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Review Article

Where Are All the Talented Girls? How Can We Help Them Achieve in Science Technology Engineering and Mathematics?

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Abstract
Women's participation in science, technology, engineering and mathematics (STEM) courses and careers lags behind that of men. Multiple factors contribute to the underrepresentation of women and girls in STEM. Academic research suggests three areas, which account for the under representation of girls in STEM: social and environmental factors, the school climate and the influence of bias. In order to engage and to retain girls in STEM, educators need to: eliminate bias in the classroom, change school culture, introduce female role models, help girls assess their abilities accurately and develop talent in areas related to science, technology, engineering, and mathematics. Educators should encourage young girls to ask questions about the world, to problem solve, and to develop creativity through play and experimentation. Women have made impressive gains in science and engineering but remain a distinct minority in many science and engineering fields. Creating environments that support girls' and women's achievements and interests in science and engineering will encourage more girls and women to pursue careers in these vital fields.

Keywords
girls, science, technology, engineering, mathematics, gifted, underachievement

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Introduction

Marie Curie, Rosalind Franklin, Lise Meitner, Barbara McClintock, Elizabeth Blackwell…do any of these names ring a bell? What about Sally Ride, Red Burns or Caterina Fake? Few of us know that the technology that operates our cell phones was designed by a silver screen star, Hedy Lamarr, in the 1940s. We may be equally unaware that United States Navy Admiral Grace Hopper was one of the first programmers in the history of computers and computer science. Women have been involved in the world of science, technology, engineering and mathematics (STEM) since the beginning. Merit Ptah (c. 2700 BCE) was an Egyptian physician; Hypatia (370–415), a mathematician and astronomer, Émilie du Châtelet (1706–1749), a French mathematician and physicist; and Caroline Herschel (1750–1848), a German-British astronomer. Women have been involved in charting planets, discovering the concepts of radiation, programming computers, and developing innovations in mathematics. In the modern era, however, the sciences and related fields are dominated by men.

Too few girls pursue STEM careers. According to STEM connector (2014), only 20 percent of STEM bachelor's degrees are held by women, and only 24 percent of STEM jobs are filled by women. A major part of the problem is that girls do not have enough female STEM role models to emulate. "There are many possible factors contributing to the discrepancy of women and men in STEM jobs, including: a lack of female role models, gender stereotyping, and less family-friendly flexibility in the STEM fields. Regardless of the causes, the findings of this report provide evidence of a need to encourage and support women in STEM" (Beede et al., 2011).

STEM is a central preoccupation of policy makers across the world. The experience of science and mathematics learning in primary and lower secondary school is related to a consideration of participation in STEM. Those experiences can establish the sense of competence that students have in the foundations of mathematics and science and can kindle their interest in science-related fields.

On the basis of the *Programme for International Student Achievement* (PISA) results for 2006 it can be inferred that Australian 15-year-olds perform well (on average) in the application of mathematical and scientific understandings to everyday problems. Only three of the 65 countries that participated in PISA 2006 Australia in Scientific Literacy. In addition, there was a difference of 26 points between the performance of males and females in Australia Scientific Literacy. These patterns of differences between males and females in Australia are similar to the average for Organization for Economic Co-operation and Development (OECD) countries although there is considerable variation among countries. In Mathematical Literacy in 2006, eight of the 57 participating countries significantly outperformed Australia (Ainley, Kos, & Nicholas, 2008). According to the PISA results for 2012, Australia's mean scores in

Science Literacy and Mathematics Literacy decreased slightly (science from 527 to 521 and math from 520 to 504). However, the difference between the performance of males and females in Scientific Literacy was reduced from 26 points to 5 points (OECD. 2013). Boys outperform girls in mathematics in 35 of the 65 countries and economies that participated in PISA 2009. On average in OECD countries, boys outperform girls in mathematics by 12 score points. In Belgium, Chile, Switzerland, the United Kingdom, the United States, and the partner countries Colombia and Liechtenstein, boys outperform girls by more than 20 score points, close to one-third of a proficiency level (OCED, 2011).

In the United States, national education policies have focused on improving the performance of U.S. students relative to their international peers, particularly in areas related to science, technology, engineering, and mathematics (National Science Foundation [NSF], 2012). One area of concern is that many students are choosing not to take advanced science and mathematics courses in high school. According to the National Science Foundation (2012), only 35 percent of high school graduates have taken precalculus and only 39 percent have taken physics. According to the 10th Annual Advanced Placement (AP) Report to the Nation (2014), only 19 percent of high school graduates take advanced placement math and science courses and only 11 percent make scores of 3 or higher on advanced placement math and science courses. Moreover, although gender gaps have closed in some STEM areas, they persist in others. For example, although girls and boys take calculus at the same rate, boys are more likely to take physics than girls, and boys are more likely than girls to take engineering in high school (NSF, 2012).

Gender gaps appear in STEM fields in many countries around the world. According to the OECD most recent report, girls "feel less motivated to learn math and have less confidence in their abilities than boys"(OECD, 2013). The PISA results reveal that overall when it comes to science, boys and girls perform similarly in science. But in Colombia, Japan and Spain a gender gap in favor of boys was observed in 2012 despite no significant difference existing in 2006.

Causes for the Underrepresentation of Females in STEM?

While women's participation in math and science professions continues to trail behind that of men, the difference is much greater in engineering and computer science than in other areas of science and mathematics (National Science Foundation, 2011). In a review of over 400 studies related to the possible causes of women's underrepresentation in STEM, Ceci, Williams, and Barnett (2009) identified reasons, including the following:

- Boys perform higher than girls in spatial reasoning and math ability, including on assessments tests such as the Scholastics Aptitude Test –

Mathematics (SAT-M) and Graduate Readiness Exam – Quantitative (GRE-Q).

- Women with high math aptitude are more likely than men with high math aptitudes to choose careers in non-math intensive areas. This differential preference appears as early as adolescence.

Although boys may outperform girls at the highest levels on math and science standardized tests, girls tend to get better course grades in math and science than boys do (Halpern et al., 2007). Additionally, standardized test scores tend to under predict girls' success in college math and science courses. According to a study by Nosek and colleagues, girls also show less interest in math and science than do boys. Girls have lower confidence in their math abilities beginning in middle school where they underestimate their math abilities. This misjudgment of their abilities and lowered confidence levels continues on into high school, (Nosek et al, 1999).

Multiple factors contribute to the underrepresentation of women and girls in STEM. After reviewing the literature, three areas emerged which account for the under representation of girls in STEM:

- Social and environmental factors that shape girls' achievements and interest in math and science
- the school climate
- The continuing influence of bias as an obstacle to women's success in STEM subjects.

Social and Environmental Factors Shape Girls' Achievement Factors in Math and Science

One possible explanation for the loss of women in STEM involves social and cultural influences. From an early age females may be influenced by expectations and stereotypes about gender roles and suitable behaviors and interests for girls. Girls may be socialized to believe that science and technology are more appropriate fields for boys (Beede et al., 2011). Girls may be treated differently than boys or they may perceive different expectations for themselves based on their sex. For example, school career advisers, teachers and parents in the Netherlands are more likely to advise boys to make academic career choices in the direction of STEM than girls, and sometimes even advise girls against such choices (Jansen, & Joukes, 2012).

People regularly form opinions and stereotypes about others before meeting them. Often these beliefs can color the way they interact with others. Individuals who belong to stereotyped groups are aware of these biases, and often respond to them in ways that are detrimental to their performance, most especially on standardized tests (Walton, Spencer, & Erman, 2013).

Also, many individuals from disadvantaged populations may internalize these negative stereotypes from a very early age and start to believe them themselves

(Walton, Spencer, & Erman, 2013). Feelings of self-doubt and lack of self-efficacy can develop, creating a self-limiting mindset. Correll (2001), reports that "boys do not pursue mathematical activities at a higher rate than girls do because they are better at math. They do so, at least partially, because they think they are better." People who believe they are capable are willing to work harder, and hard work is the stairway to achievement. Of course, this implies the opposite is true.

Boys and girls also view technology differently and have different interaction with technology. Male students have more confidence in using technology for learning than do female students (Yau & Cheng, 2012). Another issue to consider is exposure to technology. Some research supports the idea that lack of early exposure to technology for girls is contributing to the gender gap in STEM fields (Schweingruber, Brandenburg, & Miller, 2001).

Walton and Cohen (2007) revealed that in academic and professional settings, members of socially stigmatized groups were more uncertain of the quality of their social bonds and more sensitive to issues of social belonging. Walton and Cohen called this "belonging uncertainty", and they found it contributed to racial disparities in achievement. Belonging uncertainty may also contribute to the underrepresentation of women in science, technology, engineering, and mathematics (STEM) fields.

Good, Rattan, and Dweck conducted a series of studies to address the question why females might be less willing than males to pursue math-based disciplines. They tested the hypothesis that a person's sense of belonging–"one's personal beliefs that one is an accepted member of an academic community whose presence and contributions are valued"– in math can predict the desire to pursue math (Rattan, Good, & Dweck, 2012). They found that a person's sense of belonging predicted both men's and women's intention to pursue math in the future as well as other important math-related variables, such as math anxiety, math confidence, and perceived usefulness of math. These effects remained, even after taking into account prior achievement in math. In addition, prior achievement in math did not predict a sense of belonging– a finding consistent with other research that indicates a person's high ability does not ensure that that person will be intrinsically motivated to pursue the field or feel a sense of belonging for the domain (Rattan, Good, & Dweck, 2012). Girls' sense of belonging is increasingly important for their intent to pursue a career in STEM fields as well as their math or science performance.

The School Climate towards STEM

Barriers to girls' progress in STEM during their K-12 education start with the messages received in the schools. In 2006, the American Association of University Women (AAUW) conducted a survey of high school students. The survey showed that 44 percent of girls and 38 percent of boys agreed with the statement, "the smartest girls in my school are not popular," and 17 percent of girls and 14 percent of boys thought that it was true that "teachers think it is not important for girls to be good at math" (AAUW, 2010).

The literature indicates that the majority of the students in the United States who pursue STEM degrees make this decision during high school (Maltese & Tai, 2011). Therefore, students' high school experiences are important for understanding a student's success or failure in college STEM courses. Girls and women are treated differently than men in both subtle and overt ways. For example, everyday ways of conducting classroom discussions can exacerbate inequities when boys are given more attention and praise by the teacher.

Adults in the school community are powerful influencers of students' expectations. Therefore the amount of time students spend interacting with adult role models is important in aligning adolescents' ambitions toward college and career plans. Female students look to faculty as role models for balancing career and family. Women scientists benefit from role models and mentors who are aware of the different experiences of women and men in the sciences (Etzkowitz et al. 2000). A shortage of role models is another contributing influence to the underrepresentation of women in science. This shortage of role models could be directly attributed to the low number of STEM-trained teachers (Watt, Richardson, & Devos, 2013). Both role-models and mentors are important to cultivating girls' interest in STEM fields (Kekelis, Ancheta, & Heber, 2005).

Finally, there are various levels or resources are available at different schools. The number of resources and the variety of courses offered influence students' interest in STEM courses for both girls and boys. The more opportunities available for students, the more interest they will have.

The Continuing Influence of Bias

The impact of cultural bias on student interest and performance in STEM fields is well studied. In a recent large-scale study, researchers Kane and Mertz (2012) used a gender–gap index, which compares females and males in terms of income, education, health, and political participation to examine the math performance of boys and girls across more than 26 countries. The results showed that math achievement for low, average, and high achievers was higher in countries with greater gender equity. The researchers suggest that to some degree the differences in the abilities of men and women is effected by the society which live.

Implicit biases can have an impact on whether girls and women enter and stay in STEM fields. Implicit bias refers to the attitudes or stereotypes that affect our understanding, actions, and decisions in an unconscious manner. These biases, which encompass both favorable and unfavorable assessments, are activated involuntarily. Gender biases can affect students in both overt and subtle ways.

Gender bias may prevent female students from pursuing science and math from the beginning, play a role in their academic performance, and influence whether parents and teachers encourage them to pursue science and engineering careers. Studies in Israel, found girls outscored boys when graded anonymously. However, when teachers knew the name of the children, boys outscored girls. Young girls who are dissuaded were found to be much less likely to pursue advanced STEM courses later in life (Lavy, 2008).

What can We Do to Help Girls more Accurately Assess Their Abilities in Math and Science?

In both Eastern and Western developed nations, girls have closed the gender gap with boys in many areas of achievement and interest. Boys perform better than girls in mathematics in only 37 out of the 65 countries and economies that participated in PISA 2012, and girls outperform boys in five countries (OCED, 2013). Eighth grade girls have caught up with boys in math achievement (Campbell & Clewell, 1999). What can teachers do to encourage girls to choose career paths in math- and science-related fields?

One way to encourage girls to choose careers in STEM is to help them develop of strong beliefs about their abilities in these subjects. Teachers and parents can assist girls in aligning their beliefs to accurately reflect their abilities. Teachers should provide students with prescriptive and informational feedback regarding their performance and abilities. The feedback should focus on strategies, effort, and the process of learning. Feedback identifies gains in children's use of particular strategies or identifies specific errors in problem solving. Such feedback enhances students' beliefs about their abilities, typically improves persistence, and improves performance on tasks (Halpern et al, 2007). Students often receive feedback about their performance in the form of grades, test scores, or statements from teachers regarding the accuracy of a response. However, not all forms of feedback are equal in terms of their impact on students' beliefs about their abilities or in terms of their impact on performance. When teachers provide specific, informational feedback rather than general praise, students' beliefs about their abilities and their performance are positively influenced (Halpern et al, 2007).

Mentors can teach girls that academic abilities can be expanded and improved, as well as encourage female students to work hard to overcome setbacks and accept new challenges. Mentoring programs may provide many girls with exposure to and connections with a woman who has succeeded in math and science. Mentors can positively affect young adolescents' behaviors (Halpern et al, 2007). Teachers may choose to support a young girl's interest in math or science by helping her to find a suitable mentoring program. Girls and young women need female role models who have succeeded in math and science. Research shows that negative gender stereotypes can create problems for girls and women on tests of mathematics (Aronson & Steele, 2005). "Exposure to female role models who have succeeded in math has been shown to improve performance on math tests and to invalidate these stereotypes" (Halpern et al, 2007). Teachers can also create a classroom environment that sparks curiosity and avoids math/science activities that reinforce existing gender stereotypes. Research suggests that curiosity can serve to engage students in math and science content (Hidi & Renninger, 2006). Once students' interest in a topic or content area is sparked, teachers can then build on that curiosity, providing students with opportunities to engage with interesting material and potentially transforming that initial curiosity into long-term interest (Halpern et al, 2007).

The American Association of University Women made several recommendations for K-12 educators. Teachers and parents should encourage girls to have a growth mindset by telling girls that their intelligence can improve. Mindset is a concept developed and studied by researcher Carol Dweck. According to Dweck, in a growth mindset, people believe that their most basic abilities can be developed through dedication and hard work (Dweck, 2006). Also known as an incremental view of ability, this view creates a love of learning and a resilience that essential for accomplishment. When students perform well on math tests, they are more likely to say they want to continue to study math and science in the future (AAUW, 2010). "Students with a growth mindset consistently try to stretch themselves beyond their comfort zone to learn new things" (Deweck, 2012). Teachers need to express the values and practices of the growth mindset (Dweck, 2012).

Girls typically assess their mathematical abilities lower than do boys with similar mathematical achievements (Heilbronner, 2012). Adults can combat the tendency that girls have to assess their mathematical abilities as lower than they really are, by spreading the word about women's achievements in math and science and highlighting that girls and boys achieve equally well in these fields. Parents and teachers can build awareness of harmful stereotypes and encourage girls to assess their skills more accurately. Parents and teachers can encourage middle school girls with mathematics potential to participate in their local talent search. Schools can also help girls in assessing their skills by build spatial skills training into the curriculum. Spatial reasoning skills may be critical to scientific reasoning (Ganley, Vasilyeva, & Dulaney, 2014). Research indicates that spatial ability is significant for talent identification (Webb, Lubinski & Benbow, 2007). The studies by Lubinski on spatial ability for very high achievers show that "tilt" especially predicts STEM achievements (Lubinski, 2010). Advocates for this approach have noted that the correlation between spatial ability and several measures of STEM achievement suggests that spatial training should focus on improving students' spatial ability (Stieff, & Uttal, 2015). Additionally, high school girls should be encouraged by both teachers and counselors to take calculus, physics, chemistry, computer science, and engineering classes. Teachers should help girls recognize the ways in which their success in high school math and science can lead to careers in these fields.

How Do We Develop Talent in Areas related to Science, Technology, Engineering, and Mathematics?

Given the need to identify and develop promising and already accomplished students and to provide a conduit of STEM talent, the question arises, what can be done to develop talent in STEM areas? Subotnik, Edmiston, and Rayhack (2007) suggest that one of the first steps in developing talent is to discover the potential available. In other words, the talent should be expanded both in individual students and in society as a whole. The goal and purpose of discovering potential in the STEM areas should be to maximize the number and levels of promising students and not to limit the numbers of students in specialized programs. Also, educators need to seek out and identify diverse students. Aptitudes and abilities of students, regardless of gender, ethnicity, language or socio-economic background, can and should be recognized in order to help them achieve their full potential. In addition, a variety of identification measures should be used to identify STEM talent (observations of problem-solving, portfolios or research, recommendations, off-level test, especially spatial, etc.).

The National Association of Gifted Children Math and Science Task Force recommended that educators need to develop talent and strengthen opportunities at all grade levels (Adams et al. 2008). All students have STEM potential and should be provided powerful and rigorous STEM experiences. All students should take appropriate, rigorous mathematics and science classes every year from elementary through high school. Technology and engineering curriculum should be an essential part of the K-12 education. Students of any age should be allowed to progress freely to higher-level classes once they demonstrate depth of understanding of course content. Additionally, the National Science Foundation made the following recommendations help develop STEM abilities. Educators should provide opportunities for excellence. We cannot assume that the most talented students will succeed on their own. Educators must offer both formal and informal interventions to develop their abilities. Students should learn at a pace, depth, and breadth corresponding with their talents and interests and in a fashion that produces engagement, intellectual curiosity, and creative problem solving (NSF, 2010). Additionally, educators should cast a wide net to identify all types of talents and to nurture potential in all demographics of students.

Another way to develop STEM talent is to create opportunities for learning high-level, innovative mathematics, science, technology and engineering, where students can work with peers of similar interests and abilities. Opportunities should include the investigation of rich, complex problems, conducting authentic scientific research, undertaking engineering design challenges, joining STEM clubs, entering STEM contests, and accessing mentors (Subotnik, Edmiston, & Rayhack 2007). Some opportunities might include: special schools that emphasizing STEM subjects; after school or summer programs focused on providing hands-on opportunities to work in an authentic STEM context such as a laboratory, hospital, or museum; or competitions.

The Southeast Comprehensive Center (2012) suggests that teacher preparation programs need to be modified to provide deep content knowledge and requisite pedagogical skills to help increase the number of high quality teachers in math and science. The National Science Foundation recommendations say to, "encourage pre-service education and professional development for education professionals (including teachers, principals, and counselors) in the area of STEM talent identification and development. Education schools and other teacher preparation programs should emphasize teacher preparation in all areas of identification, including spatial ability recognition and the identification of talented underrepresented minorities" (NSF, 2010). Furthermore, early exposure to STEM is particularly important, since interest in STEM often begins to blossom in elementary school, and early exposure to science can strongly influence future career plans (NSF, 2010). Also, educators can utilize professional learning communities to enhance teacher instructional practice and improve student achievement in math and science. Teachers should have ongoing professional development experiences to assist them in recognizing and developing students with STEM promise, differentiating instruction and providing for continuous progress. Vertical teams of teachers should work together to prepare students for continuous progress and deep understanding and reasoning. Furthermore, globally, STEM curriculum must encourage creativity, identify growth and continuous progress, and provide opportunities for students to go beyond current levels of proficiency. Finally, schools need to have a variety of programs, such as, out-of-school programs to develop STEM talent and interest.

Conclusion

In order to increase the participation of women in STEM fields, it is of the utmost importance that more women prepare for and pursue STEM fields in high school and college. In order to do this we must interest girls in science, technology, engineering and mathematics at a young age and maintain their interest through high school and college. When women are not proportionally represented in STEM fields, both science and society suffer. By understanding what causes the underrepresentation of women in STEM areas of study, schools can begin to adjust or develop programs to address these concerns. Current evidence suggests that early educational experiences are instrumental as a catalyst for future involvement in science and technology. Parents, educators, schools, and communities should foster girls' internal assets such as confidence, self-esteem, initiative, and work ethic. We need to show girls that what they want out of their careers can be achieved through STEM. Also, educators should recognize that many girls prefer working in groups and collaborating with others to solve problems. Finally, teachers must steer clear of obvious or subtle stereotypes about girls' and women's abilities in science, technology, engineering, and mathematics. We need to make sure we provide every girl the opportunity for achievement in STEM. We should encourage young girls to ask questions about the world, to problem solve, and to use natural creativity through play and experimentation. Women have made impressive gains in science and engineering but are still a distinct minority in many science and engineering fields. Creating environments that support girls' and women's achievements and interests in science and engineering will encourage more girls and women to pursue careers in these vital fields.

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