in the classroom" (Sharp-Grier). Teacher bias on gender, therefore, means that a teacher makes an overgeneralization about a specific gender and then applies it to every student of that gender. In STEM, many teachers are guilty of being biased that boys are better at math and science than girls so they begin to believe all girls are not good at math and science and all boys are (Sharp-Grier).

Sarah Hand, Lindsay Rice, and Eric Greenlee set out to prove this bias exists in teachers by conducting a survey where teachers from a high school received a list of stereotypically masculine and feminine characteristics, found from the Dimensions of Gender Role Stereotypes. The teachers were given a grand list of all these characteristics and were told to group them into being more appropriate for the sciences or humanities. The results showed that most of the masculine characteristics were placed on the sciences side and the feminine were placed on the humanities side. Thus, proving that most teachers see males as more fit for the sciences than females (Hand).

This apparent bias that teachers hold is almost always unconscious. Most of the time, the beliefs that teachers hold originated in their childhood and stuck with them as they grew up and they do not even realize they exist. Therefore, when they are teaching, they show these biases in ways they do not even realize (Sharp-Grier).

Great Plains Network, a teaching company, did research by sending experts into classrooms to observe teachers' lessons to find some of the unconscious ways that gender bias gets shown through their teaching. One way they found is that boys receive more attention than girls. They get called on more frequently to answer questions and the teacher follows up with them more often than girls. This is detrimental particularly in science because boys will get picked to go to the front of the room and do experiments with the teacher. Here, the boy doing the experiment gets all the hands-on learning which is so crucial while all the girls are sitting and watching, which is not as stimulating. Similarly, girls and boys are often assigned different types of roles when they are in group work. If they are doing an experiment or any hands-on activity, the boys are much more frequently assigned the role of the “doer” while the girls, who have neater handwriting, are more often the recorders (GPN). Teachers most likely choose the girl to

record because she does have the best handwriting, but by doing something that seems so innocent, they are unintentionally saying that girls should be in more clerical positions while the boys can do the actual work. Additionally, both situations cause girls to be more passive learners, while boys get to be an active part of their learning process which is proven to be so critical for digesting knowledge.

Another prominent way that teachers express their bias unintentionally is through what they say about themselves. Teachers often express their doubts aloud in class. For example, it is very common to hear a teacher say, “I’m so bad at math” or “I hate math”. They may even say “I’m so stupid” after they make a mistake. The problem is that students are listening and internalizing these messages. Since the majority of teachers, primarily in younger grades, are female, the girls in their class see themselves and their potential in their teachers. When the teacher doubts themselves, or even just makes a joke about being stupid, the student hears that they will never be capable of being good at math because even their teacher who has been studying it for years is not able to be good at it. Once this thought is paired with teachers overly praising boys for their abilities, girls draw the conclusion that they are not good at math, just like their teacher, because they are female and only males are really good at math (Beilock). No teacher is explicitly telling girls that they are not as good at math or science as their male classmates are, but by directing more attention to the boys and saying that they themselves are not good at these subjects, they are slowly leading girls to draw the conclusion that their gender determines what they are capable of.

The fact that these subtle messages truly do affect students has been proven in various studies. One of these studies was called the “Educators Equity in Science, Technology, Engineering, and Mathematics II” run by The National Alliance for Partnerships in Equity, or

NAPE. NAPE set out to prove that underlying bias in teachers negatively affects their students in STEM subjects. In their study, they found over 400 teachers who admitted to using micro-inequities, which are negative, unintentional messages that result from underlying biases, in their teaching. They then had these teachers go to a four-day intensive camp, followed up by professional development days. In the National Science Foundation Advanced Technological Education program, they learned how to get to the root of their biases and ultimately eliminate them from their teaching, replacing them with micro-affirmations, which are positive, intentional messages. At the end of this project, the teachers had to go back into their classrooms and examine how their students' confidence levels changed once micro-inequities were removed from their teaching. The results showed overwhelming support for NAPE's theory as 84% of teachers reported a dramatic increase in student participation, self-efficacy, and sense of belonging. NAPE, therefore, concluded that biases that are shown, even unintentionally, in teaching do negatively impact students' confidence and achievements in STEM subjects (Sharp-Grier).

Since girls in elementary and middle school are on the receiving end of gender bias in their everyday lives at school, the idea that they are not good at STEM subjects because they are a girl is ingrained in their minds, helping to discourage them from pursuing those subjects and instead turning their interests to others, typically English. Meanwhile, boys are encouraged to become confident in their abilities. But, boys are not solely being positively affected by this by sticking with those subjects, they are also negatively affected by hearing that they are better than girls. This idea can get ingrained in their minds which contributes to the problem of men being sexist and discriminatory towards women in the STEM workforce because they think women don't belong and are not equal to them because that is what they grow up seeing and hearing.

This leads to the problem of sexism in the workplace, which is another main reason why women stay away from STEM careers (Clark).

Since the biases that teachers hold originated in their childhood and get passed along to their students in their childhood, it is clear that gender bias in STEM subjects, as well as any gender bias, is a generational problem. It becomes a cycle from one generation to the next inside the classroom, making it a place of learning not only what they can do, but what they cannot.

Teacher Bias Solutions:

As the previous section explained, many teachers have the unintentional bias that boys are better at STEM subjects than girls and they unconsciously show this in their teaching, ingraining this idea into the girls in their classroom as well. Therefore, it is crucial for teachers to get rid of this bias and stop spreading it to future generations. This is a two-step process. The first step is for a teacher to acknowledge that they have these biases, since they are almost always unconscious, and to figure out how they are showing that bias in their teaching, and the second step is to determine how they can change their teaching to eliminate that bias in the classroom.

Even if a teacher knows about studies like the one done by Hand, Rice, and Greenlee, and conferences like National Science Foundation Advanced Technological Education, mentioned above, which show that gender bias does exist in most teachers, they often have a hard time thinking this holds true for them. Therefore, instead of simply knowing that this is a problem generally, they must take action on an individual level to find out they have these biases as well. One way to do this is by taking an implicit bias test online. Typing “implicit bias test” into Google will bring up dozens of tests. A highly effective one that is used for educational purposes is on a website called Project Implicit. Their site is dedicated to identifying unconscious biases

that educators and other professionals may have that could impact their working with others. One of the tests is titled “Gender - Science IAT” and it **“**often reveals a relative link between liberal arts and females and between science and males” (“Gender - Science IAT.”). This test models the same idea that Hand, Rice, and Greenlee’s research demonstrated, but in a way that can be done at that individual level. The test asks a few general questions about the test taker’s beliefs but then focuses most of the time on doing an activity where you must click the correct key on your keyboard to categorize words as fast as you can. There are two keys used, e and i. During some of the tests e is used for male and science and i is used for female and liberal arts, and during other sections it changes so e is used for male and liberal arts and i is used for female and science. The test records how fast the test taker is able to categorize words, such as biology, geology, writing, or history, into the right category. For example, if e represents science, then the test taker should hit e when the word biology pops up. What the test typically finds is that when female is the e key along with science, the test taker hesitates longer to hit the correct key (“Gender - Science IAT.”). They have to be more intentional about what key they will hit, whereas when male and science are the same keys and female and liberal arts are the same keys, their answers are much quicker because they associate the two together so it is more automatic for them. They also get fewer errors. This test is highly effective because the test taker is not the one answering questions about their teaching or beliefs. Answering survey questions is typically not accurate, especially with gender bias in STEM because it is unconscious, so many people will answer that they do not do certain things or have certain biases when in reality they do. Since the Project Implicit test uses an activity that shows where someone has these biases plain and clear, it is much more accurate.

Once a teacher knows that their bias exists, it is then important to determine what areas this bias comes out in during their teaching. A great way to check is by recording a few science and math lessons in order to "watch your bias take fold" (Alber). As a teacher watches themselves, they should write down every time they see something they did that shows their gender bias. Some typical things could be if they call on boys a lot more, if they shut girls' ideas down more frequently, or if they assign different roles to different genders. At the end, they can see what areas of their teaching need to be worked on in order to stop that bias from showing. Recording videos is so helpful because they allow teachers to rewatch or pause them in order to really study what they are saying and doing and where that bias may come through. A teacher may notice something they did the third time watching it that they did not catch before, so rewatching is helpful. If a teacher is unable to record in their class or simply wants an extra set of eyes pointing out their bias, they can have a colleague come in and observe a lesson. The colleague can then take notes, and report back to them on where they saw biases showing through (Alber). This method is not as effective because colleagues may miss some areas since it is in real-time, but it can still be very beneficial.

Once a teacher knows all the areas where bias creeps through in their teaching, they can hone in on what they need to do to fix it in the future. For example, one of the main ways that bias is shown is by giving more attention to boys and allowing them to participate more (Alber). A lot of teachers struggle with calling on as many girls as they do boys. If this is the case, then teachers can change their teaching by being more intentional about whom they call on. This could be done by creating a measurable goal for themselves, such as: "I have to call on five girls during the math lesson today". Then, at the end of the lesson, they could evaluate themselves to see if they met that goal. Teachers can use "wait/ think time deliberately" (Alber) here to assist

them in this task. If a teacher does not just call on the first person with their hand up, or the first person they want to call on, but waits a few seconds longer and reminds themselves that they need to call on both genders, then they are more likely to succeed in their goal. If a teacher is really struggling with meeting their goal, they may want to keep a clipboard with them throughout the entire lesson and tally how many boys versus girls they call on as they go. This forces them to think about whom they are calling on. Eventually, it will become routine to focus on calling on both genders, and they will be able to ditch the clipboard. It may seem overly simple, but in reality, just being more intentional about whom teachers are calling on and giving girls more of a chance to contribute to class discussions can make them feel so much more seen and valued, and give them more of an active role in their learning which can make a huge difference in the way they see themselves in STEM subjects.

Another very common way that gender bias is shown is through grading. This can happen in two different, opposing ways. Oftentimes, “the teacher generates explanations” (Menéndez-Varela) in their mind about why kids wrote something on a test or answered a specific way which affects the way they grade the assignment. For example, they may say “I know this boy knows this, they just forgot to write it down”, so they will give them credit where credit is not due. This means that they give higher grades to boys than girls based on no evidence except their own feelings toward the students. On the other hand, teachers also sometimes fall into the trap of having different standards for different students. Some teachers may hold boys to a higher standard than girls in STEM subjects, so they will grade boys harder and give them partial credit on an answer because they want to push them to elaborate more, whereas they give a girl full credit for the same answer because they think that’s “as good as it gets” for them. This will result in girls getting higher grades than boys because they are held to a lower standard.

These two ways that show bias have two different results in grades. But the specific grades are not the important part here, the trend of boys and girls getting different grades represents the fact that the teacher is not keeping their expectations the same throughout the two genders and they are letting their personal feelings affect their grading, which over time will affect the students (Menéndez-Varela).

To change that area of their teaching, teachers can use rubrics. Rubrics ``make grading transparent, avoiding the effects of prejudices" (Menéndez-Varela). A well-constructed rubric is specific, preventing teachers from letting their personal feelings affect their grading. If a teacher is circling whether a student used three examples or only one, there is no room for them to create those explanations for why a student did or didn't do something, or think "Well, I think they meant to do this". It keeps grading very straightforward, the student either did what the rubric says or not which allows teachers to remain very consistent as they grade assignments. Rubrics also hold all students to the same standards. A well-constructed rubric has high expectations for students. Since everyone gets the same rubric, girls cannot be held to a lower standard. Going back to the first example, if a girl only gives one example instead of three, the teacher cannot say "That's as good as it gets for her" and give her full credit. Instead, the teacher has to circle the box that says they gave one example, which may only be worth one point instead of three. Overall, rubrics are an effective way of keeping grading consistent, which prevents gender bias from showing.

Below is an example of a very specific rubric that if used provides no room for any bias to come through while grading. It goes along with a performance assessment in math about the area and perimeter of a basketball court ("Rubrics").

<u>4-point Holistic Rubric:</u>

	4 Thoroughly meets standards	3 Meets standard	2 Approaching standards	1 Not yet approaching standards	0 No attempt
#1 7.G.4 7.G.6	Student correctly finds the *area* of the basketball key, with organized work that clearly shows their thinking, including correct and labeled equations, with no calculation errors, and using correct units.	Student uses a correct strategy to find the *area* of the basketball key, with work that shows their thinning, including an equation. May include minor calculation errors or incorrect units.	Student uses a partially correct strategy to find the *area*, but does not correctly find the area of the basketball key. Or student has correct answer but shows no work.	Student attempts to find the *area* but does not correctly find the area of any part of the basketball key. Or student has incorrect answers and shows no work.	No evidence of attempting the problem.
#2 7.G.4 7.G.6	Student correctly finds the *perimeter* of the basketball key, with work that clearly shows thinking, including correct and labeled equation, with no calculation errors, and using correct units.	Student uses a correct strategy to find the *perimeter* of the basketball key, with work that shows their thinning, including an equation. May include minor calculation errors or incorrect units.	Student uses a partially correct strategy to find the *perimeter*, but does not correctly find the perimeter of the basketball key. Or student has correct answer but shows no work.	Student attempts to find the *perimeter* but does not correctly find the perimeter of any part of the basketball key. Or student has incorrect answers and shows no work.	No evidence of attempting the problem.

("Rubrics")

As a bonus, rubrics also help to give praise. Another common way teachers show their gender bias is by praising boys more than girls, but the rubrics themselves can serve as a form of praise (Alexander). When a teacher hands back a rubric that has a good grade on it, the student is

proud and is encouraged to continue working hard. Even if it is not the best grade, it still provides specific feedback on what the student needs to do better in the future, and what they already understand really well, which is information girls may not be getting otherwise if teachers are not paying as much attention to them and not talking with them as much as they are with the boys.

In addition to calling on more girls and using rubrics to grade assignments, a very straightforward way to prevent bias from showing is by teachers getting to know each of their students on a more individual level. If someone knows a person extremely well and knows their strengths and weaknesses, their hobbies and interests, and their overall background, they are more likely to view them as a unique person and not just group them in with others. This makes a girl in your class not simply one of the girls, but a specific person who loves math, hates pickles, and plays soccer. The more you know someone, the fewer inferences you make about them that are stereotypical, and the more you treat them like who they actually are. This prevents teachers from falling into the trap of seeing a girl as not good in STEM because they know that that specific girl loves math and is really good at it. Eliminating gender bias from their mind about a certain student is the best way to make sure it does not come out in front of them.

Since having gender bias in STEM subjects is almost always unconscious, teachers never realize that they are doing anything wrong, so they do not see the need to focus on it and change their ways. However, once they realize that they have this bias ingrained in them and find out where it is shown in their teaching, they simply must be more intentional about what they are saying and doing to fix it. There are no crazy solutions to this problem that need to be done, just reminding themselves to pay attention to both genders and using tools, such as rubrics, to help

them will change their teaching and prevent that bias from spreading to the girls in their classroom, changing the generational cycle.

A Fixed Mindset

The next main cause of a lack of confidence in girls in STEM subjects is because they have a fixed mindset. There are two types of mindsets in learning: fixed and growth. A fixed mindset is the belief that one's intelligence is unchangeable. A person either considers themselves naturally smart or not, and no amount of hard work will change that. This causes students to shy away from challenges and feel threatened by others' successes. It also causes them to give up easily and they are more likely to cheat in school. Additionally, students with a fixed mindset view their grades as a reflection of their worth. If they do well it confirms the notion that they are smart, but if they do poorly they begin to believe they are now "stupid". Meanwhile, a growth mindset is a belief that hard work determines one's intelligence, not natural ability. Therefore, even if something is challenging, a person with a growth mindset believes that if they work at it long and hard enough, they will succeed. They embrace challenges and are inspired by others' successes. These students are much less likely to cheat because they know they can do it independently. Grades in school are simply an indication of whether they worked hard enough or if they need to go back and study a topic more (Kim).

Unfortunately, studies have shown that a fixed mindset is very common within STEM subjects. One of these studies was performed by The International STEM Journal. They surveyed 114 graduate students to ask what their gender was and what their beliefs on fixed versus growth mindsets were. The students had to answer this survey at three points throughout the school year, and in the last survey, they also had to indicate whether they would be continuing with the

program or dropping out. The results proved that most women and men have a fixed mindset in regard to STEM subjects and that most believe that men have more natural ability than women. As a result, women feel that their success is a result of luck rather than skill. Their low self-efficacies combined with frequent sexist comments results in a large percentage of women dropping out (Clark).

The fixed mindset and stereotypical beliefs that these graduate students have did not originate in college. A mindset is developed early on, beginning in the elementary grades, and for the most part, persists throughout one's life. Many different factors influence the type of mindset that children adopt. In school, explicit teaching of certain mindsets has a large impact (Haimovitz). Teachers do not simply pass along the growth mindset that they have to their students. They must be intentional in what they tell their students and what they have them do in order for them to ingrain it in themselves. Many teachers do not realize that some age-old policies they use in their classrooms today actually promote a fixed mindset. For example, not allowing corrections on work used to be universally accepted, and many teachers hold onto this idea today. They believe that if corrections are always allowed then students will not study and try to learn the material the first time around and then they will get behind. However, not allowing corrections tells the students that once you learn something, you should move on and not go back and try to fix your mistakes. It also reinforces the idea that students should play it safe and not take chances because whatever grade they get, they are stuck with, and most students are more motivated by grades than the learning process. This is especially detrimental to girls who typically have more pressure from parents and peers to do well in school (Leaper). This pressure combined with the praise that teachers typically reward more openly to boys, cause girls to not be satisfied with the same grade that a boy would be (GPN). Ultimately leading to the

idea that boys have more room to take some risks and still get a grade they are satisfied with, but girls do not. By allowing corrections, both genders could have room to challenge themselves more while still receiving that good grade at the end (Leaper).

Additionally, teachers are contributing to students developing a fixed mindset because they are not modeling the growth mindset consistently themselves. Many teachers have adopted positive messages and posters on their walls. This is a daily reinforcement for students that tells them they can learn and grow. It is very encouraging especially when a student is struggling, and they look up and see all these signs telling them they can do it. However, many teachers then contradict this idea while they are teaching. Oftentimes, when they are at the board and they make a mistake they will get frustrated or apologize. This act tells students that it is not acceptable to make mistakes and that they should be a source of anger and embarrassment. Avoiding mistakes is part of a fixed mindset. To avoid mistakes, students must avoid challenges and remain within their comfort zone. Teachers are not intentionally sending this message, but through modeling aspects of a fixed mindset, they are passing those ideas onto their students. As mentioned in the subcategory above, teacher bias, girls are most at risk of internalizing what their teachers say since they are the same gender and see themselves in them, so they notice their teachers' reactions to mistakes more often and have a stronger response to them than boys (Sharp-Grier).

When students develop this fixed mindset in math and science, they begin to avoid those subjects. They spend less time working with them because they believe that no matter how much work they put in, they will never improve so why bother? Once they develop a fixed mindset it is very difficult to get them to transform into a growth mindset. Plus, once a student has given up on certain subjects, it is very difficult to regain their interest. Therefore, in order to keep girls

interested in STEM, teachers must be very intentional in ingraining growth mindsets in them, particularly in regard to STEM subjects.

Fixed Mindset Solutions

The previous section explained how a fixed mindset is one where students believe their intelligence is fixed, so they are either smart or not. Many students, especially girls, hold this mindset regarding STEM subjects. However, this mindset is not innate, rather it is ingrained in them over time based on their life experiences. Therefore, teachers have a large impact on which mindset they develop and need to start promoting growth mindsets a lot more than they have been.

One way to do this which was briefly discussed already is by allowing corrections on students' work. The article, "Learning from Errors" explains how the American idea of "errorless learning" is flawed (Metcalfe). It is impossible for someone to never make an error, and permanently penalizing them for doing so only discourages them and prevents them from going back and learning from their mistakes. Northern University's Research Team adds to this idea by saying that, "the giving of marks and the grading function is overemphasized, while the giving of useful advice and the learning function is underemphasized in the classroom" (K. Kemp). By having final scores that cannot be fixed, teachers are focusing more on the grades themselves than the learning, which is the whole reason for the test in the first place. These unchangeable exam grades place more emphasis on competition between classmates and "determining rank" (K. Kemp) than on actual learning. This is particularly detrimental to minority groups such as "first-generation college students, or women engaged in STEM courses" (K. Kemp).

This is why allowing corrections to work is essential because it places the emphasis back on the learning rather than on the number grade. It shows students that even when they inevitably make a mistake or do not get the best grade in the class, it is okay as long as they go back and figure out where they went wrong and learn from it. Students need to understand that “Errors enhance later memory for and generation of the correct responses' (Metcalfe) so making an error is not the end of the world. It can even be beneficial because once they go fix it, it is much less likely they will make the same mistake again. Allowing corrections on work, whether on high stakes exams or simply classwork, helps promote a growth rather than a fixed mindset in students because it shows them that learning is never final, they can always fix their mistakes and learn more. It also helps get the notion of grades determining your worth out of their mind, because the grade can change.

It is clearly essential to provide corrections on work, but to do so most effectively there are two conditions that must be taken into consideration. The first thing to consider is the timetable and the second is how you are doing corrections. First of all, corrections have a time limit. “There is a short time window during which the undesirable response can be eradicated or modified and reconsolidated” (Metcalfe) at least most effectively. Therefore, teachers must get work back as soon as possible, and only give students a short amount of time to fix that work. Northeastern University did a study where they allowed teachers one week to grade the exams and get them back to students, one week for the students to make the corrections, and then one week to get them back to them again. The results of their finals demonstrated that the timetable was highly effective. If you wait too long, students will forget why they did what they did on a problem and that will make it much more difficult for them to see their errors and find what part they need to change (K. Kemp). In elementary grades, the time scheduled per day for

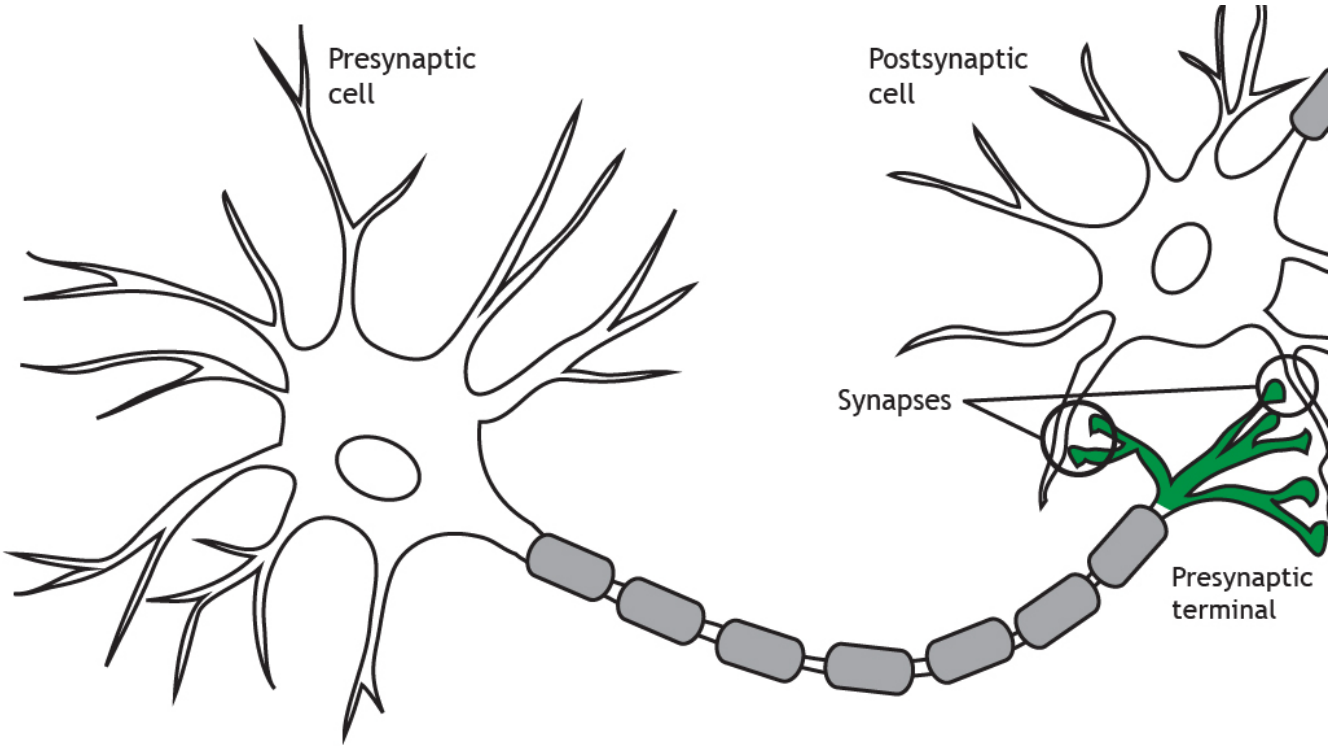
Multi-Tiered Systems of Support would be a great opportunity for students to go back and fix their errors on past work, allowing them to get it done very quickly after they turned their work in.

The second important part of corrections is how the students do their corrections. It has been proven that "Test corrections that incorporate reflection promote student use of metacognition strategies to enhance their learning because students are asked to apply retrospective analysis to their exams" (K. Kemp). When students reflect, they must think about several things. First, they need to figure out why they got the problem wrong. Then, they need to figure out the correct way to solve the problem. Finally, they need to solve the problem and find the right answer. If students were to simply write a new answer down, even if it is correct, it does not show any evidence that they understand that type of problem now and see what their mistakes were before. Providing a reflection shows that learning and error correcting has occurred, which is what truly matters.

Many teachers argue that there is not enough time to allow corrections on everything because they need to move on to the next topic, especially in math and science. However, if students do not understand the current topic, when they move onto the next one which builds onto it, they will just get more and more behind. It is worth taking the time to build up their foundation before moving on. Teachers also claim that allowing corrections will cause them to not study in the first place. But, in elementary and middle school grades, most of the studying happens within the classroom, not at home, so if they are not studying enough that simply means the teacher is not providing enough time in class to do so and would not reflect the child's work ethic.

Another way for teachers to promote a growth mindset in their students is by normalizing struggle and emphasizing that learning occurs within the struggle. When children get to a challenging problem and cannot figure it out quickly or they do not get it correct on their first try, many give up and say “I can’t do this' '. However, if teachers explicitly teach students, ideally at the beginning of the year, how challenging problems and struggles are actually what fire up the brain and allow learning to occur, then they will be less likely to quit. The teacher should explain how the learning process requires neurons, synapses, and myelin. Neurons are “nerve cells” that send and receive signals (Sriram). Synapses are the spaces in between these neurons where messages pass through and go from neuron to neuron (Penttila). Learning takes place when these messages are connected between neurons. Myelin, a “fatty substance that wraps around the neurons” (Sriram) is formed during this time and, the more myelin that accumulates, the faster and stronger these signals get and the faster the retrieval and deeper the learning is. “Challenging tasks spur the production of myelin” (Sriram) because the brain is working hard on a problem for a long time, trying different strategies. This activates many neurons and signals and builds up that myelin. Then, once the student finally gets the right answer or is shown the right way to do it, they have had so much myelin build-up that they will remember it for a longer time, and have learned it on a deeper level than if they just did simple practice and drill or if they just copied the teachers answer (Sriram). Knowing that this is how the brain works and that struggle actually is so much better than automatically knowing something, students will be encouraged to struggle and not feel as though they are failing or stupid because they did not figure out a problem right away. Teachers should reference how the brain works often to remind students that this struggle is good. For example, when students are working on a challenging task and seem confused or frustrated, the teacher should say, “Look at all those neurons firing!” to remind them it is all part

of the learning process and they are on the right track. Knowing that struggle is good will help promote a growth mindset in students because they will know that if they press on when things get tough, they will eventually succeed so they will not give up.



This is an image of two neurons, with the synapses showing the space between each neuron, and the dark gray ovals down the neuron is the myelin (Henley).

Once teachers have emphasized how the brain works and why the struggle is good, they need to then allow the students to struggle. Teachers want their students to succeed and hate seeing them frustrated, so sometimes they are tempted to jump in and give lots of hints or even tell them the answer. Although they have their best interest at heart, when they do this, they are taking away the struggle, which is the learning process. In the end, this will only hurt students, so teachers must learn to stand back and let their students struggle. Some ways to do this include:

- Giving students challenging tasks that are within their zone of proximal development (Livy)

- Giving problems that have multiple access points and have students show more than one way to get to the answer (Livy)
- Not "over-modeling" so that students simply have to copy what you just did and not think for themselves (Livy)
- Not giving too many instructions so that students do not have to explore on their own (Livy)
- Not reviewing first, but letting students do problems right away so they have to work on retrieving that information stored in their schema (Livy)
- Mixing up practice by including past topics on worksheets and in homework randomly so they have to keep retrieving that information (Terada)
- Letting students work in groups to help each other instead of you being the one to help them

On top of allowing corrections and normalizing struggle, a growth mindset can be promoted through sharing and reviewing objectives using "I can" and "I learned" statements (Many). Teachers must create objectives for every lesson and unit to figure out how students are going to show they have met the standards and are obtaining meaning from the lesson, but "if the teacher is the only one who understands where learning should be headed, students are flying blind" (Brookhart). Researchers realized that instead of just creating the objectives for themselves, teachers should be showing their students these objectives as well so they can monitor their own learning. John Hattie found that it is most efficient to share them once they have changed the wording from students will be able to statements to I can statements so that students are able to understand it better. Then, at the end of class, students should turn those objectives around and say, "I learned _____". Turning it into an I learned statement makes their

learning “visible” to them (Hattie). Oftentimes students can get lost in the activities and forget what the overall goal is, or maybe they did not even know what the overall goal was in the first place, so they never realize that they are learning what the teacher wanted them to. But, when they are told the goals at the beginning of class in these student-friendly terms, and then check in to see if they have learned them at the end of class, they are encouraged to see that they did learn something that day. This helps show that even if they don't realize it at the time, as they are working hard through problems or experiments, they really are learning, helping to prove to them that intelligence is not fixed, but is growing every day, forming that growth mindset within them.

Finally, one of the most profound yet simple ways to promote a growth mindset is being intentional about word choice. Words are extremely powerful and oftentimes students will tell themselves that they do not get something and cannot do it because it is too hard. It is crucial to teach them how to change their wording. An easy way to implement this is by creating a bulletin board that has typical student phrases, such as “I don’t get this” and then one next to it with a better way to phrase that, such as “I need to keep working at this in order to understand it better”. Then, each time a student says one of these negative phrases, point to the board and make them restate it using the positive message. Over time, they will naturally start to use the more positive messages. An example of what this bulletin board could look like is in the table below.

Don’t say this	**Say this**
I give up.	I’ll take a deep breath and then try a different strategy!
This is too hard	I will need to work hard, but I can do it!

He/She is so smart. I'll never be like that.	I should ask him/her for help!
It is good enough	Is this my best work?
I'm so stupid	I just need to try again!

(Reed)

In addition to this bulletin board, one word a teacher should spend time emphasizing is the word "yet" (The Power of Yet). "Yet" is an extremely powerful word that teachers and students can use to show that they do not understand something or cannot do it yet, but if they work hard and learn more then they will be able to do it eventually. There is a great scholastic magazine linked below dedicated to "The Power of Yet" which can be used at the beginning of the year to make this point to students. Then throughout the year, the teacher needs to uphold the use of this word. When they hear kids say something negative, they can decide to either use the bulletin board or just add yet to change their words into more positive ones. These little changes in the words used in the classroom will help promote a growth mindset because students will constantly hear the message that they can obtain that knowledge or level of ability at some point, they just need to put work in to get there. It is important that teachers follow these same rules, not just the students.

Scholastic link here: file:///Users/finns/Downloads/retrieve%20(2).pdf

Role Models

The last factor that causes girls to not have confidence in STEM subjects is that they do not have role models to look up to. Role Models are key figures in one's life. Whether a personal friend or family member, a celebrity, or even a character from a book, the person you view as a role model inspires and shapes you into the person you become, and may lead you into the career you pursue. The most impactful role models, who inspire someone to follow in their footsteps, are the ones in whom we can see ourselves. This idea of "one's mental representation of what one could become in the future" is called the possible self (Stout). It is much easier to see your possible self in someone who is similar to you, such as someone of the same gender, race, or background. If someone like you was able to attain a high-level position or make a positive change in the world, then it gives you the confidence that you can too. Therefore, the most impactful role models for young girls in terms of STEM are successful females in various STEM fields.

Unfortunately, a nationwide study shows that only 30% of all girls in middle school, high school, and college have a role model within the STEM field that is female (AAUW). This is because there are so few females in STEM fields, and even when they are, they are not often portrayed. Instead, what is typically broadcasted to the world is the white lab-coated Albert Einstein type or "the mad scientist, the geek" (Washington). This single story of the crazy old male scientist represents all the STEM fields and it creates "perceived dissimilarity" in girls, decreasing their interest in STEM (Washington). Since they cannot see themselves in a male, they look at their male role models and think "He is nothing like me, I could never be like him" which actually does the opposite of inspiring, it makes them stop trying. Since girls only see men in certain STEM fields, they feel they do not belong there. This idea of "if you don't see it, you

can't be it" (Washington) is one of the driving factors for why girls turn away from STEM at such a young age.

Two personal testimonies from Dr. Maria Halili and Professor Jennifer L. Martin exemplify this idea. As they were interviewed, they both reflected on graduate school and how their role models, or lack thereof, determined what field they chose to go into. Dr. Maria Halili went to graduate school for engineering. She recalls how; "the lectures were presented by men … I can recall looking for someone I could talk to. I found no one in engineering" (Halili). She goes on to explain in the interview how despite performing well in all her classes, she dropped the major because she simply could not see herself in that field anymore. She found one of her female professors extremely inspiring in one of her other classes so she ended up changing to that major, completely altering the course of her life. On the other hand, Professor Martin recalls how her high school physics and chemistry teacher was a woman, her doctorate program was headed by a woman, and the Nobel Prize winner Dorothy Hodgkin visited her graduate class. She was so inspired by these women and recalled how she saw that "there were people like [her] and ahead of [her] on the career path, who had excelled in their field" so she knew that she could do it as well (Halili). She stuck with physics; and even went on to get her doctorate in it, because she had so many female role models that showed her it was possible. Both women interviewed acknowledged that having female role models or not was the make or break for pursuing their specific STEM career (Halili). With over half of all women lacking a female STEM role model, it can only be imagined how many people like Dr. Halili are out there who dropped the idea of entering a specific STEM field because they could not see themselves in it.

One study done at the University of Massachusetts at Amherst also looked into the impact of female vs male professors acting as role models in STEM. This study analyzed the

results of two college Calculus classes in the Spring semester. Both of the syllabi were the same, as well as all the tests. The only difference between the two classes was that a male was teaching one class and a female the other. What the results of the study found, through surveys and observation, was that female students were greatly impacted by the gender of their professors, while males were barely affected at all. When the students took a survey, the majority of females in the class with the female professor checked off the "liked" math box, while significantly more of the females in the class with the male professor checked off the "strongly disliked" math box. Additionally, female students with the female professor estimated much higher grades for themselves than the female students with the male professor, even though the courses were all around the same level. Observers of this study also noted that females participated much more frequently with the female professor than the male (Stout). Clearly, this demonstrates that when females have someone in whom they can see themselves, they are likely to be more confident and work harder. These female professors became role models for their students simply by being successful in that field which gave them hope they could do the same. The study continued into future semesters as observers checked in with students in other math classes. They found that the females who had taken Calculus with the female professor remained confident and were able to overcome difficulties even if the next class they had was with a male professor (Stout). Therefore, proving that even having just one female role model can influence women in years to come. The one female math professor they had gave them confidence in all their future classes all throughout college. If kids had these role models at a young age, imagine the foundation it would set for the rest of their lives.

But role models do not only have to be those that you personally know. Many people state that their role models are celebrities, historical figures, or even people who are not real at

all, such as movie or book characters. Since there is a lack of female role models in STEM in real life, characters could be a great way to make up for some of that deficiency. Unfortunately, though, the film and book industry only exacerbates the problem of a single story by having mostly male figures depicted in STEM roles.

Geena Davis Institute on Gender in Media conducted a study that researched all STEM characters on shows and movies being streamed throughout the past decade. They found a total of 1,007 STEM characters. 62.9% of these characters were male compared to 37.1% who were women. Additionally, researchers found that within these characters, the men were more frequently leads while the women were in supporting roles. These female characters also matched up with the areas of STEM that women typically go into. For example, 65.8% worked in the life sciences and only 2.4% worked in engineering. The researchers then focused specifically on children's shows and found that 59.3% of STEM characters were male and only 36.3% female (“Portray Her”). This means that young children watching television are getting the impression that STEM is for men ingrained in their brains, and this idea only grows stronger the older they get.

At the end of collecting their data, the researchers distributed a survey that asked females how influential STEM characters were to them to see if their data truly mattered. An overwhelming 82.7% responded that seeing female STEM workers on television was very important to them (“Portray Her”). They ranked which female roles had the greatest impact on them. The top ten are listed below.

1. 79.0% - April Sexton, Chicago Med
2. 78.5% - Addison Montgomery, Private Practice
3. 77.7% - Temperance Brennan, Bones

4. 76.7% - Meredith Grey, Grey's Anatomy
5. 75.9% - Abby Sciuto, NCIS
6. 75.6% - Abby Lockhart, ER
7. 74.3% - McKeyla McAlister, Project Mc2
8. 73.0% - Alexx Woods, CSI:Miami
9. 68.7% - Dana Scully, The X Files
10. 64.1% - Amy Farrah Fowler, Big Bang Theory
11. 63.9% - Mindy Lahiri, The Mindy Project
12. 51.4% - Doc McStuffins, Doc McStuffins

("Portray Her")

As a result, it became clear to the researchers that characters can have a large impact on females, so what characters young girls see on TV is very important. This remains true with characters in books as well. Whether in real life or a character, who girls look up to greatly affects who they think they can become. Without role models that look like them, they think they cannot enter STEM fields.

Role Models Solutions:

The previous section explained how women are greatly influenced by having a role model who is a female in STEM, even if it is just a character on a television show they watch. Unfortunately, these female role models are hard to come by since there is such a lack of females in STEM fields and even if a female is in a particular STEM field, they do not get the spotlight often. Therefore, teachers cannot rely on their female students being able to find these role models on their own, they must supply them.

One effective way to supply those role models is to have female members of the community who work in various STEM fields come into the classroom to speak. Dr. Nadia Lopez testifies that having members of the community come in to speak to students is one of the best ways to show them that it is possible to achieve great things right where they are with what

they have. Dr. Lopez ran a school, Mott Hall Academy, in Brooklyn New York, a place where Black men often get swept into gang life, violence, and drugs. In order to combat these stereotypes, Dr. Lopez had men from the community who were successful, such as business owners and janitors come into her classes to show her boys that it was possible to succeed in their environment as black men (Lopez). Lopez's idea does not only work for black men though, it transcends across all different minority groups. People need to see someone who looks like them achieve what they never thought was possible before they can start to believe it, or even dream it for themselves. This is why having female STEM workers come into classrooms is crucial. These women can be from anywhere, but ones who students might know, such as mothers or people who they see around town, should be a priority. When New York University evaluated who the best role models for STEM were they found that when "the model likes to do 'regular person' things in their spare time", kids can relate to them better and see that they are not some larger than life genius, but a normal person who is simply dedicated and successful (Devitt). Therefore, having people from the community, who students might know from real life and see as "normal" is even better than simply being a stranger. By bringing these females into the classroom, girls can start to imagine what their own life could look like one day if they followed the same path. This plan to bring people into the classroom to speak is more feasible now than ever before thanks to modern technology. If someone cannot make enough time to come into the class or lives too far away, since not every single one *has* to be from the same community, then they can join through a video call.

Another way in which modern technology can assist teachers in giving girls more female STEM role models is through social media posts. Most teachers today have Personal Learning Networks or PLNs. A PLN is a social media account that teachers have solely for professional

reasons. Many teachers give out their PLN to parents so they can stay up to date on current lesson plans they will be executing in class or just to get general announcements more quickly. On this PLN, teachers could post photos, articles, or videos about females who have done something noteworthy in STEM. This could also be shared through emails and weekly or monthly newsletters. Including parents in these conversations is crucial because they have the power to extend these thoughts beyond the classroom and into their child's real life (Olsen). Teachers are providing parents with an easy way to initiate conversations with their daughters by posting things that they can look at together and discuss (Forbes).

Depending on how old the students are, teachers could also write an influential female STEM worker's social media handle on the board and recommend that they follow them themselves. On average, children ages 6-11 spend almost 2 hours a day during the week and 2 hours and 45 minutes on the weekend, and ages 12-17 spend about 2 ½ hours a day during the week and almost 3 hours a day on weekends on various media (Kearney). They have so much exposure to media so giving them suggestions of who to follow can help them see more positive things and continue to inspire them outside of school. Then you can ask students about what they have seen and share it with the class. Additionally, you could recommend a good show that has a female STEM lead, such as Doc McStuffins for the younger elementary grades, which also makes their media time outside of school empowering.

Watching TV or scrolling through socials that portray female STEM role models is highly effective, as proven in the previous section. Most of these strategies are focused on giving students resources to help them find role models outside of the classroom. The typical in-class version of this is through using books. The characters in books can become role models for students just as characters from a show can. Many people have spoken on the issue of a single

story being shared through books, especially children's books. When students don't see themselves in the stories, they don't feel connected to them (Ngozi). However, although there are not nearly enough, there has been an increase in females in STEM books for children in recent years. Every year NSTA provides a list of the best K-12 STEM books. Below is a list of some of these books that have female leads, and that are written by women, that you can fill your classroom library with ("Outstanding Science Trade Books for Students K–12 2022.").

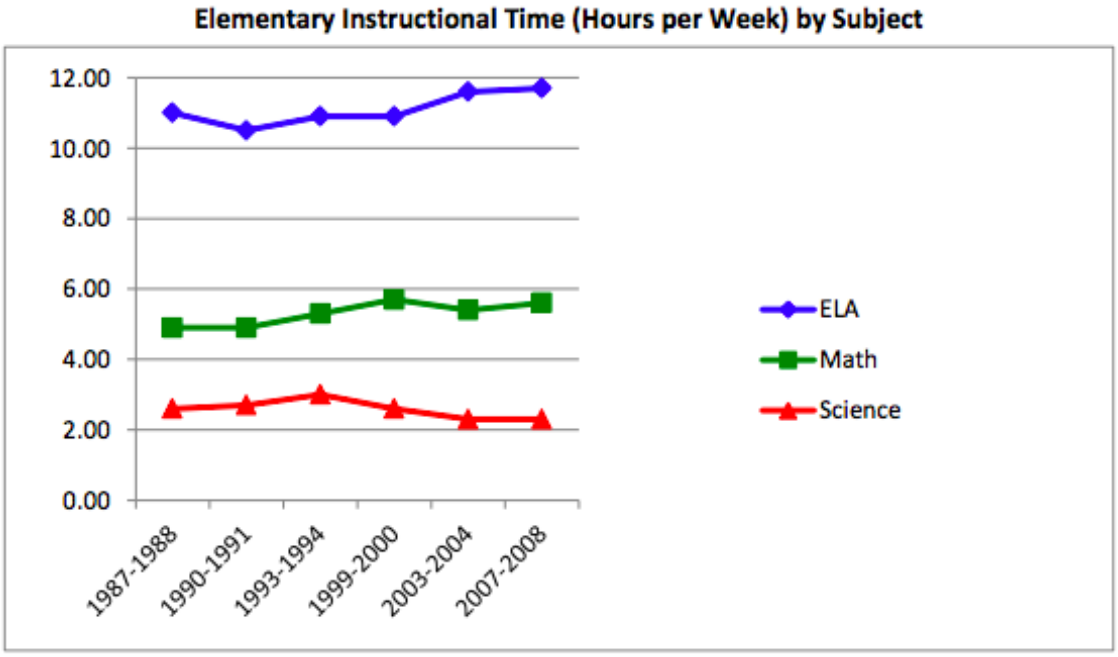
- *How to Hear the Universe: Gaby González and the Search for Einstein's Ripples in Space-Time*
- *No Boundaries: 25 Women Explorers and Scientists Share Adventures, Inspiration, and Advice*
- *Blast Off!: How Mary Sherman Morgan Fueled America into Space*
- *Fearless World Traveler: Adventures of Marianne North, Botanical Artist*
- *Saving Sorya: Chang and the Sun Bear*
- *She Persisted: Virginia Apgar*
- *Wonder Women of Science: Twelve Geniuses Who Are Currently Rocking Science, Technology, and the World*

These stories can be used in much more than just designated science times. So many of these stories fit into non-science or math standards. For example, the fifth-grade standard [5.T5] "Slavery and the struggle for civil rights for all" could be used as you read about a black female scientist or mathematician who was restricted because of their skin color (Massachusetts Department of Elementary and Secondary Education). The whole group read-aloud during English blocks would also be a great place for these stories. Plus, teachers could simply put these stories into their classroom libraries so children who are interested in them can read them during independent reading times. They could also be incorporated into stations through virtual libraries, or audiobooks. Another similar strategy is to assign podcasts for students to listen to about STEM in general or about a female's life who works in STEM. The school-appropriate podcast titled "Fierce Girls" is designed to empower young girls and has several episodes on

STEM topics, such as females who are astronauts, doctors, and pharmacists. A few of these episodes are listed below: (Fierce Girls)

- “Andrea Boyd — the girl who became the voice of space”
- “Dr Abigail Allwood — the girl who looks for life on Mars”
- “Catherine Hamlin — the girl who helped the women that no one else would”

The more you include science across all subjects, and the more you have it evident around your classroom, the more that students will start to see you as a scientist yourself. If you are knowledgeable and passionate about a subject, they will see you as an expert in that area and you can become the role model. As noted earlier in the UMASS Amherst study, simply having one teacher who is viewed as a female STEM role model can impact students for the rest of their lives. Since almost all elementary and middle school teachers are female, this is a great opportunity to give girls a role model so young. Unfortunately, across the United States science is only being taught on average for 2.3 hours a week which is almost five times less than ELA, and math for 4 hours a week, which is almost three times less than ELA (Blank). See graph below.



Source: SASS Public School Teacher Survey. Standard errors for average hours by subject and year vary from 0.03 to 0.10. http://nces.ed.gov/surveys/sass/tables/sass0708_005_t1n.asp

Due to this, students typically associate their teachers more with English than math, and especially not science. If students do not associate you with a subject, then you cannot become their role model in it. This is why incorporating science and math lessons into other areas, primarily ELA blocks which are most focused on in the younger grades, can be helpful for students to see you as experts in those fields which can inspire them that they can become experts as well.

By having a few female STEM workers come into your room throughout the year, creating a PLN and posting about important innovations women have assisted in, updating your classroom library to contain books with lead females in STEM, and dedicating more conversations to STEM topics, you can supply girls with numerous female STEM role models in a single school year. Although time-consuming, because it is more difficult to find these books and videos about females, a little extra effort can be life-changing for female students.

Conclusion

In today's society, women consist of only 27% of workers within the STEM fields while men make up the remaining 73% (Martinez). This literature review explored that in addition to factors such as workplace sexism and maternal guilt, one of the main causes for this drastic gender difference is due to the lack of confidence that females have in STEM subjects. This lack of confidence begins in the Elementary and Middle School grades, where they internalize teacher bias, begin to develop a fixed mindset, and are not introduced to many female STEM role models.

When teachers hold the belief that the girls in their class are not as good in science and math as the boys, they pass that belief on to their students. Constantly telling girls that they are not as good, even in subtle, unconscious ways slowly causes them to lose their confidence in those subjects and turn away from them. During this time in life, girls also begin to develop a fixed mindset regarding STEM subjects. They believe that their grades are a result of how smart they are, not about how hard they work. This causes girls to correlate bad grades or making a mistake on a problem with their lack of intelligence, decreasing their confidence in that topic. Once they believe that they are not smart in science or math, they begin to distance themselves from those subjects and focus on others they excel in. Finally, since young girls have so few role models who are women in STEM, they simply do not even realize that they can go into the field. People want to be like those they see, and if they don't see women in STEM, then they can't even dream of becoming one of them someday.

However, this thesis also outlines several different solutions for each cause of this lack of confidence in girls in Elementary and Middle school grades. If teachers are willing to make changes in their teaching to not show their own bias, promote a growth rather than fixed mindset,

and give several female role models to their students, then they can change the stigma of girls in STEM. By doing all of the things discussed in this essay, teachers can show girls that they can become scientists, mathematicians, engineers, or whatever else they want to be one day. Teachers can spark the dream inside the girls of becoming a woman in STEM since “The dream begins, most of the time, with a teacher who believes in you, who tugs and pushes and leads you on to the next plateau” (Dan Rather). A teacher's duty is to give students the knowledge to accomplish their dreams, but knowledge combined with confidence is what leads them to pursue those dreams.

We don't know what the future holds, out of nowhere there could be an outbreak of a disease like leprosy which Jean Watson cured, or a new need for an intention to promote safety, such as the windshield wipers which Mary Anderson made, or even another mission in space, like the race to the moon that Mary Jackson, Katherine Johnson, and Dorothy Vaughan spearheaded. Without these women our present would not be what it is, but without more women in STEM, our future will not become what it could be. We need more girls to go into the Science, Technology, Engineering, and Mathematical fields, and Elementary and Middle school teachers can make that happen.

Works Cited

Alber, Rebecca. "Gender Equity in the Classroom." *Edutopia*, George Lucas Educational Foundation, 27 Jan. 2017, https://www.edutopia.org/blog/gender-equity-classroom-rebecca-alber.

"All Nobel Prizes." *NobelPrize.org*, 2022, https://www.nobelprize.org/prizes/lists/all-nobel-prizes/.

Beilock, Sian L, and Et. al. "'Female Teachers' Math Anxiety Affects Girls' Math Achievement.' ." *PNAS*, Columbia University, Jan. 2010, https://www.pnas.org/doi/full/10.1073/pnas.0910967107 .

Blank, Rolf K. "What Is the Impact of Decline in Science Instructional Time in Elementary School? ." *NAEP*, 2014, https://oregonscience.org/resources/Documents/TOST/2018/NAEPElemScienceData.pdf.

Brookhart, Susan, and Connie Mass. "Learning Targets on Parade." *ASCD*, 1 Oct. 2014, https://www.ascd.org/el/articles/learning-targets-on-parade.

Cheryan S, et al. "Why Are Some Stem Fields More Gender Balanced Than Others?" *Psychological Bulletin*, vol. 143, no. 1, 2017, pp. 1–35., https://doi.org/10.1037/bul0000052.

Cimpian, Joseph R, et al. "Have Gender Gaps in Math Closed? Achievement, Teacher Perceptions, and Learning Behaviors Across Two ECLS-K Cohorts." *Sage Journals*, 26 Oct. 2016,

https://journals.sagepub.com/doi/10.1177/2332858416673617#bibr47-2332858416673617

Clark, Sheri L., et al. “Women’s Career Confidence in a Fixed, Sexist STEM Environment.” International Journal of STEM Education, vol. 8, Jan. 2021. EBSCOhost, https://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1315872&site=ehost-live&scope=site.

Correll, Shelley. “The Myth of the Male Math Brain .” *AAUW*, Stanford University, https://www.aauw.org/resources/article/the-myth-of-the-male-math-brain/.

Devitt, James. “Which Role Models Are Best for STEM? Researchers Offer Recommendations in New Analysis.” *NYU*, 1 Dec. 2021, https://www.nyu.edu/about/news-publications/news/2021/december/which-role-models-are-best-for-stem--researchers-offer-recommend.html.

Duffy, Alison. “Worcester Polytechnic Institute Welcomes the Class of 2021 - and More Women than Ever.” *WPI*, 22 June 2009, https://www.wpi.edu/news/worcester-polytechnic-institute-welcomes-class-2021-and-more-women-ever.

Fierce Girls. *ABC Radio*, 22 Apr. 2021 https://www.abc.net.au/radio/programs/fierce-girls/catherine-hamlin-helping-women-in-ethopia/12502220.

Forbes, Diane. “Professional Online Presence and Learning Networks: Educating for Ethical Use of Social Media.” *International Review of Research in Open and Distributed Learning*, Nov. 2017, https://files.eric.ed.gov/fulltext/EJ1163210.pdf.

“Gender - Science IAT.” *Project Implicit*, https://implicit.harvard.edu/implicit/takeatest.html.

“Georgia Institute of Technology Student Life Stats .” *US News and World Report*, Georgia Tech, 2021, https://www.usnews.com/best-colleges/georgia-institute-of-technology-1569/student-life#:~:text=Georgia%20Institute%20of%20Technology%20has,of%20students%20live%20off%20campus.

Haimovitz, Kyla, and Carol Dweck. “The Origins of Children’s Growth and Fixed Mindsets: New Research and a New Proposal.” *Child Development*, Stanford University, Dec. 2017, file:///Users/finns/Downloads/ContentServer%20(11).pdf.

Halili, Maria A., and Jennifer L. Martin. “How to Make the Invisible Women of STEM Visible.” *Australian Journal of Chemistry*, vol. 73, no. 2/3, Mar. 2020, pp. 75–77. *EBSCOhost*, https://doi.org/10.1071/CH19286.

Hand, Sarah, et al. “Exploring Teachers’ and Students’ Gender Role Bias and Students’ Confidence in STEM Fields.” Shibboleth Authentication Request, 16 Oct. 2017, https://assumption-illiad-oclc-org.lib.assumption.edu/illiad/illiad.dll?Action=10&Form=75&Value=68676.

Hattie, John. Visible Learning for Teachers: Maximizing Impact on Learning. United Kingdom, Taylor & Francis, 2012.).

Henley, Casey. “Synapse Structure.” *Foundations of Neuroscience*, Michigan State University Libraries, 1 Jan. 2021, https://openbooks.lib.msu.edu/neuroscience/chapter/synapse-structure/.

Huang, L, et al. “Gender Diversity the Past Two Decades at the Massachusetts Institute of Technology.” *Gender Diversity across MIT*, 2017, https://kiwi.oden.utexas.edu/mit-gender-diversity.php.

Kearney, Melissa S., and Phillip B. Levine. “Role Models, Mentors, and Media Influences.” *Future of Children*, vol. 30, no. 1, Mar. 2020, pp. 83–106. *EBSCOhost*, search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1262726&site=ehost-live&scope=site.

K. Kemp. “Test Corrections Appear to Benefit Lower-Achieving Students in an Introduction to Biology Major Course: Results of a Single-Site, One-Semester Study.” *Journal of Microbiology & Biology Education*, U.S. National Library of Medicine, 30 July 2021, https://pubmed.ncbi.nlm.nih.gov/34594440/.

Kim, Myung-Seop, and Soowon Park. “Growth of Fixed Mindset from Elementary to Middle School: Its Relationship with Trajectories of Academic Behavior Engagement and Academic Achievement.” *Psychology in the Schools*, vol. 58, no. 11, 2021, p. 2175.

Labuda, Cecille Pemberton.“The STEM Gap.” *AAUW*, AAUW, 1 July 2022, https://www.aauw.org/about/.

Leaper, Campbell, Timea Farkas, and Christia S. Brown. "Adolescent Girls' Experiences and Gender-Related Beliefs in Relation to their Motivation in Math/Science and English."

Journal of Youth and Adolescence, vol. 41, no. 3, 2012, pp. 268-82. *ProQuest*, https://lib.assumption.edu/login?url=https://www.proquest.com/scholarly-journals/adolescent-girls-experiences-gender-related/docview/920816769/se-2, doi:https://doi.org/10.1007/s10964-011-9693-z.

Leeper, Angela. “The Women Who Invented Windshield Wipers; Mary Anderson and Her Wonderful Invention." *Booklist*, vol. 110, no. 15, 1 Apr. 2014, p. 77. *Gale Literature Resource Center*, link.gale.com/apps/doc/A365457384/LitRC?u=mlin_oweb&sid=googleScholar&xid=4be227da. Accessed 29 Sept. 2022.

Leprosy - “Pioneering Women in Past, Present and Future.” *RSTMH*, 5 Mar. 2020, https://rstmh.org/news-blog/blog/leprosy-pioneering-women-in-past-present-and-future.

Lerner, Phyllis, and David Sadker. “Gender Equity In The Classroom.” *GPN*, Great Plains Network, 1999, http://shopgpn.com/guides/760_0000g.pdf.

Livy, Sharyn, et al. “Challenging Tasks Lead to Productive Struggle!” *APMC*, 2017, file:///Users/finns/Downloads/retrieve%20(1).pdf.

Lopez, Nadia. *The Bridge to Brilliance: How One Woman and One Community Are Inspiring the World*. Penguin Group USA, 2017.

Many, Tom. “Crafting ‘I Can’ Statements: A Practice Worth Pursuing.” *TEPSA*, 2021, https://www.tepsa.org/resource/crafting-i-can-statements-a-practice-worth-pursuing/.

Martinez, Anthony, and Cheridan Christnacht. “Women Are Nearly Half of U.S. Workforce but Only 27% of STEM Workers.” *Census.gov*, United States Census Bureau, 8 Oct. 2021, https://www.census.gov/library/stories/2021/01/women-making-gains-in-stem-occupations-but-still-underrepresented.html#:~:text=Women%20Are%20Nearly%20Half%20of,Only%2027%25%20of%20STEM%20Workers&text=Despite%20making%20up%20nearly%20half,and%20math%20(STEM)%20workforce.

Massachusetts Department of Elementary and Secondary Education. “History and Social Science Framework.” *Current Curriculum Frameworks - Massachusetts Department of Elementary and Secondary Education*, 2018, https://www.doe.mass.edu/frameworks/.

Menéndez-Varela, José-Luis, and Eva Gregori-Giralt. “The Contribution of Rubrics to the Validity of Performance Assessment: a Study of the Conservation–Restoration and Design Undergraduate Degrees.” *Routledge*, University of Barcelona, 2016, file:///Users/finns/Downloads/retrieve%20(3).pdf.

Metcalfe, Janet. “Learning from Errors .” *Annual Review of Psychology*, Columbia University, 2017, https://www.annualreviews.org/doi/10.1146/annurev-psych-010416-044022.

Ngozi Adichie, Chimamanda. “The Danger of a Single Story .” *TED Talk*, 7 Oct. 2009, https://www.youtube.com/watch?v=D9Ihs241zeg.

Olsen, G, and M.L Fuller. “The Benefits of Parent Involvement: What - Schoolwires.” *Education*, 2017, https://tx50000103.schoolwires.net/cms/lib/TX50000103/Centricity/Domain/21/Parent%20Liaison/benefits-parent-involvement-research.pdf.

"Outstanding Science Trade Books for Students K–12 2022." *National Science Teaching Association*, 2022, https://www.nsta.org/ostb22.

Penttila, Nicky. "What Happens at the Synapse?" *Dana Foundation*, Dana Foundation, 26 Aug. 2019, https://dana.org/article/qa-neurotransmission-the-synapse/#:~:text=The%20synapse%2C%20rather%2C%20is%20that,as%20one%20hundred%20thousand%20synapses.

"Portray Her: Representations of Women STEM Characters in Media ." *If/Then*, Geena Davis Institute on Gender in Media, https://seejane.org/wp-content/uploads/portray-her-full-report.pdf .

Reed, Catherine. "Growth Mindset: Power of Positive Thinking." *The Brown Bag Teacher*, 21 July 2016, https://brownbagteacher.com/the-power-of-positive-thinking/.

"Rubrics." *SFUSD Mathematics*, https://www.sfusdmath.org/rubrics.html.

Sharp-Grier, Martina L. "CHANGEMAKERS FOR EQUITY: CTE Teacher Examine Unconscious Bias Through Micromessaging." *Techniques: Connecting Education & Careers,* vol, 97, no. 1, Feb. 2022, pp. 28-32. *EBSCOhost*, https://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=154965294&site=ehost-live&scope=site.

Sriram, Rishi. "The Neuroscience behind Productive Struggle." *Edutopia*, George Lucas Educational Foundation, 13 Apr. 2020, https://www.edutopia.org/article/neuroscience-behind-productive-struggle/.

Stout, Jane G., et al. “STEMing the Tide: Using Ingroup Experts to Inoculate Women’s Self-Concept in Science, Technology, Engineering, and Mathematics (STEM).” *Journal of Personality & Social Psychology*, vol. 100, no. 2, Feb. 2011, pp. 255–70. *EBSCOhost*, https://doi.org/10.1037/a0021385.

Terada, Youki. “8 Proactive Classroom Management Tips.” *Edutopia*, George Lucas Educational Foundation, 7 Aug. 2019, https://www.edutopia.org/article/8-proactive-classroom-management-tips?gclid=Cj0KCQjwocShBhCOARIsAFVYq0h0GgqDVkhmTdfrgq3V7Z2OtaguSshAfRLdaQTRtVpSq2nvqGIpDg8aAgYdEALw_wcB.

The Power of Yet. Scholastic News, Sept. 2020, file:///Users/finns/Downloads/retrieve%20(2).pdf.

Towns, Ann. “The Status of Women as a Standard of 'Civilization'.” *European Journal of International Relations*, SAGE, 2011, file:///Users/finns/Downloads/The_Status_of_Women_as_a_Standard_of_Civ.pdf.

Washington, Jesse. “Declining Numbers of Blacks Seen in Math, Science Fields.” *Community College Week*, vol. 24, no. 7, Nov. 2011, pp. 10–11. *EBSCOhost*, search.ebscohost.com/login.aspx?direct=true&db=aph&AN=70489050&site=ehost-live&scope=site.

“2021 AP Program Summary Report.” *College Board*, 2021, https://reports.collegeboard.org/media/pdf/2021-ap-program-summary-report_1.pdf.