STEM Interest in Elementary School Children

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ABSTRACT

STEM is a fast-growing field, and it is becoming increasingly important with technological innovations; however, the STEM workforce is still predominantly composed of men. This paper will highlight how these gender disparities may be emerging at a young age by examining differences in female and male self-efficacy and the impact of the school environment. It will also provide an alternative model to the STEM pipeline. The purpose of this study is to determine whether disparities are occurring at an elementary level, and if so, what factors they may be the result of. Currently, most research is focused on how these disparities emerge in higher education; thus, this research aims to see if there is another key group being excluded by existing research.

Introduction

In examining the different fields that comprise the term STEM, there are notable differences between the fields that make up the acronym STEM (science, technology, engineering, and mathematics). For example, mathematics is the only field elementary students are distinctly learning. Unlike other subjects like history, mathematics concepts taught in one year are not repeated in subsequent years apart from occasional review (Schielack and Seeley, 2010). This indicates that misunderstanding prior math concepts could have a "snowball effect," which could lead to challenges in learning new concepts; such challenges may decrease students' self-efficacy and interest. In terms of science, subjects like biology, chemistry, and physics are not concretely introduced in elementary education. Instead, ideas of experimentation, scientific method, and relationships between humans and other universal systems are taught. Elementary students receive the least exposure to engineering and technology, apart from projects that utilize building skills. However, interest in these specific fields is associated with science because engineering is associated with core science subjects.

Self-efficacy and school environment have been noted as major contributors to why less women work in STEM fields. Many sources state that when going into high school, women and men have an equal interest in STEM, but by the time they graduate, women are not likely to declare a STEM major. This may be due to their self-efficacy, which corresponds to their self confidence in their skill set and ability to perform well in these subject areas. Some research papers have explored these disparities at younger levels, and they do note that women do not consistently show lower interest levels, performance levels, etc. in these subjects. School environment includes the school's resources and mentorship. Specifically, past researchers have asked whether the environment is conducive for learning STEM subjects and promoting equal opportunity among men and women. This paper will be focusing on this section to better understand where the disparities are truly occurring so society can help bridge the gap.

The paper seeks to answer the question: in the United States, how do both self-efficacy and school environment affect female and male elementary students differently in STEM areas? Previous research and localized data from a Dallas School show that female elementary students have lower self-efficacy than their male counterparts and their self-efficacy decreases from elementary school to graduation. Moreover, the school environment has an impact on female students as well because there is little female mentorship and or discussion of female STEM figures, which does not provide a conducive environment to encourage female participation in STEM.

Elementary Students' Thinking

When learning different concepts, assignments related to science will often include interactive activities where students can test and develop their spatial skills, which is essential for physics concepts (McClure, 2017). These activities can include building "rollercoasters" with the objective to get a marble from point A to point B through a series of ramps. This will appear deceivingly simple to most adults; however, there is an involved thinking process occurring for elementary students (McClure, 2017). In a Wonder I article, two elementary students wrote about their experiences, and it was evident that they displayed scientific curiosity and skill as they used experimentation. They were able to determine that the higher a ramp is, the faster the marble will go, and provide other variables to experiment with for future inquisition (Beeth and Huziak, 2002). Adults, misunderstanding the importance of the relationship between these assignments and their impact on students, can discourage them and decrease interest and exposure, which can have negative effects since "early STEM exposure is critical for later educational outcomes" (McClure, 2017).

Moreover, while technology is not directly taught at an elementary level, it is introduced in some capacity, and understanding the skills associated with this field can aid in developing appropriate teaching methods. It is widely accepted that project-based learning provides students with more opportunities to apply their knowledge and develop their communication and collaboration skills, which is important in all STEM fields (Hung, ang, Huang, 2012). Apart from this, elementary students learn several other subjects like English and Social Studies. In developing the skills necessary for STEM, it can be important to understand how these are also nurtured in other classes, which suggests an interdisciplinary approach.

Social Studies includes a range of history and social science topics to help students develop skills and knowledge "for civic competence" (Solomon, 1987). While the objective of social studies is to understand how different ideas and ways of thinking influenced current knowledge and events, it is rarely approached in this fashion. In U.S. education, it is often taught by memorizing mundane facts and knowing a basic timeline of American history (Solomon, 1987). However, the aim of this class corresponds to skills in science because it is important for students to understand scientists' past thinking and the emergence of scientific principles and theories (Ingram, 2009). Thus, a holistic attitude towards school environment and children's thinking development can cultivate students' interest in STEM.
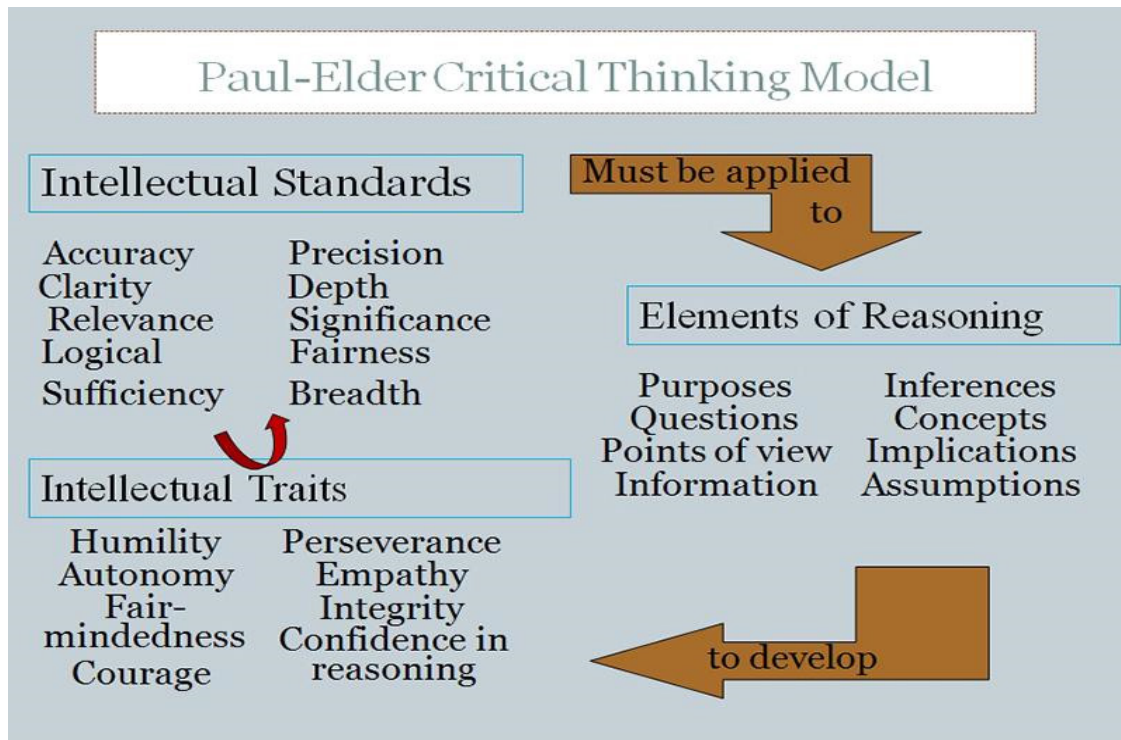
Figure 1. Paul- Elder Critical Thinking Model

The Paul-Elder Critical Thinking Model introduces a basis for critical thinking and its implications for development, which corresponds to reasoning in STEM. For instance, intellectual standards based on "accuracy" and "logic" relate to the scientific method and other thinking processes (Lee, 1943). Applying this to how students ask questions, understand concepts, and form assumptions can widen the scope of this method to promote critical thinking and creative thinking (Moeller, Cutler, Fielder, 2013). Finally, this develops courage and confidence in reasoning, which are important attributes associated with retention in STEM fields and developing interest (Lee, 1943).

Male and Female Thinking and Emotions

From birth, there are few neurological differences between males and females, yet there are growing disparities in interest and performance in STEM subjects. However, experience changes brain structure and function and is a contributor to these emerging gaps (Eliot, 2010). Maternal care has a significant impact on a child in terms of memory function and altered stress responses, which corresponds to how students behave when encountering challenges within subjects and developing a conceptual understanding of school material (Eliot, 2010). Science and math subjects involve frequent tests as the concepts can become more abstract, making them more difficult to comprehend (Clements and Sarama, 2016). It is important to note that the concept applied to maternal care extends to any mentor figures in one's life, which includes school faculty and specifically teachers.

Additionally, differences in experiences start with stereotypes and perceptions of gender. Boys are expected to have more aggressive tendencies, "while girls are presumably encouraged to be gentle, nonassertive, and passive" (Restak,1979). This notion can inadvertently lead to discrimination in the classroom and behavioral discrepancies. For instance, girls may be less inclined to raise their hands when they need assistance. Girls tend to be more aware of social cues, which can lead to "sensitivity" in engagement because they are more reaction focused (Restak,1979). In contrast, boys become more fixated on inanimate objects rather than a person, which indicates spatial ability but also

can be a contributor to lack of focus (Restak,1979). Discrepancies occur in male and female teachers as male teachers give more approval and nurturing to boys while female teachers do this more with girls (Perdue and Connor, 1978). The differences between boys and girls are not differences of intelligence or capability but thinking and behavior. This indicates that when environments do not adapt to account for these differences, it results in gender disparities in STEM.

Elementary Students Self-Efficacy and Varying Attitudes

An elementary students' relationship with STEM is dependent on their self-efficacy. STEM subjects are notoriously considered difficult; in fact, math anxiety can act as a barrier to math performance, and in turn, affect interest level (Erturan and Jansen, 2015). Math anxiety differs for girls and boys as girls tend to have more anxiety and score lower on math achievement assessments (Erturan and Jansen, 2015). However, they generally have better grades. This means girls feel less prepared for tests and have less confidence in their abilities to perform well. These discrepancies are correlated with learning values and social construction of gender. Elementary girls will often rate their own math abilities low, which can be tied to social messages that math is "more appropriate for boys" (Cvencek, Meltzoff, Grennwald, 2011).

Furthermore, a child's self-efficacy can be influenced by a teacher's confidence in their own abilities and the students'. The self-efficacy of elementary school science teachers affects their teaching because many don't feel pre-pared or knowledgeable enough to aid in their student's learning experience (Bleicher, 2007). However, through engaging in more "hands on" activities during training, their confidence increases, which has a positive impact on their student's learning. Because students benefit from immersive, project-based assignments, specifically when they pose questions and are challenged to think critically, a teacher's grasp on leading this activity is crucial. If the teacher cannot guide the students and help them explore their own ideas, then the students conceptual understanding and thinking process is limited, which can decrease self-efficacy and interest over time in STEM subjects.

Bandura's Theory of Social Learning suggests that there are four factors that influence one's self-efficacy: performance, vicarious experience, verbal persuasion, and emotional arousal (Bleicher, 2007). As noted, performance can affect how one perceives their capability. Vicarious experience is gaining confidence through observing others' performance. As discussed previously, girls tend to be more perceptive and are more influenced than boys by others' actions, which could indicate that seeing other people struggle (especially females) can decrease their own self-effi-cacy. Verbal persuasion is words of encouragement or disapproval, which can vary between boys and girls depending on the teacher and affect them differently and generally equally. However, emotional arousal may lead to an even bigger discrepancy, as stressors in performance have a particularly harmful impact on young girls. Clearly, self-effi-cacy is a contributing factor to elementary students' interest in STEM and has a more significant influence on females.

Gitanjali Rao

Gitanjali Rao is a 15-year-old girl who invented a lead detection device for water at the age of twelve. She said her inspiration to build this device came from learning about the crisis in Flint, Michigan, and she thought innovation was the best way for her to help (Crimson Education, 2020). While she developed the device in middle school, it is likely she developed the curiosity and skills required at an earlier age. In an interview with *Time Magazine*, she noted that she has been thinking about using STEM to solve problems from the time she was in the second grade. Her research on nanotube sensor technology began at ten and this research was ultimately applied to her device.

Rao has spent her recent efforts promoting STEM and inspiring youth. In *Time Magazine*, she said "I don't look like your typical scientist. Everything I see on TV is that it's an older, usually white man as a scientist…from personal experience, it's not easy when you don't see anyone else like you." She touches upon the importance of mentorship and having female role models in your daily life and in the media. Apart from her parents, who pursued science fields, Rao is heavily influenced by Marie Curie and modern scientists Emmanuelle Marie Charpentier and

Jennifer Anne Doudana. This supports the notion that learning about women scientists can support STEM interest (Mohan, 2020). Additionally, when asked about her experimental process, she explains how she did not use traditional methods. She elaborated that in school she was taught the scientific method, which illustrates how to "come up with a hypothesis, test your hypothesis, analyze your data, and come up with a conclusion and if it doesn't work, do it again" and goes on to say the engineering design process is very similar (Crimson Education, 2020). She then states that "the thing about innovation is it can be taken in your own way, you can make innovation whatever you want" (Crimson Education, 2020). Thus, being exposed to STEM and how to think in new ways helped her cultivate and maintain interest.

To explain her process and help kids implement this way of thinking into their own lives so they can develop their STEM interest, Rao wrote and published a book: *A Young Innovator's Guide to STEM*. Within the book, she has three sections: Discover, Solve, Implement. The Solve section is split into chapters detailing her coined process: observing, brainstorming, research, building, communicating, failing, and iterating. To aid the reader in implementing this process, she provides diagrams and models. For instance, in the observing chapter, she uses a fishbone diagram.
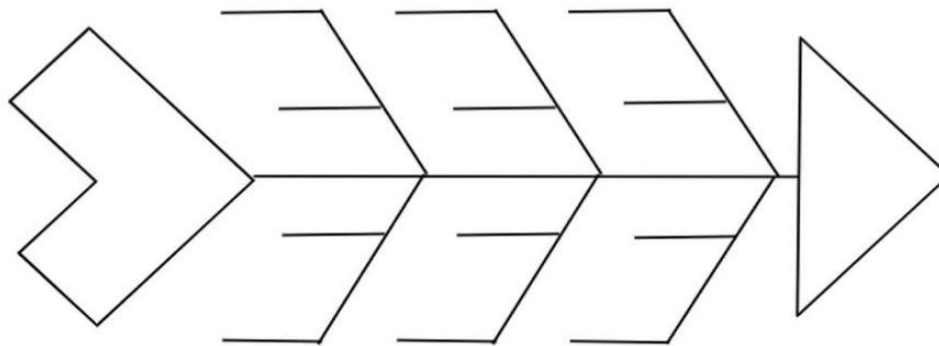
1. Fishbone Diagram

Figure 2. Fishbone Diagram, a system to identify contributing factors to a problem or a concept.

Rao explains that the first step in the innovation process is looking for a problem that you want to solve, and she suggests drawing inspiration by simply going outside. She mentions when she did this with other students that they were able to pull from their interests and their surroundings to identify problems. For instance, one girl loved plants and realized "a lot of plants have a lot of pollen, and my dad gets allergies in spring because of the flowering plants." The diagram allows the students to map out this thinking in a systematic manner while encouraging creativity and innovation. The "bones" of the fish are major causes of the problem. In forming the "belly," the student continuously asks, "why does this happen?" to form deeper causes and help them discover the root of a problem, which creates the sub-causes/smaller fish bones (Clary & Wandersee, 2010). While the method has potential problems (like coming to conclusions that may be untrue because the student is solely focusing on their prior knowledge), this activity acts as a great launching point because it challenges the student to critically think to discover true answers in the research process.

In addition, she asks the reader to answer a series of "confirmation questions":
- Is your problem worthwhile?
- If your answer is no, how can you make it more worthwhile?
- Is your problem timely?
- If your answer is no, how can you make it timelier?
- Does your problem spark further research?

- If your answer is no, how can you make it spark further research?
- After your analysis, what is the problem you choose to solve? Why?

Again, these questions make the reader critically think about the problem they want to solve by considering its purpose, relevance, implications, and why the student wants to pursue answering it. While all the questions posed are important to consider, the last question reminds the reader to pursue something they are interested in, which creates a stronger relationship between the reader and their interest in STEM. It is important that the research is based on one's own curiosity and personal experiences. Both diagrams correlate to the Paul-Elders Thinking Framework and focus on key attributes associated with success in STEM, such as critical thinking, complex problem solving, judgment and decision making, and social perceptiveness (Jang, 2016). The school environment is still important as kids learn about different thinking approaches in school. Therefore, implementing these strategies or modeling them in an elementary curriculum can aid in establishing an environment that promotes these values, and subsequently, and cultivates interest in STEM fields.

School Environment

Elementary teachers' interactions with students are a critical component in creating a nourishing atmosphere. Their teaching methods can increase or decrease interest of elementary students in STEM. An empathetic approach to their students' challenges and learning process will help teachers better support them and their needs (Rimm-Kaufman and Sawyer, 2004). For instance, if two students cannot answer a math word problem, a common response will be to review the concept. However, they may be performing poorly for different reasons. One student could be having difficulty with the arithmetic portion while another may be struggling with identifying an approach to solve it. Each case is unique and would require a different approach to fill in the gaps in their conceptual understanding. Additionally, when children ask for assistance and the teacher does not give a response suited to the child's learning style, it can lower the child's self-efficacy as they assume they may be "too dumb" or don't possess the necessary skills or knowledge to answer the question correctly (Lehane and Goldman, 1976). Again, this can have a more dire impact on girls as they are more conditioned to be "passive," which leads to less participation. (Cvencek and Greenwald, 2011). Thus, it is important for teachers to read social cues and be reflective in their interactions with students to ensure the child's self-efficacy is maintained and they have a conceptual understanding of the given material.

Moreover, the presence of gender stereotypes between students and their peers can have a debilitating effect on students' engagement and curiosity. Boys and girls will tend to form separate peer groups and establish distinct cultural identities around these groups. Small interactions for projects or activities are not sufficient because the separateness in groups leads to belief that boys and girls are very different from one another (Adler, Kless, Adler, 1992). As a result, this can lead to girls and boys treating each other differently. Specifically, since boys and girls are more impressionable at a young age, they will incorporate ideas of masculinity and femininity into their actions based on how they interact and observe others' behaviors, which influences presence and command (or lack thereof) of an environment/classroom (Adler, Kless, Adler, 1992). A school environment contributes to these ideals when students observe the interactions between teachers, faculty, and other students. Literature read by kids can also influence these stereotypes. While there have been efforts in the last few decades to ensure there is equal representation of women and men in children's books and both genders are portrayed in a positive, non-stereotypical manner, the teacher's childhood experience of more traditional, patriarchal literature remains influential in the teaching and understanding of literary works (Sadker, Sadker, Klein, 1991).
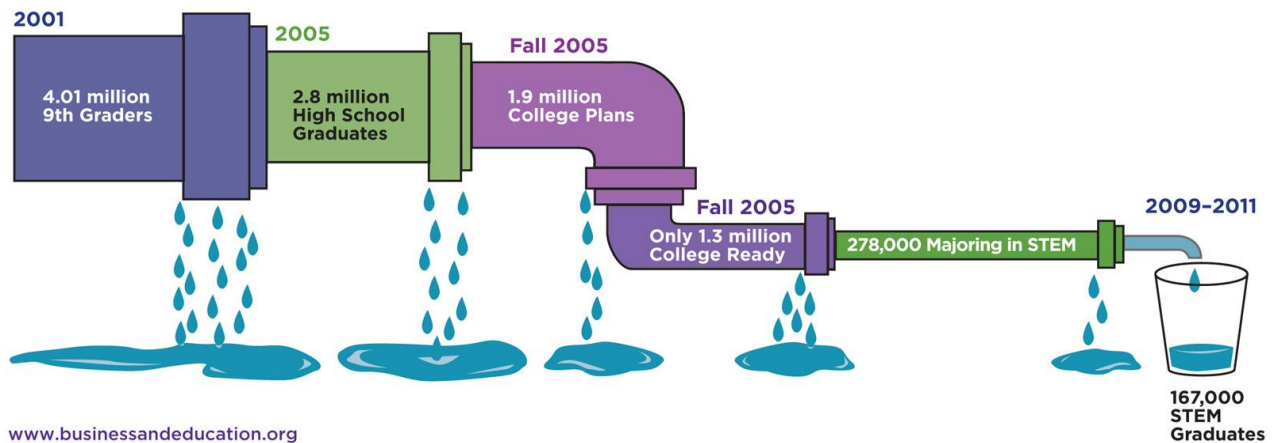
Figure 3. A Leaking STEM Pipeline about retention in STEM fields

Figure 3 shows the so-called "STEM Pipeline", which illustrates interest retention in STEM fields at various ages. As the figure demonstrates, failures in retention in STEM fields occurs at an early age. As this paper has shown, gender disparities in STEM fields occur in elementary schools. Engaging STEM experiences at the elementary level could create a smooth STEM pipeline (Peterson, 2014). Thus, the pipeline should be revised to include the number of elementary students and interests in STEM. Since the retention of female students in STEM has become a global issue and concern, the pipeline should also provide a holistic perspective on the gender balance of the "leakage" in STEM and not just retention of students. Lastly, there can be a resurgence in interest after mitigation (Ainley, 2006). In other words, a student's interest in science could decrease in elementary school and increase in middle school, so the lack of interest is not permanent. Consequently, the pipeline should address potential changes in interest to better understand in which grade levels there is a decline in retention and an increase in gender gaps.

Counterargument and Limitations

While there is evidence to support that gender disparities occur at a younger level, there is also research that supports the notion that interest for female and male students is equal when entering high school and gender disparities predominantly occur in high school and college (Ohara, 1962). Thus, more research should be conducted on students' interest in pursuing a STEM career rather than simply being interested in STEM subjects to better understand these gaps and how to solve them. Secondly, it is often assumed that gender stereotypes and disparities are not as influential at a young age because kids do not fully understand social construction of gender and societal expectations and perceptions. However, it is evident that the stereotypes affect the school environment and students' self-efficacy, which can lead to psychological changes in one's view of their abilities and expectations of themselves. Thus, whether a child consciously understands gender roles, it affects their STEM interest at an early age and potentially long-term (depending on intervention).

Recommendations for Elementary Teachers, Schools, and Librarians

Teachers should try to be aware of how they interact with students and ensure they treat the male and female students equally. This includes having equal expectations for students based on their gender and handling behavioral problems

in the same way to encourage active participation for both students. Apart from being more empathetic and situationally aware, the teachers can try and implement daily meetings with the students individually (Rimm-Kaufman and Sawyer, 2004) to discuss the student's learning style, difficulties, and how their relationship with STEM. In doing so, the student and teacher can build a stronger connection, which will help the teacher be aware of how to better support the student and make the student feel more comfortable with asking for assistance as the student understands the teacher's care and interest in their success. Secondly, the teacher should have confidence in their own skills and the child's ability to succeed under their mentorship and teaching.

The schools can ensure that there are adequate resources to develop STEM skills like experimental materials and visual aids to promote project-based activities and hands-on experiences. Schools can also ensure there is an equal number of female STEM teachers as role models to play a crucial role in a female students' self-efficacy and sense of belonging (Heidi Blackburn, 2017).

Librarians should ensure students have access to literature about science to explore their interest, as well as an equal number of biographies and autobiographies that cover female historical figures' accomplishments and journeys in STEM. This will foster an environment that supports and encourages girls pursuing STEM. Additionally, there should be up-to-date research available on gender disparities in STEM, teaching practices, elementary students' development, and STEM skills to help the schools in planning, outreach, and intervention (Heidi Blackburn, 2017).

Conclusion

This paper discusses the gender disparities in STEM and their emergence in elementary school, the resolution being integral to closing gaps and retaining students in STEM, particularly women. It has been clearly shown that girls have a lower self-efficacy than males due to gender stereotypes and experiences, which causes neurological differences. Similarly, the role of mentorship, peer and teacher interactions, and teaching practices involving STEM play a key role in the understanding of STEM concepts and student interest. Overall, the findings indicate that it is worth exploring gender and interest in STEM more deeply at an elementary level, as education at this young age can have more significant effects on retention than most researchers think. For a deeper understanding of the impact of self-efficacy and school environment on students' interest in STEM and the differences between boys and girls, data analysis should be conducted. This could be done by interviewing elementary students and asking them about the impact of the various variables covered, as well as observing their interactions, engagement, and performance in class. For further inquiries, STEM graduates and students who changed from STEM majors to non-STEM majors should be interviewed as well to reflect on the role their elementary experiences had on their career path and note when their interest deviated and spiked. Doing so may help find a pattern and determine a solution to the global problem of gender disparities in STEM.

Acknowledgments

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