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Changing the Conversation about Girls and STEM

Jo Boaler, The White House, April 28th, 2014

What do we know?

Achievement for girls and boys in STEM subjects is equal at all levels of school, but shocking inequalities persist in participation, especially as levels get higher (Boaler & Sengupta-Irving, 2006). This restricts girls' access to a wide range of jobs; it also impoverishes the disciplines of mathematics, science and engineering enabling a cycle of inequality to continue. Many factors contribute to the decisions girls make, some of which have received extensive funding and attention. The need for role models, and the positive contribution played by after school clubs and camps that engage girls in STEM work are well understood and documented (GSUSA, 2008). But important and actionable causes of inequality have been neglected in recent decades and new research evidence underscores their importance. These may be considered under two broad headings: (1) Teaching and Identity development and (2) Beliefs and Messages.

Teaching and Identity Development

Mathematics plays a significant role in students' decisions to opt out of STEM, especially but not only because it is a prerequisite for STEM majors. In most mathematics classrooms across the country mathematics is offered as a dry, abstract, repetitive subject with few opportunities for understanding. This is particularly harmful for girls, who have a greater desire for depth of understanding than boys, and higher levels of anxiety when they do not understand (Boaler, 2009). When mathematics is taught well as a broad multi-dimensional subject that involves inquiry, making connections, and reasoning about methods, all students achieve at higher levels and girls choose to participate in mathematics and science. Studies that compare traditional and inquiry based teaching of mathematics find that girls achieve at higher levels and participate more in inquiry classrooms, but for boys participation and achievement is the same in both conditions. This occurs because girls have a greater need for understanding, wanting to know why methods work and where they come from. This has been studied and found to be true in mathematics and science classrooms (Boaler, 2002; Zohar & Sela, 2003). In a meta-analysis of 123 informal STEM programs for girls, including summer and after school clubs, researchers summarized the features that girls rated as creating engagement and positive identity formation. The top four features chosen by girls: wanting hands on experiences, project based curriculum, curriculum with real life applications and opportunities to work together, all speak to the teaching of STEM subjects. Role models were also cited but girls believed them to be less important than opportunities for collaborative, inquiry based STEM work (GSUSA, 2008).

Recent evidence from neuroscience is suggesting that math should never be associated with speed, yet mathematics classrooms across the country privilege fast, procedural thinkers. Scientists now understand that when students are anxious the working memory in the brain is blocked - this is the part of the brain where math facts are held. Timed tests in which students as young as first grade are required to complete 50 questions in 3 minutes, are used across the US. These cause the early onset of math anxiety for students, and they are especially damaging for girls (Boaler, 2014).

Girls who want to understand deeply – who want to know why methods work, where they come from and how they connect to broader conceptual domains are denied access to STEM subjects because of the procedural teaching that pervades the US, and the constant emphasis, especially in mathematics, on speed. These deep thinkers are the students who are most suited to high-level work in mathematics, science and engineering and who could advance the disciplines and break cycles of inequitable teaching.

Learning is not just about accumulating knowledge, it is a process of identity development as students decide who they are and want to be (Wenger, 2000). For many girls the identities they see on offer in mathematics and science classrooms are incompatible with the identities they want for themselves (Boaler & Greeno, 2000). They see themselves as thinkers and communicators and people who can make a difference in the world (Jones, Howe & Rua, 2000); in procedural classrooms they come to the conclusion that they "just do not fit in". This relates in part to the lack of good role models but it also relates to the forms of knowledge that are privileged in many mathematics and science classrooms that leave no room for inquiry, connections or depth of understanding.

Beliefs and Messages

Powerful new evidence points to the importance of the beliefs girls hold about their own potential when they are choosing to opt in or out of STEM subjects. Students with a 'growth mindset' who believe that smartness increases with hard work, are those who engage in learning behaviors that produce high achievement. They are more persistent, willing to learn from failure, and more likely to choose challenging work and subjects. Students with a fixed mindset that believe that they are either smart or not are those who achieve at lower levels and who do not choose hard tasks or subjects (Dweck, 2007).

Mathematics is the subject with the most fixed mindset thinking in the US, many students believe that math ability is a 'gift' and they can either do mathematics or they cannot (Boaler, 2013). The damage caused by fixed mindset thinking is exacerbated by stereotyped messages. Researchers have found that when girls in university mathematics departments receive stereotyped messages about who belongs, those with a growth mindset reject the messages but those with a fixed mindset opt out of STEM subjects (Dweck, 2006b). Fixed mindset thinking affects students from across the achievement spectrum but it is particularly prevalent among high achieving girls (Dweck, 2006b).

Girls in the US are given the idea that mathematics is not for girls from the early years of school. Elementary teachers, 87% of whom are female, sympathetically offer statements such as "maybe math isn't for you, you are good at English" when students struggle or don't do well on timed tests. Girls believe these messages and they lead to diminished performance and participation. Researchers found that when mothers told their daughters "I was no good at math in school" their daughter's achievement immediately went down (Eccles & Jacobs, 1986). In a recent study Beilock *et al* (2009) found that the levels of anxiety of female elementary teachers predicts the achievement of the girls in their classes, but not the boys. Girls look up to their female teachers and identify with them at the same time as teachers are conveying the idea that math is hard for them, or they are just not a "math person". We now know that the ideas girls hold about STEM subjects and their own potential are hugely important for their achievement and participation; this is critical, actionable information as students' and teachers' ideas can be changed (Blackwell *et al*, 2007).

Evidence of Change / The Future

In the summer of 2013 Jo Boaler taught an online class to teachers and parents entitled "How to Learn Math". A central theme of the course was the messages students receive and the need to teach students a growth mindset and to reject gender stereotypes. Forty thousand people took the course; at the end 93% said they were 'very' or 'extremely' satisfied and 95% said they would change their teaching, or ways of helping their own children, as a result. Eight times as many people finished the MOOC as is typical and thousands of teachers wrote detailing the changes they were making. Many of the messages came from elementary teachers explaining that the course had been 'life changing' as it had shown them that they could be successful in math and the damaging messages they had received in their lives were wrong. The course, for teachers and parents, has now re-opened http://scpd.stanford.edu/instanford/how-to-learn-math.jsp

In June 2014 a new Stanford MOOC called "How to Learn Math – for students" will teach the ideas directly to students, of any age. The MOOC comprises six interactive sessions that teach students that they can do math, that stereotyped and fixed messages about math are wrong, and that math is a living, connected subject. The course also teaches students mathematics strategies that will encourage success. This MOOC is expected to reach 2 million students.
https://class.stanford.edu/courses/Education/EDUC115-S/Spring2014/about

At the conclusion of the teacher/parent course, and in response to huge demand for the continued availability of growth mindset messages about mathematics, youcubed.org was launched; a non profit whose mission is to harness the power of new technologies to transform mathematics education in the US and beyond, erasing damaging messages, widespread failure and trauma. http:// youcubed.stanford.edu

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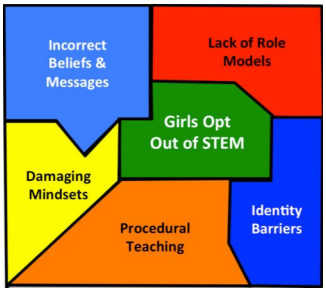
Promoting Girls' Participation in STEM: Recommendations for Change

Teaching:



- A move to inquiry based teaching in K-12 mathematics and science. This will require high quality professional development
- Change teachers' beliefs about who can learn mathematics, science and engineering
- Teach coding / computer science K-12
- Make research evidence on the brain and learning available to teachers in practical, accessible forms

Teacher Messages

- Not: "math isn't your thing" or "math is hard"
- Not: "you need a lower math class"
- Change praise from "you are smart" to "you worked hard", "you learned"

Parent Messages

- Don't share "I couldn't do math at school" or any negative feelings about math
- Communicate growth praise, not "you're so smart", but "it is great that you have learned that"

Students

- Need growth mindset interventions, particularly within mathematics
- Need opportunities to engage in inquiry mathematics and science - in school, after school, online
- Need opportunities to work collaboratively on challenging mathematics and science projects

Online courses, websites, and other technologies – for students, teachers, parents, administrators will be critical to the changes needed.

Helpful Web Links

General Mindset Interventions: http://www.mindsetworks.com ($79/student)

Mathematics and Mindset Intervention https://class.stanford.edu/courses/Education/EDUC115-S/Spring2014/about (free)

The Mathematics Revolution, resources for teachers, parents, student, administrators: youcubed.stanford.edu

Changing Teachers' / Parents' Mindsets, Ideas and Messages to Students: http://scpd.stanford.edu/instanford/how-tolearn-math.jsp

Mathematics, Messages, and the Common Core: http://www.theatlantic.com/education/archive/2013/11/the-stereotypesthat-distort-how-americans-teach-and-learn-math/281303/

Evidence on the Damage Caused by Timed Tests and Recommendations for Alternatives: Downloadable at youcubed.stanford.

Report on STEM participation and informal learning opportunities: http://www.girlscouts.org/research/resources/evaluating_promising_practices_in_informal_stem_education_for_girls.pdf