Master A., & Meltzoff, A. N. (2016). Building bridges between psychological science and education: Cultural stereotypes, STEM, and equity. *Prospects-UNESCO, 46*, 215-234.

Prospects (2016) 46:215–234
DOI 10.1007/s11125-017-9391-z

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Building bridges between psychological science and education: Cultural stereotypes, STEM, and equity

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Published online: 20 March 2017

Abstract There is a gender gap in science, technology, engineering, and mathematics (STEM) education. This presents a worldwide problem of inequity. Sociocultural stereotypes associating STEM with males act as barriers that prevent girls from developing interests in STEM. This article aims to show that we can increase equity and enhance outcomes for a broader number of children around the world by integrating psychological and educational science. The article discusses four strands of research in an effort to build a bridge between psychological science and educational practice and policy. First, it describes how stereotypes can act as barriers that prevent girls from developing interests in STEM. Second, it summarizes psychological experiments demonstrating that counteracting stereotypes can increase girls' interest in enrolling in STEM courses. Third, it examines new results showing that children adopt the pervasive stereotypes of their culture starting from surprisingly young ages, and it shows that children's stereotypes influence their academic attitudes and performance. Fourth, it describes innovative practical interventions that can increase and equalize motivation and engagement in STEM for both boys and girls. In each of these sections, the authors link scientific findings with educational applications. Cultural stereotypes contribute to educational inequities, but scientists, educators, and policymakers can together make a difference to reduce stereotyping and boost girls' interest in STEM worldwide.

Keywords STEM · Gender · Stereotypes · Equity · Psychology · Identity · Inclusion

We thank S. Cheryan and D. Cvencek for their long-term collaboration on these topics. Supported by grants from the National Science Foundation (SMA-0835854 and SMA-1640889).

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Equity in education is a worldwide concern. In particular, the gender gap in science, technology, engineering, and mathematics (STEM) remains a large and persistent problem internationally. Girls report lower interest and self-confidence than boys in STEM in most countries (Mullis, Martin, and Foy 2008; Sjøberg and Schreiner 2010), and perform worse on standardized STEM tests in some countries (Else-Quest, Hyde, and Linn 2010; Mohammadpour, Shekarchizadeh, and Kalantarrashidi 2015). Women are less likely than men to earn STEM degrees and work in STEM careers (European Union 2009; OECD 2015a). For example, women earn only 25% of math and engineering degrees on average across OECD countries (OECD 2011). Women are also less likely to hold leadership positions in scientific research collaborations (OECD 2015b). Yet, when countries have greater gender equality (particularly educational equality), girls succeed just as much as boys in performance on standardized STEM tests (Else-Quest, Hyde, and Linn 2010; Guiso, Monte, Sapienza, and Zingales 2008; see also Charles and Bradley 2009). Smaller gender gaps in math performance and representation in science are also found in countries with weaker stereotypical beliefs associating STEM with males (Miller, Eagly, and Linn 2015; Nosek et al. 2009).

Gender stereotypes and inequalities mean that many young women are missing out on opportunities to contribute to, and benefit from, careers in STEM. STEM fields drive technological innovation and bring economic and public health benefits, yet many countries face shortages of STEM workers (European Round Table of Industrialists 2009; van Langen and Dekkers 2005). Increasing the number of women who enter STEM could help ameliorate the global shortage of STEM workers. Policymakers are calling for ways to reduce gender-based educational disparities in STEM. These concerns are being expressed worldwide, including a White House conference (Rodríguez and Garg 2016) and meetings sponsored by UNESCO and the Organization for Economic Co-operation and Development (OECD 2011; see also Brown 2016; DeJarnette 2012).

Although both recruitment and retention of women in STEM fields are problems (Ceci and Williams 2010; Ceci, Williams, and Barnett 2009; Hewlett et al. 2008), recruitment is the larger concern because girls are much less likely than boys to choose STEM fields in the first place (de Cohen and Deterding 2009; Miller and Wai 2015). For example, even if every woman in the U.S. who intended to major in computer science and engineering upon entering college stayed in these fields, men would still be significantly more likely to earn computer science and engineering degrees than women (Cheryan, Ziegler, Montoya, and Jiang 2017).

Although many factors influence STEM gender gaps, the gender difference in young students' interest and motivation in STEM is a major contributor to later disparities in STEM majors and careers (Ceci and Williams 2010; Smith, Brown, Thoman, and Deemer 2015). This difference is driven, in part, by cultural stereotypes. Widespread stereotypes associate STEM with boys more than with girls (Cheryan, Master, and Meltzoff 2015; Nosek et al. 2009). We have hypothesized that two stereotypes are intertwined: (a) a "cultural fit" stereotype (the belief that "math is for boys") and (b) an "ability" stereotype (the belief that boys have more ability to do STEM problem-solving than girls); see Figure 1. New research establishes that these two stereotypes begin to influence girls' self-concepts, interest, and motivation starting as early as elementary school and through older grades as well (Cvencek, Meltzoff, and Greenwald 2011; Master, Cheryan, and Meltzoff 2016; Steffens, Jelenec, and Noack 2010).

In this article we review evidence pertaining to the pervasive stereotypes that connect STEM with boys more than with girls. We discuss how cultural stereotypes are internalized in children's minds and begin to shape their beliefs about what field is for them and where

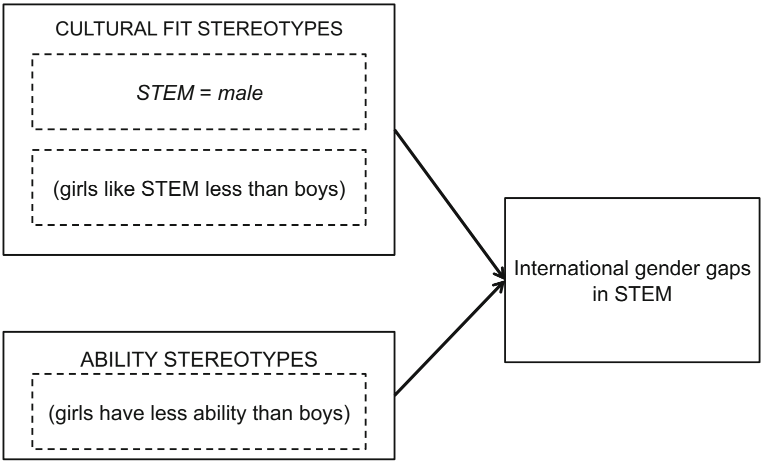


Figure 1 Two types of stereotypes
Note: Students have stereotypes about who "fits" in STEM and who has "ability" in STEM. Both types of stereotypes signal to girls and women that they do not belong in STEM fields.

they "belong". Our review and analysis covers a wide span of ages, from preschool children to high school students. We discuss how advances in basic science have also led to educational interventions that may help ameliorate the effects of stereotypes and increase children's interests, motivation, and engagement with STEM disciplines.

Barriers to STEM engagement

Which career to enter may seem like a free choice, but scientific research demonstrates that significant social barriers exist to girls' entry into such STEM fields as computer science and engineering (Ceci, Williams, and Barnett 2009; Cheryan, Master, and Meltzoff 2015). These include: (a) the attitudes of parents, teachers, and others who think that these careers are better suited for boys (Eccles, Jacobs, and Harold 1990; Sadker and Sadker 1994); (b) the current lack of visible representation and role models in these fields (Dasgupta 2011; Meltzoff 2013; Murphy, Steele, and Gross 2007); (c) girls' systematic underestimation of how well they will do in these fields (Correll 2001; Ehrlinger and Dunning 2003); and (d) discrimination in these fields that may prevent qualified women from gaining the same opportunities as their male counterparts (Moss-Racusin, Dovidio, Brescoll, Graham, and Handelsman 2012; Reuben, Sapienza, and Zingales 2014). In recent years, women have overcome such barriers in formerly male-dominated fields such as medicine and law, yet remain underrepresented in many STEM fields.

Importantly, there are large variations in women's underrepresentation *among different STEM fields*, and this is informative for scientific theory and educational practice and policy. The gender gap in STEM participation is especially large in technological fields such as computer science; see Figure 2 (Cheryan et al. 2017). For example, in the U.S. in 2012, women earned about half of the bachelor's degrees in a variety of STEM fields: 59% in biological sciences, 43% in math and statistics, and 41% in physical sciences (National Science Foundation 2015). In sharp contrast, women's representation was extremely low in engineering (19%) and computer science (18%). Given the growing prominence of

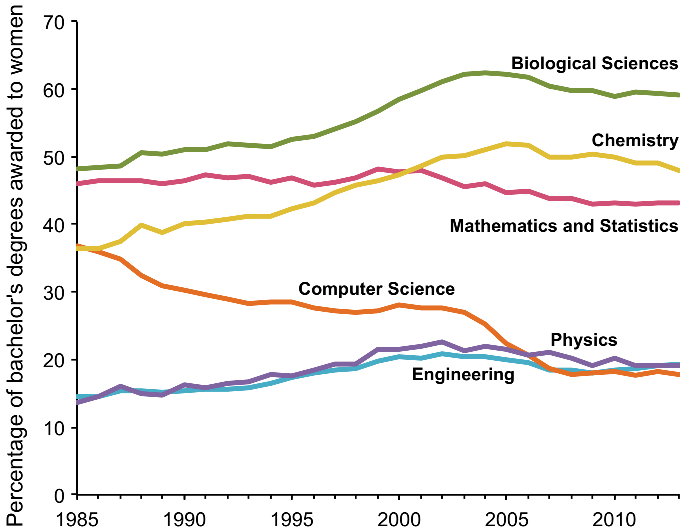


Figure 2 Percentage of bachelor's degrees awarded to women in STEM fields, 1985–2013
Source: Adapted from Cheryan et al. (2017), using data from the National Science Foundation, National Center for Science and Engineering Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR), https://webcaspar.nsf.gov

computer science and technology in the modern world—and the prestige and salary levels associated with this work—it is a particularly important equity issue to close the gender gap in computer science.

The cause of gender gaps in these academic choices is unlikely to be solely academic ability (Hyde 2014; OECD 2011). A meta-analysis of 7 million American children in grades 2 to 11 (using state test scores in math) showed no gender differences at any grade level, with effect sizes from -0.02 to 0.06 (Hyde, Lindberg, Linn, Ellis, and Williams 2008). A close examination using a different math test that included more advanced problem solving showed that the average effect size of the gender difference in grade 12 was 0.07. Across countries, the gender gap in high school math achievement varies widely but is correlated with measures of gender equity (Else-Quest, Hyde, and Linn 2010), raising the possibility that efforts to increase gender equity globally might help to reduce the remaining gaps in math achievement. There is a moderate gender gap in spatial performance (Voyer 2011; see also Maeda and Yoon 2013), which is relevant because spatial cognition is necessary in many STEM fields. However, this gender gap may be due at least in part to boys' greater experiences with certain activities such as video games that can improve spatial skills (Feng, Spence, and Pratt 2007). Thus, the gap in measures of spatial performance has strong potential to be reduced through interventions that train spatial skills (Uttal et al. 2013), and provide young girls with experiences they have been missing.

Dissecting the problem

Importantly, evidence suggests that any gender differences that may exist in performance or ability do not fully explain the existing gender gaps in participation. For example, gender differences in high school STEM achievement do not explain gender gaps in college enrollment (Riegle-Crumb, King, Grodsky, and Muller 2012). Instead, research points strongly to nonacademic factors—sociocultural stereotypes and self-concepts—that create a lower sense of belonging among women than men in certain STEM fields (e.g., Cheryan et al. 2017).

We categorize the stereotypes about STEM into two types (Figure 1): stereotypes about the "cultural fit" of fields and stereotypes about who has "ability" in those fields. These stereotypes are related, but it is useful to distinguish between them for both theoretical and practical reasons.

By *cultural fit stereotypes*, we mean stereotypes that define the type of person who is typically seen as fitting into that field. Males are associated with STEM fields and perceived to like these fields more than women do (Carli, Alawa, Lee, Zhao, and Kim 2016). Computer scientists are stereotyped in contemporary U.S. society as male, technologically oriented, and socially awkward (Cheryan, Plaut, Handron, and Hudson 2013; Margolis and Fisher 2002). Other stereotypes about the culture of computer science include that it is isolating and does not involve communal goals such as helping or working with others (Diekman, Brown, Johnston, and Clark 2010).

By *ability stereotypes*, we mean the pervasive belief that characterizes males as having more ability, talent, or potential for success in STEM (Beilock, Rydell, and McConnell 2007; Schmader, Johns, and Barquissau 2004; Spencer, Steele, and Quinn 1999). There is a further perception that STEM fields require "genius"—also stereotypically associated with males (Leslie, Cimpian, Meyer, and Freeland 2015). Both cultural fit and ability stereotypes can be transmitted by the media, role models, academic environments, parents, and peers (Cheryan, Master, and Meltzoff 2015).

When girls compare themselves to these stereotypes, they feel a mismatch that signals to them that they do not "belong" in these STEM fields (Master, Cheryan, and Meltzoff 2016). This acts as a barrier to their interest—if they do not feel that they belong, they are not interested in taking courses or developing potential interests in these fields. Of course, many people in these male-stereotyped and male-dominated fields do not fit the stereotypes that are attributed to them. But beliefs have the power to affect students' attitudes and choices, even if these perceptions are disconnected from reality. In the next three sections, we describe research findings from psychological science about stereotypes acting as barriers to STEM and concrete ways to reduce these barriers and boost interest in STEM, including in the classroom itself.

How STEM stereotypes deter girls: The importance of a sense of belonging

Stereotypes about STEM act as "gatekeepers", constraining who enters these fields (Cheryan, Master, and Meltzoff 2015). Experimental studies have shown that these stereotypes can play a causal role in girls' interest in STEM. For example, we conducted research with U.S. high school students to assess whether the classroom environment might convey stereotypes that affected girls' interest in enrolling in introductory computer science courses (Master, Cheryan, and Meltzoff 2016; see also Cheryan, Meltzoff, and Kim 2011; Cheryan, Plaut, Davies, and Steele 2009). These introductory courses are particularly important for students to enroll in, because they create a pipeline to later majors and careers. The decision to forgo even one feeder course can effectively prevent students from majoring in STEM (Moses, Howe, and Niesz 1999; although this varies across countries, see van Langen and Dekkers 2005). Thus, investigating factors that encourage girls to enter introductory "pipeline" courses is crucial.

We showed high school students (ages 14–17) photographs of two classrooms (Master, Cheryan, and Meltzoff 2016). In one classroom, computer science stereotypes were salient through the objects in the classroom, while the other classroom contained objects that did not project those stereotypes. The stereotypical objects included the most obvious things, such as computer parts and books, but also other objects considered "geeky," like Star Trek posters. Our nonstereotypical objects included things commonly found in a classroom or office space, such as potted plants and nature posters. We then asked students how interested they would be in enrolling in a computer science course in each classroom. We also measured students' computer science interest in a premeasure, before they saw either classroom.

What we found was that stereotypes mattered—especially for girls; see Figure 3. Girls were three times more likely to be interested (with 35% instead of 13% reporting positive interest) in taking a computer science course when the classroom did not project current computer science stereotypes, compared to the classroom that made stereotypes salient. Boys were equally interested in taking computer science regardless of how the classroom looked. A second experiment replicated these findings, even when we simply described one classroom or the other to students.

Why does the design of the classroom environment affect girls' interest in computer science? We traced the difference in interest to differences in girls' sense of belonging in each classroom. By "belonging", we mean students' sense that they would fit in with the people, materials, and activities within that environment. The physical objects served as cues about who belonged in that particular environment and signaled the culture of the people associated with that environment. In our studies, girls were more likely to feel that they belonged in the nonstereotypical classroom—that they would fit in and be similar to the other students—than the stereotypical classroom.

Although a sense of belonging is important for academic interest in general (Cook, Purdie-Vaughns, Garcia, and Cohen 2012; Walton and Cohen 2007), it is particularly important for girls and women in STEM. When girls feel that they belong, it can transform their experience in male-dominated fields (Walton, Logel, Peach, Spencer, and Zanna 2015). Women's sense of belonging in STEM is a strong predictor of their STEM interest and motivation (Good, Rattan, and Dweck 2012; Smith, Lewis, Hawthorne, and Hodges 2013).

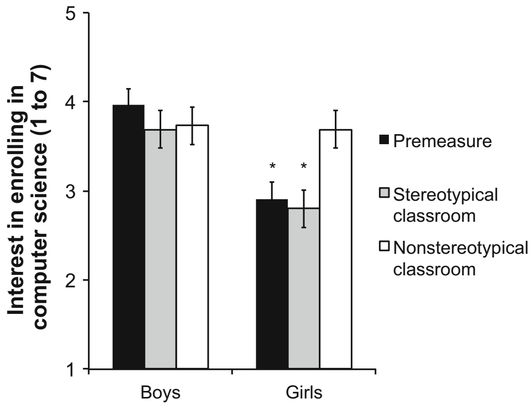


Figure 3 Interest in enrolling in a computer science course
Note: Girls reported significantly less interest (*$p < .05$) in a premeasure and when the classroom contained stereotypical objects, compared to when the classroom contained nonstereotypical objects or compared to boys' interest. All *error bars* are ± standard error.
Source: Master, Cheryan, and Meltzoff (2016)

Of course, in our studies, we found individual differences among both girls and boys; some girls were more interested in computer science in the stereotypical classroom, and some boys were more interested in computer science in the nonstereotypical classroom. On average, however, the nonstereotypical classroom was far more effective in boosting girls' interest in the computer science course, yet had no negative impact on boys' interest.

Educational applications

Twice as many U.S. high schools now offer AP computer science compared to a decade ago (College Board 2015). Even more schools in the U.S. say they want to add computer science to their curriculum. But this will make no difference if girls choose not to enroll in these courses. The best way to encourage girls is to remove the stereotypes keeping them out. Changing actual classrooms—and making sure that girls are aware that they are welcome and valued in these classrooms—can make a difference. Redesigning classroom environments to communicate a broader image of STEM fields can help to increase girls' belonging and interest in enrolling in STEM courses, without dissuading boys. If we can show a broader picture of who "belongs" in computer science, we can get more girls willing to give it a try. By changing the stereotypes, we open the door to many more girls (and even some boys) who would not otherwise consider computer science.

Changing the design of classrooms is an inexpensive and effective way to create educational change. Classroom environments may be more practical targets for policymakers and educators than changing other sources of stereotypes such as the media (Cheryan, Plaut, Handron, and Hudson 2013) or role models (Cheryan, Drury, and Vichayapai 2013). Students spend significant time in academic environments such as classrooms, computer labs, hallways, and teachers' workspaces, and the designs of these environments directly influence students' learning (Cheryan, Ziegler, Plaut, and Meltzoff 2014). Many high school teachers decorate their classrooms or hallways, and some educators may be inadvertently including cues that communicate to girls that they do not belong in that course, while others may be decorating their classrooms in ways that effectively reduce gender disparities. The design of these spaces can communicate who is welcome in that space and influence students' interest in pursuing certain fields of study.

Origins of STEM-gender stereotypes

When do children first learn about the stereotypes linking STEM with boys? Most research on STEM-gender stereotypes with children has examined math stereotypes. Thus, we focus primarily on math-gender stereotypes in this section and recommend that future research examine stereotypes across a wider range of STEM fields.

In early elementary school, children begin to associate math with boys and reading with girls (Cvencek, Meltzoff, and Greenwald 2011; Galdi, Cadinu, and Tomasetto 2014). They do so when stereotypes are measured using certain types of explicit measures and are especially likely to do so with measures of "implicit" or unconscious stereotypes (the Child Implicit Association Test, which measures children's speed at responding when boys/math and girls/reading are categorized together, relative to boys/reading and girls/math; see Cvencek, Meltzoff, and Greenwald 2011; Cvencek, Meltzoff, and Kapur 2014 for details). More research is needed, but we think that these measure children's ideas about cultural fit, in terms of which gender is typically linked to an academic discipline.

In terms of the ability stereotype that boys are better at STEM, children at the youngest ages tested (K to second grade) tend either to believe that the genders are about equal in ability (Steele 2003) or to show an explicit bias that their own gender group is better at math and science (Galdi, Cadinu, and Tomasetto 2014; Heyman and Legare 2004; Kurtz-Costes, Rowley, Harris-Britt, and Woods 2008; Passolunghi, Rueda Ferreira, and Tomasetto 2014). By the end of elementary school, most children, including both girls and boys, begin to hold adult-like ability stereotypes that boys are better at math and science, which is revealed across a range of different measures.

Even more surprising is that children seem to have caught the adult stereotype about differences among STEM fields. According to our newest research, stereotypes about ability in very male-dominated fields such as computer science and robotics begin to influence children early in development. Our research found that 6-year-old U.S. children, both boys and girls, report that boys are significantly better at robotics and programming than girls, though these same children do not hold the more general stereotype that boys are better at math and science (Master, Cheryan, Moscatelli, and Meltzoff in press).

Although there is not yet strong causal evidence that STEM-gender stereotypes influence young children's STEM achievement, correlational studies suggest that stereotypes are associated with negative outcomes for girls (Passolunghi, Rueda Ferreira, and Tomasetto 2014; Plante, de la Sablonnière, Aronson, and Théorêt 2013; Shenouda and Danovitch 2014). For example, implicit math-gender stereotypes predict German middle school students' self-reported math grades (Steffens, Jelenec, and Noack 2010). Also, implicit math-gender stereotypes correlate with children's own identification with math, which in turn is correlated with children's actual math achievement (Cvencek, Kapur, and Meltzoff 2015).

There is also some causal evidence that STEM-gender stereotypes can negatively affect girls' performance in math, at least in the short term. "Stereotype threat" refers to concerns about confirming a negative stereotype about one's group; these concerns can cause decrements in performance on tasks relevant to the stereotype (Shapiro 2011; Steele 1997). Several studies have examined stereotype threat in children. One study activated stereotypes by having 6-year-old Italian children color a picture of a boy succeeding at a math problem and a girl failing to respond (Galdi, Cadinu, and Tomasetto 2014). Girls whose math-gender stereotypes were activated performed more poorly on a math test compared to girls who colored a stereotype-inconsistent picture in which a girl succeeded at math. Another study found that fifth- and eighth-grade Italian girls performed worse on math tests after they saw information that 9 out of 10 successful mathematicians are male (Muzzatti and Agnoli 2007). A meta-analysis of stereotype threat in children across 47 studies and 3,760 girls found that it has a small but consistent effect on STEM performance (Flore and Wicherts 2015).

These studies indicate that children are susceptible to stereotypes in elementary school. Stereotypes can drive girls away from engaging in STEM fields and in certain cases can hinder their performance. Even though STEM stereotypes, similarly to other stereotyped generalizations about a group, are often inaccurate—e.g., it is certainly not true that all boys are better than all girls at STEM—children absorb them at an early age. What can educators and policymakers do to encourage young girls to disregard the stereotypes and develop interest in STEM?

Intervention science: Practical ways to increase children's STEM engagement

Educators and researchers are devoting a good deal of attention and work to reducing gender inequities in STEM in college and the workplace. We think it is vital to start earlier to set a strong foundation for STEM among young girls.

Promoting the STEM engagement (beliefs, attitudes, and behaviors) of *young* children may be particularly beneficial (Maltese and Tai 2010; Newcombe and Frick 2010). This is because early experience and skills seem to have long-term consequences for developmental trajectories not only in neuroscience (the concept of a "sensitive period") but in several domains of human behavioral development as well (Heckman 2006; Hulleman and Barron 2016; Meltzoff, Kuhl, Movellan, and Sejnowski 2009). (We are aware that the mechanisms involved in neural versus behavioral development are different, and thus the sensitive-period analogy to behavioral skill development should be considered with caution.) Longitudinal studies indicate that early numeracy activities such as counting predict later math ability in childhood (Skwarchuk, Sowinski, and LeFevre 2014), and children's involvement in puzzle play improves spatial transformation ability (Levine, Ratliff, Huttenlocher, and Cannon 2012). Training studies show that both math and spatial skills are highly malleable and can be improved with practice (Ramani and Siegler 2008; Uttal, Miller, and Newcombe 2013).

Our research has investigated two practical ways to encourage young children's interest and motivation in STEM. We have designed interventions based on (1) increasing *experience* and (2) providing *social information* about what other "in-group" members do.

Early intervention #1: Increasing experiences

One reason that girls may be less likely than boys to be interested in STEM is because they have fewer early experiences to spark their interest (Cheryan et al. 2017; Martin and Dinella 2002). In elementary school, girls spend less time than boys playing with computer games (Cherney and London 2006), electric toys and fuses (Jones, Howe, and Rua 2000), and spatial and science-related games and toys (Jirout and Newcombe 2015). With fewer experiences with STEM activities, girls have fewer opportunities to trigger their interest and build their skills (Terlecki and Newcombe 2005). Of course, correlational studies doe not establish causation.

We examined this issue experimentally by testing whether positive experience with computer programming could boost girls' STEM motivation (Master et al. in press). We designed this experimental study with six-year-old U.S. children. We randomly assigned children either to a treatment group that was given experience programming a robot using a smartphone, or to control groups (who either did no activity or a different activity not related to STEM). The treatment experience significantly increased girls' technology-related motivation (as measured by their interest and self-efficacy) and eliminated the gender gap with boys' motivation—suggesting that providing girls with early experiences can boost their motivation in STEM. These results are encouraging, because they suggest that girls' interest in STEM is not set in stone but is malleable and can be changed through interventions.

Educational applications

In terms of practical applications for educators and policymakers, policies that ensure that more young girls experience computer science courses, summer camps, or workshops could help to trigger girls' interest in this STEM field. The type of activity used in our research could also be added to existing programs and curricula. It is important to note that interest can decrease over time if girls do not have further opportunities to continue to engage with that topic (Hidi and Renninger 2006). Girls may need to become involved in long-term programs to prevent them from losing interest in robotics and programming. Making computer science courses required parts of the educational curriculum could also help more girls realize their interests in this field (Cheryan et al. 2017; Cvencek, Kapur, and Meltzoff 2015).

Early intervention #2: Social group membership

We also designed a second way to boost young children's motivation in STEM based on children's social motivation. Social learning from early childhood onward is built on connecting oneself to others who are "like me" (Meltzoff 2007, 2013). Belonging to groups is argued to be a fundamental human motivation (e.g., Baumeister and Leary 1995). Being part of a group increases adults' motivation for group STEM activities (Master, Butler, and Walton 2017; Master and Walton 2013; Walton, Cohen, Cwir, and Spencer 2012).

We thus designed a novel study to test whether we could boost children's motivation for a STEM task by having them complete this task as part of a group versus as an individual (Master, Cheryan, and Meltzoff 2017). We brought 141 four-year-old U.S. children into our lab. They did two activities: a math activity and a puzzle activity. For one of these activities, children were made to believe that they were part of a group. For the other activity, children completed the task all by themselves.

Each group had a special color; see Figure 4. For example, children in the green group put on a green t-shirt. Then they sat at a green table with a green flag, and took the group's activity out of a green box. Children saw a poster that showed pictures of children in the child's group, all wearing a green t-shirt just like theirs. For the other (individual) task,

Figure 4 Sample illustrations of the group condition
Note: Images show the experimental setup for the group condition taken from the participant's perspective (**A**), and a participant in the group condition (**B**). In this illustration, the in-group color is *green*, the other-group color is *orange*, and the individual color is *yellow*. Children showed greater engagement for the STEM task they completed in the group situation than the task they completed as an individual.
Source: Master, Cheryan, and Meltzoff (2017)

children were also provided with t-shirts of a certain color, and there was a poster on the wall with pictures of other children. However, that poster showed children wearing different colored shirts, which did not match theirs. For example, if children wore a yellow shirt for the individual task, then none of the children on the poster would have a yellow t-shirt. This helped emphasize their solo status.

We discovered that children showed significantly more motivation for the group task compared to the individual task. Children persisted longer on the group task and correctly placed more pieces for that task. Afterward, we asked children to rate how fun each task was and how good they were at each one. On average, children rated the group task as more fun and said that they felt like they were better at it. Children were also more likely to pick the group task when asked to choose which task they liked better.

Educational applications

These findings are relevant to educational settings, which may emphasize learning either in groups or as individuals. Children in the U.S. and many (but not all) other cultures traditionally spend a large portion of classroom time working independently. For example, one study found that U.S. eighth graders worked individually 80% of the time in math class (U.S. Department of Education 2003). However, these results suggest that children will be more engaged in STEM when they feel connected to others who are working on the same STEM tasks.

Teachers can work to create classroom-wide groups to make sure everyone feels included: “Our whole class does math together”. Another approach could be to combine a motivational manipulation like this one with a skills-based intervention in order to provide tools that help children learn and the drive to use those tools (Bailey, Watts, Littlefield, and Geary 2014; Cohen, Purdie-Vaughns, and Garcia 2012). In this sense, motivational interventions provide a complementary approach to skills-based curriculum interventions (e.g., Siegler 2009). Such approaches could (in a nonstigmatizing way) target groups that are most in need of additional help in school, such as girls in STEM. These kinds of motivational interventions may be more likely to last over time when they lead to recursive processes that reinforce a positive cycle of academic success and motivation (Cohen, Garcia, Apfel, and Master 2006) or create positive changes in the classroom environment that lift the achievement of all students (Powers et al. 2016).

Integrating psychological science and education to increase equity

Bringing more girls and women into STEM fields is important for advancing societies—and it is also a global equity concern. When women are less likely to pursue STEM and computer science, they lose valuable economic opportunities, especially given the recent emphasis on technological innovation in the twenty-first century. UNESCO has made inclusive and equitable educational opportunities one of its primary sustainable development goals (UNESCO 2015).

Equity in STEM is also an important issue for developing countries. Achievement differences in STEM are larger in developing countries (Mohammadpour, Shekarchizadeh, and Kalantarrashidi 2015). If women start out even further behind men, then the opportunities that derive from STEM could be even more valuable for these women than for women in more developed countries. In developing countries, it may be important first to increase girls' access to education more generally (OECD 2011). However, a vitally important follow-up step would be to train educators on how to counteract stereotypes. UNESCO offers a training manual for educators on how to avoid gender stereotypes in curriculum development for countries including Mali, Zimbabwe, and Zambia (UNESCO 2004). If women can overcome these barriers, STEM education can bring them further opportunities.

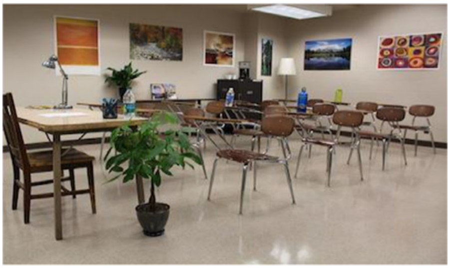
Equity is also an important issue to consider in terms of socioeconomic status (SES). There is an SES gap in spatial skills among U.S. students, although this has been less well studied than the gender gap (Jirout and Newcombe 2015). There is also evidence of an interaction between SES and gender, such that boys from middle- and high-SES backgrounds outperform girls, but there is no gender difference for children from low-SES backgrounds (Levine, Vasilyeva, Lourenco, Newcombe, and Huttenlocher 2005). This suggests that boys, particularly those from higher-SES backgrounds, may have previously been given more opportunities to build their spatial skills.

One way to think about learning opportunities in STEM—such as an elective computer science course or a visit to a science museum—is that each one is like a charging station. Each opportunity allows children to charge up their skills and motivation in STEM. Some children (especially boys from higher-SES backgrounds) have access to more opportunities, which lets them charge their skills and motivation more frequently. But other children have fewer chances to charge their STEM skills and motivation. Thus, interventions to boost STEM motivation such as those reported in this article may be especially important for girls and for students from lower-SES backgrounds, to help maximize their potential for success in STEM. The participants in our studies came from a variety of backgrounds. Most participants in the high school studies about classroom environments came from a public school in which 65% of students were eligible for free or reduced lunch. Although further research is needed to address this issue, we are optimistic that interventions to boost motivation can be effective for students from lower-SES backgrounds (see also Hanselman, Bruch, Gamoran, and Borman 2014; Harackiewicz, Canning, Tibbetts, Priniski, and Hyde 2016).

In this article, we have discussed some of the reasons why girls are less likely than boys to pursue STEM. We focused on the effects of cultural stereotypes, although there may be other contributors. We have argued that girls' underrepresentation is not due to an intractable, immutable lack of interest or ability. Instead, girls' choices are driven, to a large degree, by sociocultural factors—for example, stereotypes about who typically does STEM and who has ability in STEM (see Figure 1). These perceptions, even if they are not accurate, help shape the academic choices that girls make by sending a message about where they belong. These stereotypes are culturally determined and transmitted, and they are malleable. Changing the stereotypes early may have cumulative effects, and we can design new ways to attract more women into STEM, to the benefit of all of society. We next describe materials that we have developed, based on scientific findings, that can be used to raise awareness about these important issues.

Four evidence-based practical messages

Based on the research findings from our studies and those of others, we see four messages that can be used to address the issue of increasing STEM participation (Figure 5).



Broaden beliefs about who belongs

Students may hold stereotypes about who belongs in STEM. To help all students feel welcome, design classrooms to include welcoming objects, like plants, or use social media to highlight the wide range of people in STEM.

Challenge beliefs about fixed abilities

Students may believe that ability is fixed—you either have it or you don't. You can emphasize that STEM ability is like a muscle: the more you exercise it, the better you get. You can also highlight the value in mistakes as a natural part of the learning experience.

Show that STEM can make a difference

Students care about making the world a better place. Emphasize how STEM careers involve working with and helping others.

Provide positive role models

Show students that someone 'like them' can succeed. Role models don't have to be female – just relatable.

Figure 5 Four evidence-based insights into how to motivate more students, especially girls, into STEM

Broaden who belongs and diversify images

First, broadening beliefs about who belongs is critically important. Instead of portraying STEM fields as narrow fields that are easily stereotyped, we can alter how the culture of STEM is represented in students' minds. Some students may fit the stereotypical image of who belongs in STEM, and we do not want to dissuade these students. However, we do want to show that not everyone in STEM fits this stereotype, or needs to in order to belong. We want to convey that diverse opportunities exist to pursue everyone's unique interests using the tools of STEM. Our research shows that sending a nonstereotypical image of computer science can boost girls' interest (Master, Cheryan, and Meltzoff 2016). Rather than attempting to wholly eliminate current STEM stereotypes (which can be stubborn and resistant to change), a more adaptive strategy may be to *diversify the image* of these fields so that students do not think that they must fit a specific type to belong in computer science. Media and role models who show many different kinds of people working in and enjoying STEM can help to diversify the stereotypes. By showing variability in what it means to be a part of STEM, we may not only attract more girls but also be more accurate about what STEM is like and the potential ways that students can use STEM to transform the world.

Teach growth mindsets

Second, educators should challenge beliefs about fixed abilities. Research from Dweck and her colleagues has shown that believing that ability is malleable (rather than fixed) can have a powerful effect on students' motivation in school (Blackwell, Trzesniewski, and Dweck 2007; Dweck and Master 2009; Paunesku et al. 2015; Yeager et al. 2016). For girls in STEM—who face pervasive stereotypes that they have less STEM ability—it is even more important to believe that they can improve their STEM ability through effort (Dweck 2007; Good, Rattan, and Dweck 2012). Students also benefit from hearing about the mistakes and struggles of others in STEM (Hong and Lin-Siegler 2012; Lin-Siegler, Ahn, Chen, Fang, and Luna-Lucero 2016).

Talk about helping others and making a difference

Third, educators can show that STEM makes a positive difference in the world. Girls (and boys) often care deeply about wanting to work with and help others (Diekman et al. 2010). However, there is a widespread (mis)perception that STEM fields do not offer these opportunities (Diekman, Weisgram, and Belanger 2015). Helping girls see the potential for these communal experiences in STEM can boost their interest. For example, students who learned about a day in the life of a scientist whose daily activities were highly collaborative had more positive attitudes toward science careers than students who learned about an independent scientist (Diekman, Clark, Johnston, Brown, and Steinberg 2011).

Show role models "like me"

Fourth, educators can provide positive role models. Although educators commonly receive this suggestion, we emphasize that role models for girls do not necessarily need to be female, just relatable and similar to the self along certain key dimensions. Seeing that someone "like me" (Meltzoff 2007) can succeed in STEM can be powerful for girls when facing stereotypes that communicate that they do not belong. There are many dimensions on which others can be perceived to be "like me" (Meltzoff 2013). For example, college students reported more interest in—and thought they would be more successful in—computer science after an interaction with a computer science major who did not fit the cultural stereotypes (e.g., they had hobbies like hanging out with friends), compared to someone who did fit the stereotypes of having hobbies like playing video games (Cheryan, Drury, and Vichayapai 2013; Cheryan, Siy, Vichayapai, Drury, and Kim 2011). The computer science major's gender mattered less than other factors. If students feel similar to someone in STEM, this can help them see how they themselves can fit into STEM as well. Other research shows that role model gender may matter most in cases when girls are very concerned about ability stereotypes (Master, Cheryan, and Meltzoff 2014).

Sparking change: Summary

To make a difference worldwide, we need to change the messages we send to young girls and boys about who belongs in STEM. We should start early—before pervasive societal STEM stereotypes take hold. These stereotypes act as barriers that communicate to girls that they do not belong or cannot succeed in STEM. Without these barriers, girls will have more truly equal opportunities to pursue the benefits of STEM. By working together, scientists, educators, and policymakers can help to remove these barriers and open the door for girls to explore their interests in STEM.

Gender gaps in STEM also represent an example of the value gained when education and psychological science are brought together in a more integrated science of learning (Meltzoff et al. 2009). Cognitive and social psychology offer the opportunity to conduct carefully controlled research studies to better understand girls' motivation and achievement in STEM. Educators have the opportunity to contribute directly to girls' experiences in the classroom and inspire future research directions. By building bridges between psychological science and education, we can broaden cultural stereotypes to create greater equity in STEM.

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