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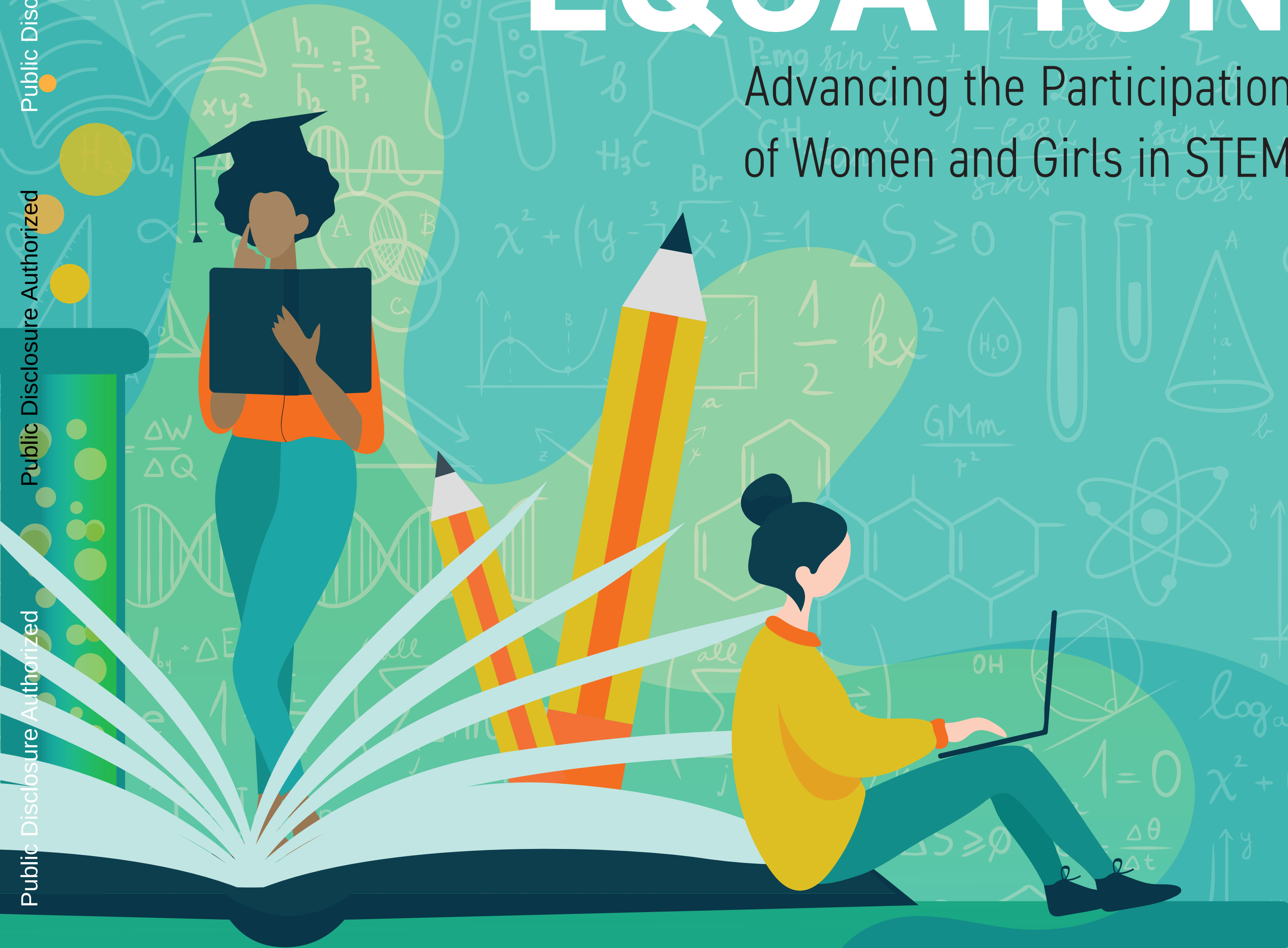
THE EQUALITY EQUATION

Advancing the Participation of Women and Girls in STEM



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Authors & Acknowledgments

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Abbreviations & Acronyms

CEDEFOP	European Centre for the Development of Vocational Training
ISCO	International Standard Classification of Occupations
NSF	National Science Foundation
OECD	Organisation for Economic Co-operation and Development
PISA	Program for International Student Assessment
PASEC	Program for the Analysis of Education Systems
SACMEQ	Southern and Eastern Africa Consortium for Monitoring Educational Quality
TIMSS	Trends in International Mathematics and Science Study
UN	United Nations
UNICEF	United Nations Children's Fund
UNESCO	United Nations Educational, Scientific and Cultural Organization
UIS	UNESCO Institute for Statistics
WEF	World Economic Forum
WiSci	Women in Science

Executive Summary

The economic and social prosperity of countries depends on the state of science, technology, engineering, and mathematics (STEM). Yet, women and girls continue to be underrepresented in STEM studies and careers, although there is wide variation among countries and across STEM fields. Beyond the wage gap that comes with women being underrepresented in STEM jobs, the gender gap in STEM is an inefficient allocation of labor and talent, and a missed opportunity for economies.

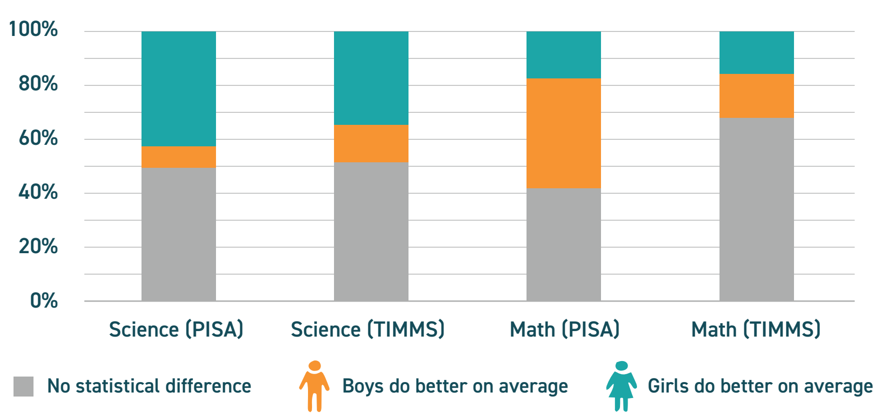
This report explores the participation of women and girls relative to men and boys in STEM-related education and employment through a global, comprehensive review of the evidence. The report focuses on both the drivers and the solutions related to the participation of women and girls in STEM.

IDENTIFYING GENDER GAPS IN STEM EDUCATION AND CAREERS

Globally, girls and boys enroll and complete primary school at about the same rates. Gender gaps in attendance and completion, to the disadvantage of girls, are concentrated mainly in some low-income countries, mostly in Sub-Saharan Africa. In secondary education, in Sub-Saharan Africa, the lower-secondary completion rate is 46 percent among boys compared with 41 percent among girls. On the other hand, in Latin America, girls are 5 percentage points more likely than boys to complete lower-secondary school.

In STEM learning, girls often score equal to or higher than boys in science and mathematics (figure ES. 1). Gaps between boys and girls in the last four decades have closed as a result of both improvements in mean scores of girls and a decline in the scores of boys, especially at the upper end of the distribution. The evidence on Sub-Saharan Africa, though, differs from global averages: boys score significantly higher in mathematics in 14 of the 19 economies.

FIGURE ES.1. Girls do as well or better than boys on science and math tests



Note: See details in Table 1 of report.

At the tertiary level, more women are enrolled in universities and have higher graduation rates than men around the world. Yet, women are significantly less likely to enroll in many (but not all) of the STEM fields. Women are well-represented in the life sciences but not in computer science, engineering, and physics. As country income rises, the gender gap between the likelihood of studying in a STEM field widens. Likewise, this gap increases with measures of greater country gender equality, described as a gender-equality paradox. Scholars disagree on the underlying drivers of this paradox.

The skewed pattern of differences by sex in fields of study translates into occupational sex segregation in the workforce. Even when women study in STEM fields, they are less likely to pursue careers in STEM. Eastern European countries are an exception: STEM educated women and men have similar rates of employment.

To compensate for inadequate STEM labor market data, research careers have been used as a proxy indicator. Relative to the share of women who have attained tertiary education, women's participation in research shows a precipitous drop—although women account for 54 percent of university graduates globally, they represent only 34 percent of researchers. Further, the share of women working in specific areas—data and artificial intelligence, engineering, and computing—is especially low, consistent with the field of study data from universities.

FACTORS THAT DRIVE STEM GENDER GAPS

If the level of enrollment and test scores are not lower for girls and women, what drives the STEM gender gap? A growing body of literature examines the drivers of why women do not pursue STEM studies or jobs, though with the caveat that most studies are from high-income countries, have small samples, and do not use experimental or quasi-experiment approaches.

One strand of evidence points to how stereotypes and biases influence gender gaps in STEM, especially in classrooms and educational materials in many countries. For example, men are more likely to be depicted as professionals in science (whether by name or as an illustration), while women are more likely to be depicted as teachers. Between 8 percent and 20 percent of mathematics teachers in Latin America reported that they believed mathematics is easier for boys. Such biases have been shown to result in lower self-confidence in STEM among girls and women.

These stereotypes and biases extend to tertiary education. Male and female professors in the United States both assigned lower ratings for competence to women compared to that of men among equivalent applications among science students; they considered the women applicants less competent and suitable for the job and offered a lower salary and less mentoring.

Bias and stereotyping also emerge in the home. Surveys show that parents show a greater preference for sons to work in STEM. Additionally, male students disproportionately identified their male peers as more knowledgeable about biology compared to female students who perform better.

Finally, women face more discrimination in the workplace than their male colleagues, especially in more male-dominated STEM fields. This can discourage women from applying for STEM jobs and can drive greater attrition from these occupations.

OPTIONS TO CLOSE GENDER GAPS IN STEM

The leaky STEM pipeline is path dependent, starting early and continuing throughout the life cycle. One starting point is correcting gender biases in learning materials. Additionally, extracurricular activities, such as museum visits, competitions, clubs, and robotics and coding camps, offer promise in building interest, fostering positive attitudes, inspiring greater confidence, and developing relevant skills in STEM studies and careers among both boys and girls. Interest in STEM can be fostered before tertiary enrollment through collaborations between primary and secondary schools and STEM departments at universities.

Few interventions target parents, although parents influence children's achievements and aspirations. Even a one-day event that engages parents of girls in STEM can contribute to reshaping parental attitudes toward the participation of girls in engineering.

Role models provide examples of the kind of success that one may achieve ("I can be like her") and often supply a template of the behaviors necessary for success. At the tertiary level, mentorship from faculty predicts the development of a science identity as well as deeper interest in science and promotes persistence in science fields among female undergraduates. Financial incentives may be another important option for bringing more women into STEM studies in universities.

Female peers also matter. The presence of more female peers in classrooms might help reduce women's implicit bias that engineering is a man's field and help women feel more confident about their own STEM abilities.

Finally, the private sector can play a role by bringing financial support to initiatives, facilitating exposure to female role models, and offering internship opportunities targeting secondary school girls.

LOOKING FORWARD

Notwithstanding the studies reviewed in this report, there are areas ripe for more data and further research, especially from low and middle-income contexts using rigorous methodologies and larger samples.

Starting with the basics, better sex-disaggregated and comparable test scores in primary and secondary levels, and enrollment statistics by field of study in tertiary education would help inform understanding of gender gaps. More rigorous and comparable global data is needed to track male/female gaps in STEM jobs, especially more data on jobs outside of academia. While challenging, building consensus on defining STEM jobs in labor force and other surveys would be of value.

Innovative not-at-scale initiatives need testing and impact evaluation. Interestingly, some recent studies have found that in some male-dominated sectors, male role models help women enter higher-paying industries. However, in the case of STEM, the emphasis has been on female role models who help girls and women overcome negative gender stereotypes. More testing on the relative influence of female versus male role models would enhance the evidence base, as would experiments that seek to influence parents (mothers or fathers) and thereby shift their aspirations for their sons and daughters with regard to STEM.

Finally, greater coordinated engagement with the private sector will be pivotal, both for funding initiatives to get girls into STEM studies but also to understand what works in largely private sector STEM careers.

1 Introduction

Science, technology, engineering, and mathematics (STEM) are vital to the economic and social prosperity of countries. These fields produce thinkers, researchers, and technicians who advance progress in health, education, food security, nutrition, transportation, infrastructure, energy, communications, and other sectors. STEM innovations play a central role in solving global challenges, such as overcoming disease, protecting the environment, increasing energy access and efficiency, and enhancing education (UN 2017). Moreover, STEM jobs are often good jobs for workers. Demand for workers in STEM is rising, and these jobs pay more (Rothwell 2013) (for evidence on Europe and Central Asian countries, see Muñoz Boudet et al. 2019; on digital and information and communication technology [ICT] jobs, see World Bank 2016).

Women and girls continue to be underrepresented in STEM careers, although there is wide variation among countries and across STEM fields. The gender gap in STEM careers contributes to large gender pay gaps (ILO 2018). Beyond income disadvantages for women because they have less access to STEM careers, the gender gap in STEM is also a missed opportunity for economies and an inefficient allocation of labor and talent. Shortages in STEM workers are a threat to economies, compromising the potential to reap the benefits of advances in STEM (CEDEFOP 2016; Dobson 2013).

Gender gaps in STEM can have broader negative consequences by influencing the products that STEM brings to economies and society. Encouraging the participation of more women in STEM is arguably critical to improving the tools STEM produces (West, Whittaker and Crawford 2019). For example, fewer women (and people of color) in STEM can translate into less-accurate facial recognition software (Buolamwini and Gebru 2018) and flawed medical studies, which compromises women's health (Dhruva, Bero, and Redberg 2011; Del Giudice 2015; Liu and Mager 2016; Criado-Perez 2019). Seemingly gender-neutral technology can be compromised by gender gaps. A large technology company that tried to automate its recruitment process using artificial intelligence found that, because the industry is dominated by men, and the majority of the résumés used to train the algorithm were associated with men, the system downgraded résumés associated with women or graduates of women's colleges (Meyer 2018).

This report explores the participation of women and girls relative to men and boys in STEM education and employment. We discuss a number of proposed policy solutions but also acknowledge the large gaps in both the status of STEM gender gaps and what works to close them, especially as it relates to low- and middle-income contexts.

2 Gender gaps in STEM education and careers

This report starts by examining the global patterns of gender gaps in education and learning pertinent to the path to STEM jobs divided into pre-tertiary and tertiary, and then examines the gender gaps in STEM labor opportunities.[1] A set of key findings that emerge from looking at the available data are presented in box 1, omitting many nuanced details that are described in detail below.

BOX 1. Key facts about gender gaps in STEM education and careers

- In the subset of countries with standardized science and mathematics test data, there is no systematic advantage for boys. And in some countries, girls are outperforming boys.
- Overall, girls tend to do better in these tests in countries with low average levels of learning, with the exception of African countries where boys score higher than girls in mathematics.
- Globally, tertiary enrollment and graduation rates are higher among women than men.
- Yet, women are less likely to undertake studies in STEM fields, particularly engineering, ICT and physics.
- Women who study STEM fields are less likely to enter into STEM careers and exit these careers earlier than male peers.
- Women are particularly underrepresented in jobs at the technical frontier. In the 20 leading economies, women account for 26 percent of workers in data and artificial intelligence, 15 percent of workers in engineering, and 12 percent of workers in cloud computing.

MUTED GENDER GAPS IN EDUCATIONAL ACHIEVEMENT ON THE PATH TO POSTSECONDARY

Globally, in primary school, girls and boys enroll and complete at about the same rates. This is a remarkable achievement of recent times. Gender gaps in attendance and completion to the detriment of girls are concentrated mainly in some low-income countries, mostly in Sub-Saharan Africa, where 71 percent of boys, but only 67 percent of girls complete primary education. In some Latin American

1 For a detailed discussion of these aspects for countries in Europe and Central Asia, see (Muñoz Boudet et al. 2019).

countries, there is a reverse gap in attendance and completion rates whereby, on average, girls are 5 percentage points more likely than boys to complete lower-secondary school. Overall, differences by sex in enrollment and completion are modest compared with the gaps in education outcomes between high- and low-income countries and between rich and poor households within countries (World Bank 2018).

In secondary education, even with significant gains as in primary school, enrollment and completion rates are lower, and there are considerable differences in rates between countries according to income level. Sub-Saharan Africa exhibits the lowest completion rates in lower-secondary education, at 43 percent, while at least two-thirds of children complete this level in other regions. Similar to the gender gaps in primary school, Sub-Saharan Africa shows the largest gap in lower-secondary completion, at 46 percent among boys compared with 41 percent among girls. In Latin America, meanwhile, girls are 5 percentage points more likely than boys to complete lower-secondary school.

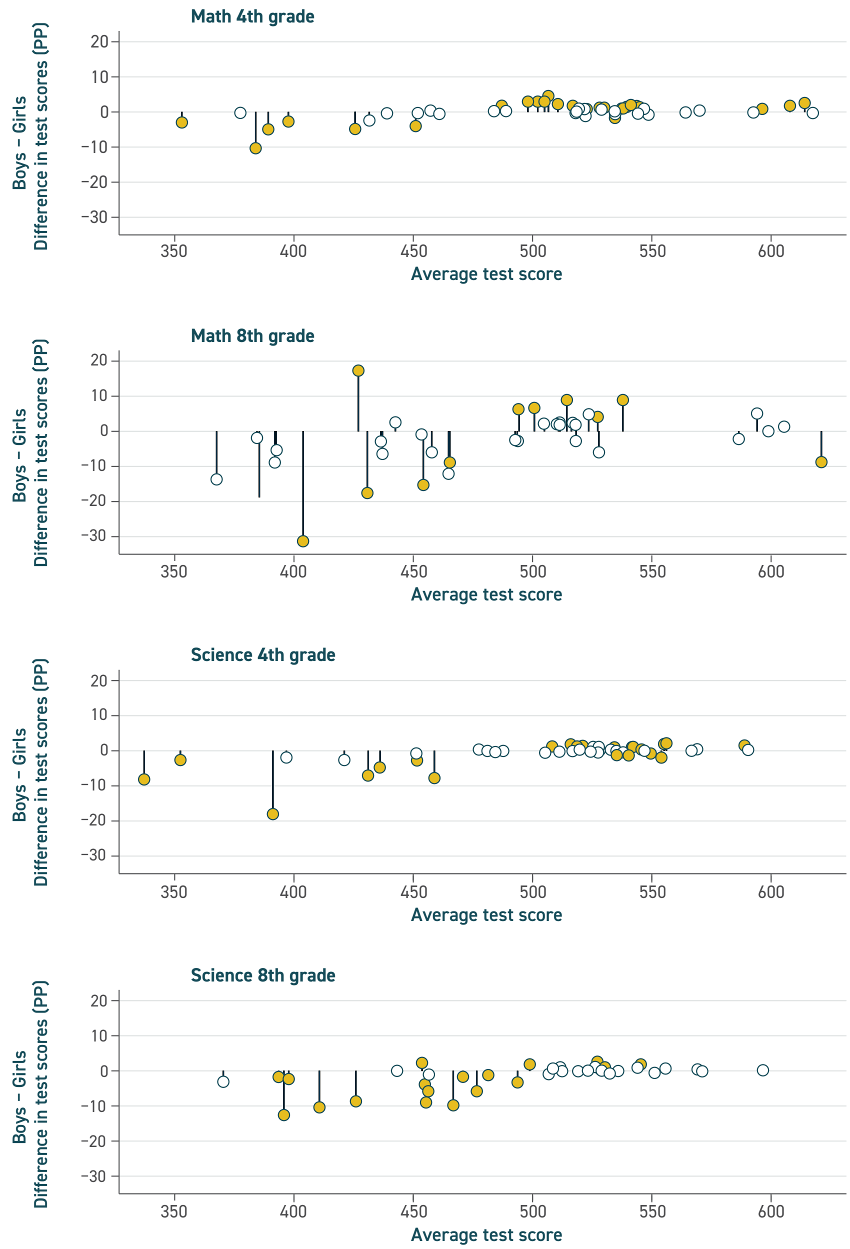
To explore how STEM gaps emerge in education, this study focuses on results related to mathematics and science test scores rather than enrollment in general. This section draws on prominent international testing data, from the Program for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS)[2] for the analysis.[3]

2 PISA tests 15-year-olds in mathematics, science, and reading across 80 economies every three years, irrespective of school grade. Innovative learning areas, such as collaborative problem solving and financial literacy, are also included. Students are asked to solve mathematics problems, interpret texts, and explain scientific processes. TIMSS assesses mathematics and science achievement at grades 4 and 8 in up to 57 economies. In mathematics, the assessment covers a range of skills, including algebra, geometry, data interpretation, and probability. The science assessment covers biology, chemistry, physics, and the earth sciences. Both assessments provide critical data, and both also show limitations, such as the omission of low-income countries. Even though PISA and TIMSS data are highly correlated, they are not directly comparable (Altinok, Angrist and Patrinos 2018). There are differences in assessment scales, the use of grade-oriented assessments (TIMSS) versus age-oriented assessments (PISA). Moreover, it is difficult to define a common grade metric because students start school at different ages. The tests also differ in the sample of economies and the subject coverage. Lastly, TIMSS is based on curricula, whereas PISA focuses on the application of skills (Rindermann and Ceci 2009).

3 PISA covered 79 economies in 2018, and TIMSS covered 57 economies in 2015, including within-country educational systems that participated separately, for instance, Hong Kong SAR, China. While the coverage of both assessments has expanded, no low-income economies participated in the latest surveys. Only two Sub-Saharan African countries, both upper-middle-income economies—Botswana and South Africa—participated in the TIMSS 2015, and none participated in the PISA 2018. However, low-income economies do participate in regional assessments. For example, some African countries participate in the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) and the Program for the Analysis of Education Systems (PASEC) of the Conference of Ministers of Education of Francophone Countries. In Latin America, countries participate in the Latin American Laboratory for Assessment of the Quality of Education of the United Nations Educational, Scientific, and Cultural Organization (UNESCO). These regional assessments are likewise not comparable with other international assessments.

Data of TIMSS 2015 show that girls often perform as well as or better than boys in science and mathematics (figure 1). The data indicate no statistically significant differences by sex in science achievement in primary school in 25 of 47 economies. In the other 22 economies, the scores are higher among boys than girls in 11 and the average difference is 8 points. The scores are higher among girls than boys in the 11 others and the average difference is 24 points. Girls tend to do better in countries with low levels of learning among children overall. These patterns are similar in mathematics in primary school.

FIGURE 1. Girls perform better than boys in economies where scores are below average



Source: TIMSS 2015 data.
Note: PP stands for percentage points. The hollow dots indicate that differences in expectations are not statistically significant.

The evidence on Sub-Saharan Africa presents a different picture. Using Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) and the Program for the Analysis of Education Systems (PASEC) data on 19 African countries surveyed between 2003 and 2006, Dickerson, McIntosh and Valente (2015) find a significant difference in mathematics test scores in favor of primary-school boys in 14 of 19 economies. However, the magnitude of the gap varies widely by the area of residence, parental educational attainment, and school characteristics, including the sex of teachers.

TIMSS data show no statistically significant differences by sex in science achievement in secondary schools in 19 of 37 countries. Girls outperform boys in 13 countries, at an average difference of 29 points, and boys outperform girls in 5 countries, at an average difference of 11 points. In mathematics in secondary schools in a larger number of countries, there are no differences by sex. Similar to the case in primary schools, the overall test scores in secondary schools are lower than average in the few economies in which girls perform better than boys in both science and mathematics. The overall patterns in the most recent PISA data (2018) resemble those described in the TIMSS data (table 1). However, across regions, score differentials are more moderate in the PISA data than in the TIMSS data (UNESCO 2017).

TABLE 1. International tests show a mixed picture of gender gaps at secondary

	Science		Mathematics	
Indicator	**PISA**	**TIMSS secondary**	**PISA**	**TIMSS secondary**
No statistical difference	39	19	33	25
Boys do better	6 (11 pts)	5 (11 pts)	32 (10 pts)	6 (9 pts)
Girls do better	34 (13 pts)	13 (29 pts)	14 (11 pts)	6 (17 pts)
Number of economies	79	37	79	37
Overall average score, points	**458**	**506**	**459**	**481**

Source: PISA 2018 and TIMSS 2015 data.
Note: Statistical differences are assessed at 5 percent. Average point differences are indicated in parentheses.

The countries in the TIMSS and PISA data are not the same. Among the subset of 32 countries that have been assessed in both mathematics and science, the test results show no gender gaps in only about a third (table 2). Differences by sex in science scores are statistically significant in both assessments in 10 of these countries. In none of them, however, do girls outperform boys in both assessments, while boys outperform girls in both PISA and TIMSS only in Hong Kong SAR. In no country do girls do better in science in PISA, while boys do better in science in TIMSS, but in 9 countries, boys do better in PISA, while girls do better in TIMSS. In mathematics, differences by sex are significant in both assessments in 7 of the 32 economies. Neither sex performs better in both assessments. In 5 countries, girls perform better than boys in PISA, while boys outperform girls in TIMSS. Boys perform better in PISA, while girls perform better in TIMSS in only 2 countries.

TABLE 2. Gender gaps in STEM vary between the two major international assessments

Indicator	Science	Mathematics
No difference in PISA and TIMSS	10	12
Girls do better in PISA and TIMSS	0	0
Boys do better in PISA and TIMSS	1	0
Girls do better in PISA and boys do better in TIMSS	0	5
Boys do better in PISA and girls do better in TIMSS	9	2
No difference in PISA and girls do better in TIMSS	1	2
No difference in PISA and boys do better in TIMSS	4	1
No difference in TIMSS and girls do better in PISA	0	5
No difference in TIMSS and boys do better in PISA	7	5
Number of economies	32	32

Source: PISA 2018 and TIMSS 2015 data.
Note: Statistical differences are assessed at 5 percent.

These patterns reflect a narrowing in gaps driven by improvements in mean scores of girls and a decline in the scores of boys especially at the upper end of the distribution test scores in the last four decades, which factor plays the larger role has not been studied (Zhu 2018). The changes in science scores among secondary-school girls in 17 countries were large between the 1995 and 2015 TIMSS rounds. Nonetheless, the averages were not higher among girls than boys in any of these countries in 2015 (UNESCO 2017). A comparison of PISA mathematics scores suggests that the gap in favor of boys diminished in 5 of the 64 countries participating in both the 2009 and 2018 PISA rounds because of improvements in scores among girls. In 8 countries, the reduction in the gap was caused by a large drop in the scores among boys. The average gap in science narrowed across member countries of the Organisation for Economic Co-operation and Development (OECD), but this was because the performance declined more among boys than girls over the same period.

The 2018 PISA results show a complex picture in the gender gaps at the bottom and top of the performance distribution. Variation is larger among boys, who are overrepresented in the lowest and highest scores in mathematics and science, a result also found in earlier PISA rounds and in other assessments (Baye and Monseur 2016). Gender gaps in favor of boys among the top performers are substantial in 45 economies in mathematics, but in only 19 economies in science, out of 79 economies.

Consistent with patterns in the TIMSS and PISA test scores, the few studies tracking trends in gender gaps in the acquisition of competencies over the life cycle find that boys and girls ages 4–10 perform similarly (Lindberg et al. 2010). Gaps in test scores by sex evolve with age. Combined data from several large-scale international assessments in high-income countries and following representative samples of birth cohorts show that the advantage of boys and men in numeracy is expanding (Borgonovi, Choi, and Paccagnella 2018). The expansion is pronounced at ages 15–27.

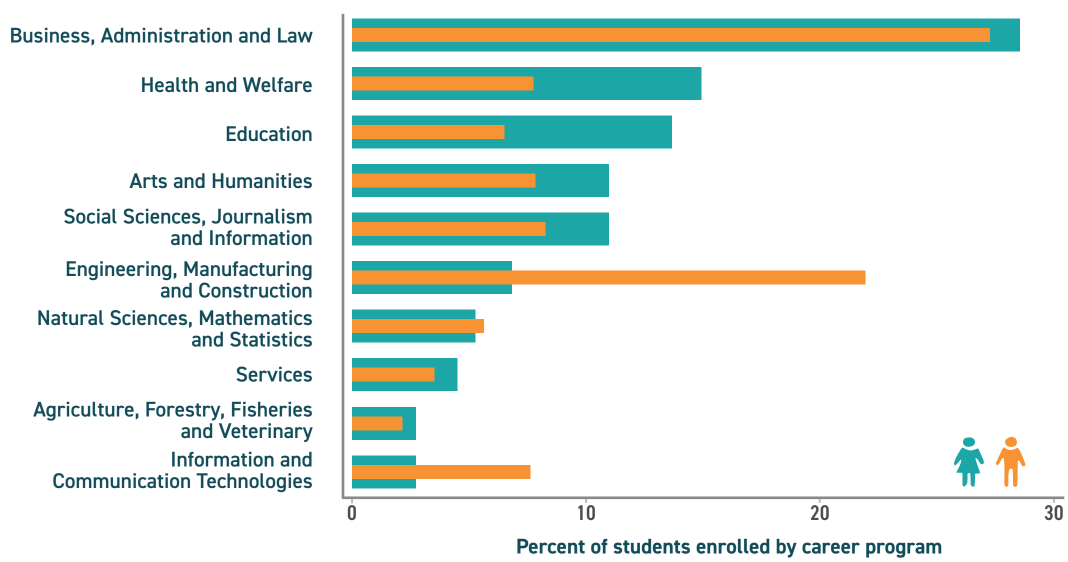
NOTABLE GENDER GAPS IN STEM AT THE TERTIARY LEVEL

Globally, more women than men are enrolled in universities (114 women for every 100 men), and graduation rates are higher among women. The same is true of master's degrees. In each case, women represent 54 and 56 percent of all graduates. Among individuals who have obtained doctoral degrees, 46 percent are women (UIS 2020). However, Sub-Saharan Africa is an exception. It has low rates of postsecondary educational attainment among both men and women, and women are less likely than men to be enrolled in university (gross enrollment ratios of 8 percent and 11 percent, respectively), a gap which has shrunken dramatically over the last 20 years.

While the higher global rates of enrollment and graduation and the differences in performance in pre-tertiary mathematics and science test scores, women are less likely to major in specific STEM fields. Globally, only 7 percent of women choose to study engineering, manufacturing, or construction, compared with 22 percent of men (figure 2). Enrollment rates in the natural sciences, mathematics, and statistics are generally low: 5 percent among women and 6 percent among men. In ICT studies, the enrollment rates are only 3 percent among women versus 8 percent among men. Women earn more than half the undergraduate degrees in biology, chemistry, and mathematics in the United States, but fewer than 20 percent of the undergraduate degrees in computer science, engineering, and physics (NSF 2014). The share of women graduates in scientific fields has increased markedly since 2001 in all developing regions except Latin America and the Caribbean, where women's participation was already high (Huyer 2015).

While women are often less likely to study STEM fields, more women participate in some STEM areas largely because they have higher overall enrollment numbers in universities in many countries than men. Indeed, more women than men are studying the natural sciences, mathematics, and statistics because of the large enrollment rise in 2000–15 (UNESCO 2017). Women account for 55 percent of such students even if they are less likely to study these fields.

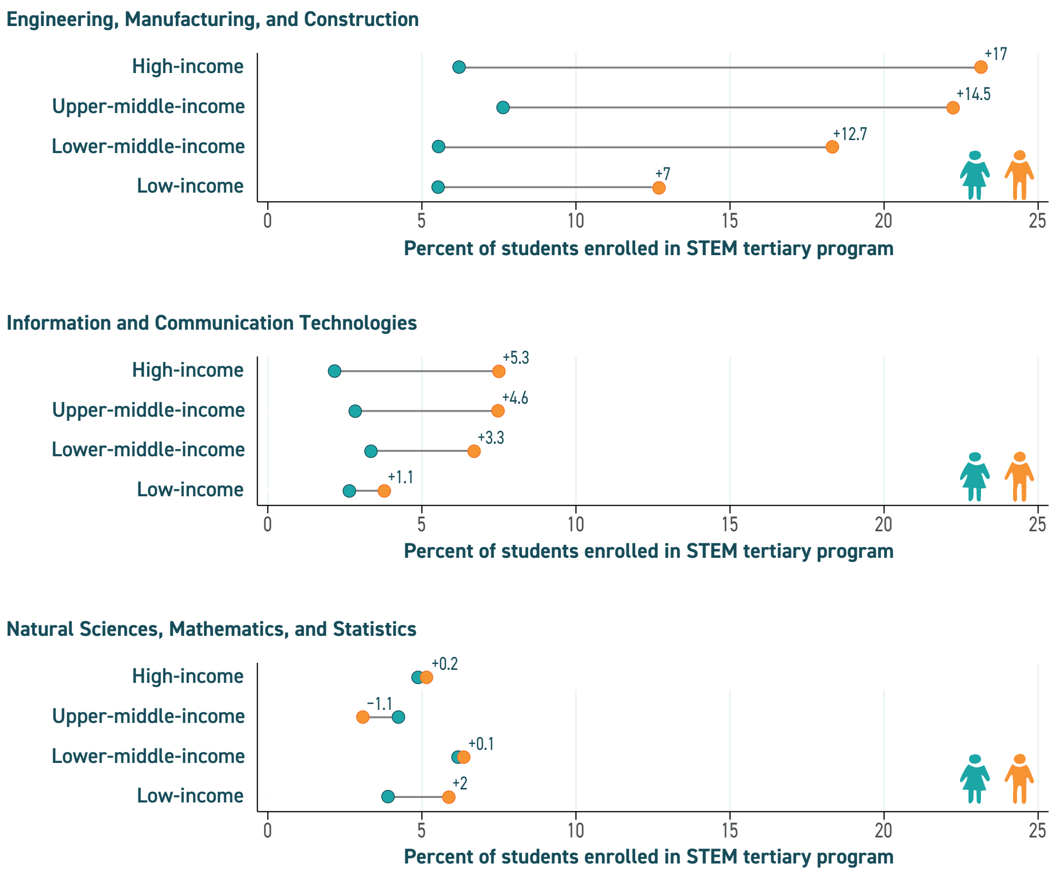
FIGURE 2. Women are less likely to major in STEM



Source: UNESCO Institute for Statistics.
Note: Most recent data point between 2015-2019 (unweighted averages).

As country income rises, gaps between women and men in STEM fields of study widen (figure 3). Women in low-income countries are 7 percentage points less likely than men to enroll in tertiary programs in engineering, manufacturing, and construction. In upper-middle-income and high-income countries, the gaps widen to 15 and 17 percentage points, respectively. A similar pattern, but with narrower gaps, is observed in ICT career programs in tertiary education. In higher-income countries, enrollment rates among women are greater. Thus, the gap in the shares of men versus female students in STEM fields of study is smaller than implied by the share of men and the share of women who choose STEM versus other fields of study.

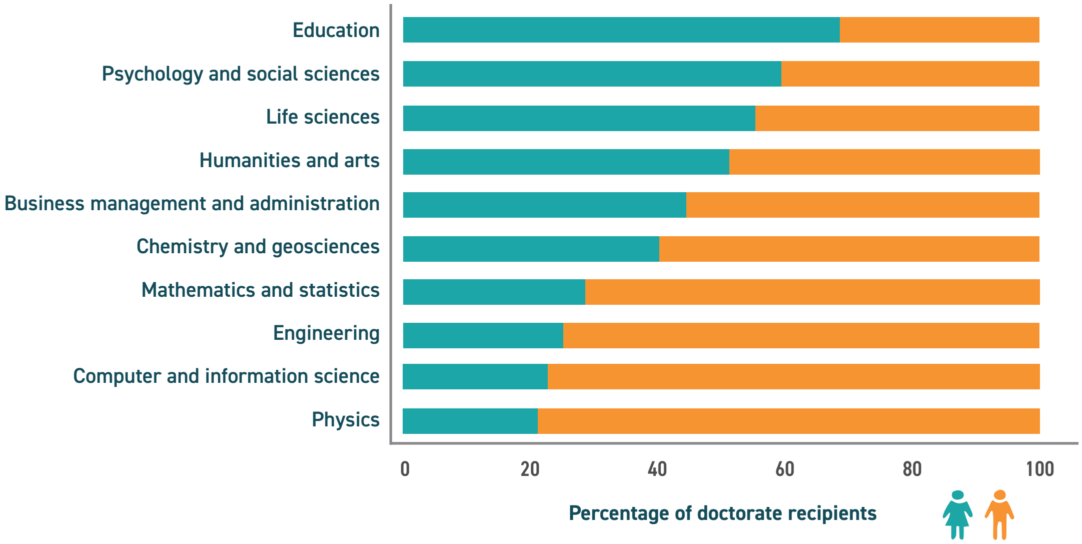
FIGURE 3. Gender gaps in tertiary STEM enrollment increase as country income rises



Source: UNESCO Institute for Statistics.
Note: Most recent data point between 2016-2019.

Men are just over half of all PhD graduates in the U.S. (54 percent) and dominate most STEM doctoral degrees (figure 4). But there is substantial variation among STEM disciplines and subfields. Women earned 55 percent of the PhDs in life sciences (agricultural sciences and natural resources, biological and biomedical sciences, health sciences) but 23 percent for computer and information science and 21 percent for physics. This has changed little in the last decade (up from 22 percent and 20 percent in computer and information science and physics respectively in 2008). Within engineering, a field that is heavily dominated by men, there is a notably higher share of women in bioengineering (41 percent) than electrical engineering (20 percent).

FIGURE 4. Men dominant among STEM doctoral degrees in the U.S.



Source: NSF data from 2017.

The larger incidence of gender gaps in STEM in higher-income countries highlights a paradox: countries characterized by greater gender equality exhibit wider gender gaps in STEM (box 2).[4]

BOX 2. Do more gender-equal countries have larger STEM gender gaps and, if so, why?

Some countries, such as Finland, Norway, and Sweden, are characterized by greater gender equality, but large STEM gender gaps. The gaps are wider in these countries than in countries that rank poorly in gender equality. This has been described as a gender-equality paradox (Stoet and Geary 2018).

This paradox may be explained by how an individual's education decisions are influenced by the individual's relative academic strengths. Girls perform better than boys in reading in every country that participated in the 2018 round of PISA. Girls perform as well as or better than boys in science or mathematics in many countries. The advantages of girls in reading and the advantages of boys in mathematics result in gender gaps in STEM education pathways because of the expectancy-value theory—the idea that expectations, personal values, and beliefs affect behavior—and because the choices people make to pursue academic success are based on personal strengths. The influence of personal academic strengths may be amplified in countries characterized by greater gender equality, greater freedom of choice among women, and the smaller opportunity cost of forgoing more profitable STEM careers.

The main paper that proposes this analysis measures gender equality using the World Economic Forum's (WEF) global gender gap index (Stoet and Geary 2018).[a] The WEF Index is negatively correlated with the ratio of women's to men's likelihood to graduate in STEM (−0.48), using data of the Institute for Statistics from UNESCO for 105 countries between 2015 and 2018. This negative correlation is confirmed using four other alternative measures to the WEF Index—the World Bank's Women, Business, and the Law index (−0.51), the OECD's Social Institutions and Gender Index (SIGI) (-0.51), the United Nations Development Programme's Gender Inequality Index (GII) (-0.47), and the Basic Indicator of Gender Inequality (BIGI) (-0.55) (authors' calculations; the signs of SIGI, GII and BIGI are reversed such that greater values indicate greater gender equality and not the same set of countries for each correlation, though there is considerable overlap).

Since the publication of the work of Stoet and Geary (2018), some researchers have raised issues with the original study (including Richardson et al. 2020) (a corrigendum by the original authors was published in 2019). These issues include questions about the methodology, the calculation of the share of women graduates of STEM programs, and the indicator used to measure gender equality. While this work challenges the evidence on the underlying reasons for the negative correlation between country gender equality and the likelihood of women compared to men to pursue STEM studies, the negative correlation itself is robust by different measures of the STEM gender gap and using different country gender equality measures.

Notwithstanding debates around appropriate measures of STEM gender gaps and country gender equality, the simple correlations suggest a paradox that remains to be unpacked.

a. The World Economic Forum measures gender equality in four main areas: economic participation and opportunity, educational attainment, health and survival, and political empowerment. See WEF (2020).

4 However, the gaps in mathematics and science test scores are smaller or reversed in countries characterized by greater gender equality (Guiso et al. 2008; McDaniel 2015). Moreover, in Arab society, girls often outperform boys by a wide margin (Friedman-Sokuler and Justman 2020; UNESCO 2017).

AND GENDER GAPS CONTINUE IN STEM CAREERS

As women and men shift from education into careers, three intertwined factors underpin the underrepresentation of women in STEM jobs. First, women are less likely to undertake studies in STEM fields at the tertiary level. Second, among those people who do follow studies in STEM fields, women are more likely than men to shift out of STEM careers once they are in the labor market. Third, women have lower levels of participation in the labor force.

Globally, women are less likely than men to enter and more likely to leave the STEM workforce.[5] In Europe, women who study in fields dominated by men, such as many STEM subjects, experience substantially slower entry into the labor market relative to other women and to men in general (Mills and Präg 2014). Relative to other fields, women in science and engineering jobs exhibit higher exit rates than their male counterparts (Hunt 2016).

Research on STEM jobs has focused overwhelmingly on the academic careers of undergraduate students pursuing STEM majors and has tracked gender gaps in the faculty hiring process, tenure, research collaboration, and research publishing. Other studies concentrate on the careers of industrial researchers working for private organizations. However, there is little research on STEM careers outside academia, and most of the research centers on the STEM labor market in the United States.

Available data show how the skewed pattern of differences by sex in fields of study translates into occupational sex segregation. Even if they study in STEM fields, women do not necessarily work in STEM jobs. In 2015, across the United States, women represented 40 percent of employed individuals whose highest degree was in a science and engineering field, but only 28 percent of these women were in science and engineering occupations (NSF 2018). Computer science, ICT, and engineering emerge as especially problematic because of differences by sex in attrition during the transition from school to career. Among students graduating in ICT or computer science in the United States, women are less likely than men to work in a computer-related job (38 percent vs. 53 percent, respectively), and there is also a gap in engineering (24 percent vs. 30 percent, respectively) (Funk and Parker 2018). Similarly, in the Republic of Korea, women represent 26 percent of the graduates in STEM programs, but only 20 percent of the researchers in STEM and 10 percent of people active in engineering and technology (UIS 2019). In countries with high shares of female researchers, such as Argentina, women are less likely than men to work in the private sector, which offers higher salaries and opportunities for career progression (UIS 2018). On the other hand, in eight Eastern European countries, STEM educated women and men have similar access to science and engineering jobs, though STEM educated men are more likely to work in ICT jobs (Muñoz Boudet et al. 2019). However, few STEM graduates end up in STEM professions regardless of sex.

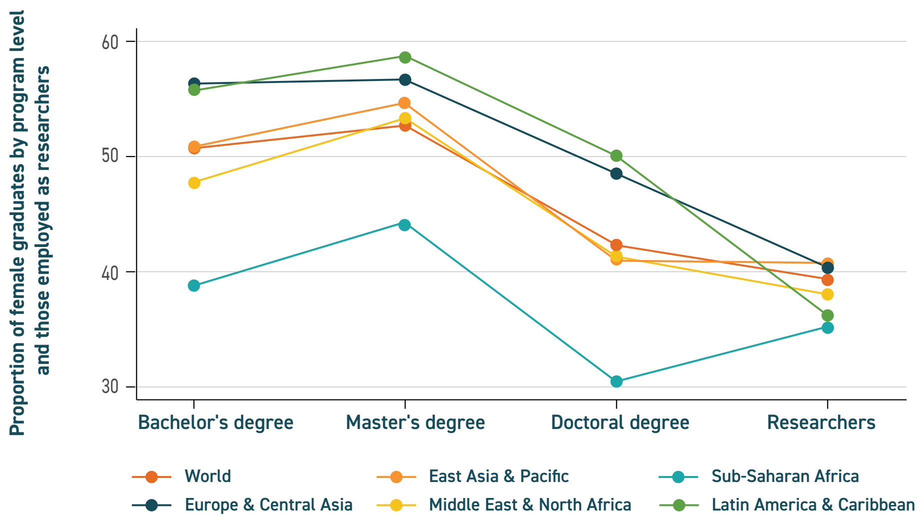
Research careers have been used as a proxy indicator of STEM careers gaps, even if not explicitly STEM-focused. Globally, relative to the share of women who have attained tertiary education, women's

5 Generally, on the STEM labor market, the data are scant on global trends and gender gaps specifically. A challenge in reporting on global trends is the lack of consistency and comparability. While some consensus exists on the definition of STEM fields of study, no consensus exists on the definition of STEM jobs or on whether such jobs should include STEM-enabled jobs or merely jobs that make substantive use of STEM. For example, the International Standard Classification of Occupations (ISCO), a classification structure of the International Labour Organization, includes architects and life science professionals under the category science and engineering professionals (ILO 2012). Similarly, the Bureau of Labor Statistics in the United States follows a standard occupational classification that adopts a wide view of STEM occupations that encompasses actuaries, anthropologists, economists, and midwives (SOC [Standard Occupational Classification] [database], Bureau of Labor Statistics, United States Department of Labor, Washington, DC, https://www.bls.gov/soc/). Similarly, no consensus exists on whether people working as STEM teachers or as technicians and assistants in research laboratories should be included in the STEM workforce. And finally, there is no agreement on whether social scientists in fields such as applied statistics or economics should be included.

participation in research shows a precipitous drop after studies (figure 5). Only 39 percent of all researchers are women. These data mask important differences across countries and regions. Countries in Europe and Central Asia exhibit higher rates (more than 50 percent of researchers in Bulgaria, Latvia, and Lithuania are women), partly as a legacy of the Soviet Union; however, men in STEM professions earn more than women in the same professions (Muñoz Boudet et al. 2019). The share of female researchers in Latin America and the Caribbean is also relatively high, at an average of 36 percent. East Asia and the Pacific stands out because it shows the greatest variation in the share of female researchers across economies, ranging from 16 percent in Japan to 76 percent in Myanmar.

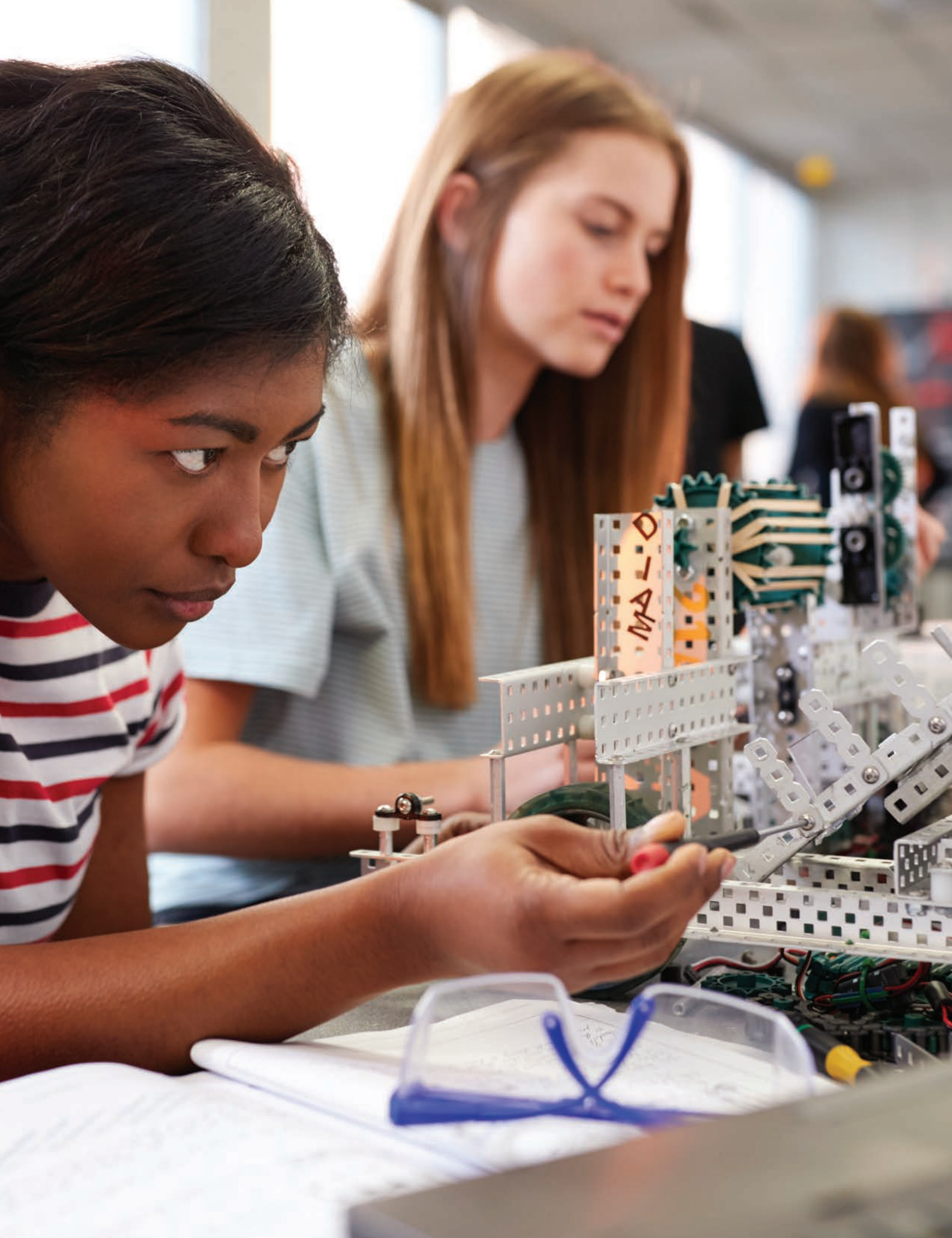
Women are particularly underrepresented in jobs at the technical frontier. In the 20 leading economies, women workers account for 26 percent of workers in data and artificial intelligence, 15 percent of workers in engineering, and 12 percent of workers in cloud computing (WEF 2020).

FIGURE 5. The absence of female researchers because of a leak in the pipe



Source: Institute for Statistics, UNESCO. Most recent data point between 2015 and 2018.
Note: Mean values represent the population- weighted averages of the results in countries on which data are available. Regional aggregates include developed and developing countries. The number of countries for which data are available on graduates and researchers are included in each regional average in parentheses. World (109 and 60 countries, respectively), East Asia and the Pacific (17 and 8), Europe and Central Asia (45 and 30), the Middle East and North Africa (12 and 8), Sub-Saharan Africa (16 and 6), and Latin America and the Caribbean (13 and 8).

There is also a gender wage gap in STEM careers, a phenomenon that is consistent with outcomes in other sectors. Evidence shows that the choice of major significantly affects an individual's earnings potential and fields dominated by men tend to lead to occupations that are remunerated more generously. For example, economics—a non-STEM field dominated by men—has the highest earnings among social sciences (Carnevale and Cheah 2015), yet women have yet to break into higher faculty levels in economic departments (Lundberg and Stearns 2019). Among men and women pursuing STEM research jobs in the US, women earn an average of 31 percent less than men, of which two thirds of the gap can be attributed to differences in wages across STEM fields and differences in access to research funding. The remaining portion of the gap is explained by the parenting status of the worker, suggesting that women who have children earn less than their men counterparts (Buffington et al. 2016).



3 What factors drive STEM gender gaps?

Many factors that underlie the gender gaps described in chapter II emerge along the achievement path in STEM. This section discusses the drivers of these gaps along the path from early schooling into work. A systems approach is adopted for the analysis.[6] The gender gaps in STEM careers are, to a large extent, the result of a path dependent process, meaning that there is no quick fix to closing these gaps.

FACTORS ALONG THE EDUCATION PATH TO POSTSECONDARY

A large and growing body of evidence points to how stereotypes and biases influence gender gaps in STEM. Whether the biases involve perceptions about who is talented in science and mathematics or about who can or should be working in STEM jobs, the evidence—mostly drawn from European countries or the United States and based on small samples—points to the ways biases influence a range of psychological states, characteristics, or processes that are seen as critical drivers of gaps (UNESCO 2017; Fiske, Dasgupta, and Stout 2014). These psychological factors include aspirations, identity, interests, mindsets, motivation, self-confidence, and self-efficacy.[7] The stereotypes and biases that are relevant are not confined to one environment, but cut across environments, from peers to parents and teachers and to classroom materials. The stereotypes and biases emerge early along the education path and even before the start of the education path.

Implicitly associating mathematics and science with men is correlated with boys performing more effectively. During a half million implicit association tests conducted among adults in 34 countries, 70 percent of the test-takers demonstrated a tendency to associate the word male with science and the word female with liberal arts (Nosek et al. 2009). Moreover, in countries in which people strongly associate mathematics and science with men, boys in grade 8 scored higher, on average, in science and mathematics.

One way in which stereotypes become manifest in the education system is in the materials used to teach children. Several studies find that, in curricula and educational materials in many countries, including Bangladesh, China, India, Indonesia, Malaysia, Pakistan, Romania, and the United States, characters are portrayed in stereotypical roles in the household and at the workplace (Mahmood and Kausar 2019; Ellis 2002; Miroiu 2004; Shi and Ross 2002; Guo and Zhao 2002; Chen and Chen 2002; Blumberg 2008; Islam and Asadullah 2018; Blumberg 2015, respectively). Men are more likely to be depicted

6 One might also discuss the transition from early schooling to work with reference to development periods (Fiske, Dasgupta, and Stout 2014). An alternative framework would be an ecological approach as presented by UNESCO (2017), which discusses factors across four domains: the individual, the family, institutions, and society.

7 This section discusses these psychological areas, but without a formal analysis of the varied and nuanced definitions of the concepts. For more details, see Bandura 1997; Mason et al. 2013; Hart 2012.

as professionals in science (whether by name or as an illustration), while women are more likely to be depicted as teachers (Kerkhoven et al. 2016). It is difficult to quantify the impact of such bias in textbooks and curricula, but there is an intuitive concern that children internalize stereotypes by sex and that this influences their attitudes and aspirations.

Biases are also evident among teachers. For instance, girls are taught that mathematics consists of a set of rules, whereas boys are encouraged to exert more independence (Hyde and Jafeee 1998). In Italy, when math teachers held stronger implicit stereotypes (*math=boys*), female students, especially those with lower scores to start, performed worse on standardized tests, reported less self-confidence in math, and opted into less demanding academic tracks. Teacher stereotypes did not affect boys (Carlana 2019). Between 8 percent and 20 percent of mathematics teachers in Latin America reported that they believed mathematics is easier for boys (UNESCO 2016). Biases can also become manifest in more subtle ways. Hearing sexist comments from teachers and peers about the ability of girls in mathematics and science is correlated with lower levels of self-perception of competency among school girls in the United States The negative effects on girls' sense of competence was more pronounced for Latinx girls. (Brown and Campbell 2010).

Among teachers in Greece, bias in behavior in favor of boys in science classes had a positive effect on the scores of boys and a negative effect on the scores of girls in a national exam that determines university admission and has an influence on the choice of students on fields of study (Lavy and Megalokonomou 2019). An increase in teacher bias in the last two grades of secondary education lowered the probability that girls would study mathematics, physics, computer science, or business administration. In the US, an experiment found that despite identical transcripts, school counselors were less likely to recommend Black female students for advanced placement calculus and rated them as the least prepared (Francis, de Oliveira, and Dimmitt 2019). Studies in France and Israel similarly find that teacher bias in favor of boys affects the performance of boys and girls on tests; these were among the first studies to examine the causal impact of secondary-school practices and differences by sex in outcomes, including the choice of field of study (Terrier 2015; Lavy and Sand 2018).

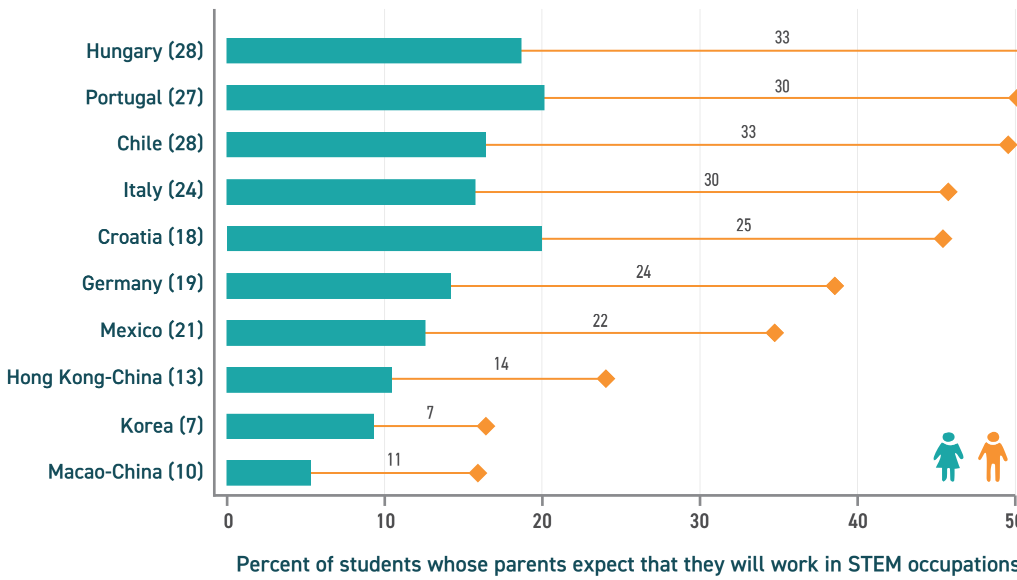
In Zimbabwe, a qualitative study on schools finds that gender bias in the classroom is pervasive (Mutekwe and Modiba 2012).[8] Boys received more teacher-initiated contact than girls, including more attention during exercises involving teacher questions and the provision of teacher feedback. The educational materials used in the classroom, especially textbooks and wall charts, typically showed only men. Women were shown in aprons, looking after babies, and cooking. Teachers brought up the subject of marriage often in reference to girls and made offhand remarks that girls should do domestic chores and care for the family. Subjects such as mathematics and physics were often classified by teachers as masculine, while teachers classified home economics, biology, and tourism as feminine.

Parents naturally factor into the achievements and aspirations of children. Children who are encouraged by their parents to participate in after-school STEM activities become more interested in these subjects—and girls with university-educated parents participate more in these activities and get better grades in science (Simpkins, Davis-Kean, and Eccles 2006). In Kenya, encouragement from parents and teachers contributed to increasing the enrollment of girls in physics classes (Ooyo 2011). Parental support predicts the persistence of adolescent girls in the study of mathematics and science in secondary school (Leaper, Farkas and Brown 2012). However, parents are not immune to bias against girls in STEM. In several countries, parents show a greater preference for sons to work in STEM (figure 6). Gender biases within

8 Efforts are being made to create a scale to measure the extent of the stereotypical gender beliefs of teachers. See Nurlu 2017.

families are correlated with the performance of girls in mathematics. In the United States, in families with a greater preference for sons (measured by parents who continued to have children until a boy was born or by mothers who expressed traditional views on gender roles), girls performed less well in mathematics relative to girls in other sorts of families (Dossi et al. 2019). It might well matter which parent (the mother or father), but there is lack of evidence to speak to this.

FIGURE 6. Parents have a greater expectation that sons will take up STEM careers

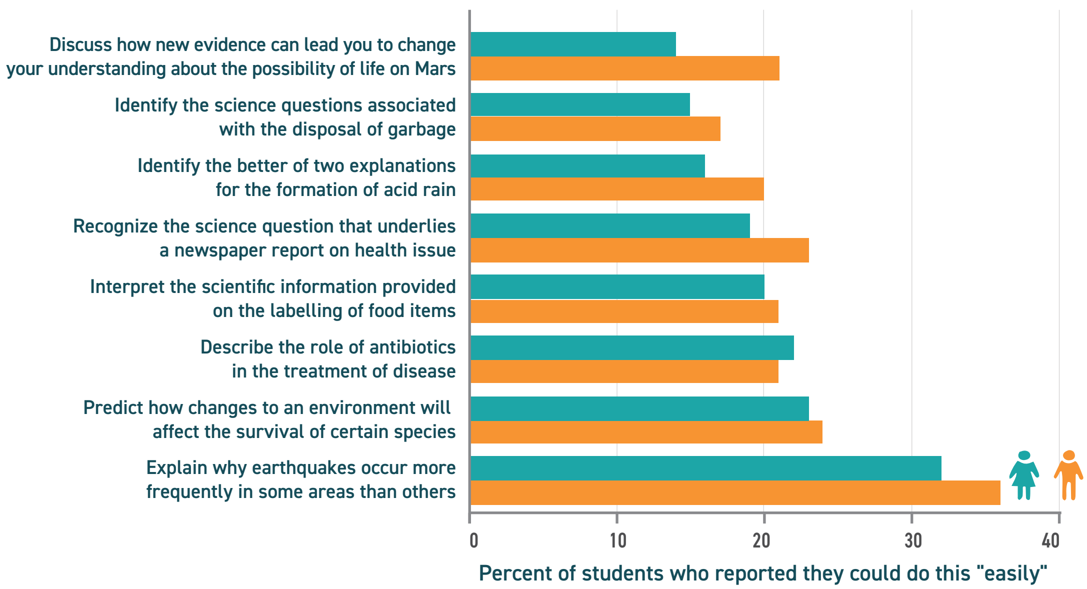


Source: PISA data 2012.
Note: All differences by sex are statistically significant. Countries and economies are ranked in descending order by the share of boys whose parents expect them to work in STEM occupations when the boys reach age 30. The figure in parentheses is the gender gap conditional on mathematics, reading and science performance.

Disproportionately portraying men in STEM roles and reinforcing stereotypes about who works in STEM jobs in teaching materials among young students are intertwined with perceptions of capabilities that together form a vicious cycle. Studies have found that, by age 6, girls in the United States are less likely to associate brilliance with their sex and start to avoid activities that are aimed at children who are "really, really smart" (Bian, Leslie and Cimpian 2017a; 2017b). Females are often associated with the stereotype that they do not have raw talent (Leslie et al. 2015; Bian, Leslie and Cimpian 2017a, 2017b; Bennett 1996; Kirkcaldy et al. 2007; Lecklider 2013; Tiedemann 2000). The association of brilliance with masculinity affects gender gaps in STEM because fields of study that are perceived to require brilliance are more likely to be STEM fields (Leslie et al. 2015).

While causality is difficult to prove, many assert that these stereotypes and biases encourage a loss of confidence among girls with regards to STEM.[9] [10] Girls in secondary schools in Sweden are more confident that they can succeed in careers where women are well-represented, such as health care and education (Tellhed, Bäckström, and Björklund 2017). A weaker sense of self-efficacy and a weaker self-concept are correlated with lower test scores (OECD 2015) (figure 7). In Europe and Central Asia, girls show higher levels of anxiety toward both science and mathematics (Muñoz Boudet et al. 2019). In Japan, differences in mathematics self-efficacy fully account for gender gaps in PISA mathematics scores (Sundharam 2019). Meanwhile, in the United States, although boys have higher self-efficacy in mathematics than girls, they have lower test scores (Louis and Mistele 2012).

FIGURE 7. Girls are less likely to report that they can easily do tasks in science



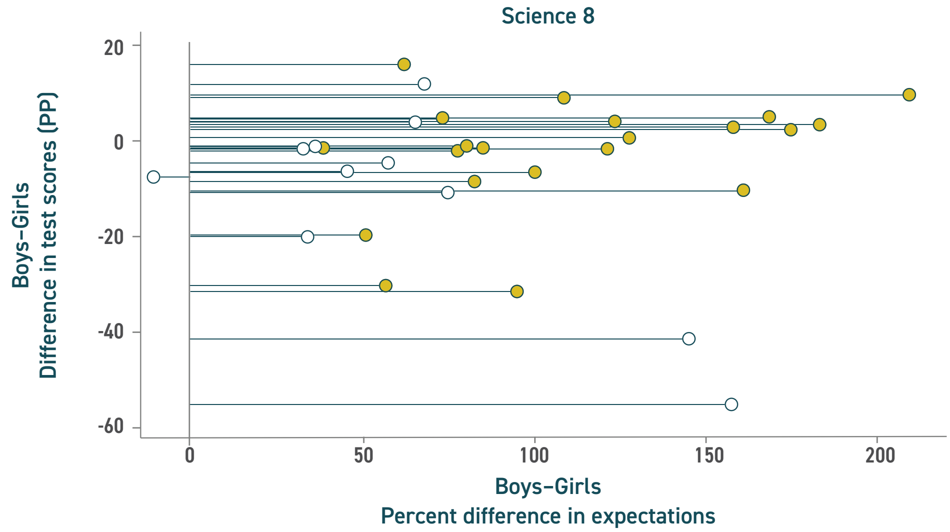
Source: UNESCO 2017.

In combination, such psychosocial differences are widely considered to drive the divergence in interests and aspirations between girls and boys with respect to STEM. Girls and boys have markedly different aspirations in terms of career fields. Among top performers in math and science in grades 4 and 8, boys are much more likely to expect or aspire to a career in STEM fields in the more than 30 countries surveyed through PISA with corresponding test scores (figure 8 which shows grade 8 science). Similar results are found for the over 70 countries with the reporting on aspirations but no test scores.

9 There are many nuances and distinctions among concepts associated with confidence in STEM, such as self-efficacy (the extent to which students believe in their own ability to solve mathematics tasks) and the self-concept (the belief of students in their mathematics abilities) (OECD 2015).

10 This relates to the concept of "growth mindset" which is the belief that intelligence is malleable through effort (Dweck 2006). Effort is interpreted as the pathway to improvement and school provides a space to improve one's ability, rather than to prove it through looking smart. Setbacks offer a way to practice resilience and work harder, rather that serving as a reflection of one's capabilities. Failure is perceived as an opportunity to try again, rather than a time to give up. Student growth mindset beliefs predict math achievement (Claro, David, and Dweck 2016), and sometimes with larger impacts for girls (Good, Aronson, and Harder 2008; Degol et al. 2018). In addition to the student's own growth mindset, parents' growth mindset can matter too, potentially with a larger association for girls than boys for mindset in math ability (Chen, Kopotic, and Zamarro 2017).

FIGURE 8. Girls show less aspiration than boys to work in science or engineering



Source: Data of PISA 2018.
Note: PP stands for percentage points. The hollow dots indicate that differences in expectations are not statistically significant.

The findings of country-specific studies are similar. In Croatia, although girls score better in physics, they are significantly less likely than boys to choose physics in their school leaving exams (Jugović 2017). Meanwhile, boys exhibited a higher perceived level of competence and benefited from a greater expectation of success relative to girls, and girls, who were less interested in pursuing physics, tended to associate physics with men rather than women. Students generally thought boys and men were more talented in physics and in occupations in the technical sciences. In the United Kingdom, girls ages 10–11 who had not expressed aspirations in science associated science with masculinity, desired more nurturing or glamorous jobs, and could not imagine themselves as scientists (Archer et al. 2013). A study in New York found that, while boys and girls both entertained stereotypes and beliefs that put them off of STEM, the effect was greater among girls, who showed less interest in pursuing science careers (Valenti 2016). The aspiration to engage with STEM at young ages can have long-lasting impacts. Girls in Southern California who expressed a strong interest in science and engineering careers had developed an early interest in engineering by third grade (Aschbacher and Tsai 2014).

Beyond the sociocultural factors that influence gender gaps in STEM, there is little or no evidence that sex differences in biological functions influence academic ability overall or the ability to succeed in STEM subjects (Blickenstaff 2005; UNESCO 2017; Ceci and Williams 2007).[11] And what might appear to be a biological function may be the result of social influences.[12] While young boys have small advantages over young girls in spatial functioning (Casey et al. 2008), which is considered important in STEM studies, even this modest difference may be attributed to household environment (Reilly and Neumann 2016).[13]

11 As recently as 15 years ago there was an active disagreement about the existence of differences by sex in intrinsic interest in STEM, including views help by the former president of Harvard (Jaschik 2005) and a pioneering Yale University computer scientist (who stated "The real explanation is obvious: Women are less drawn to science and engineering than men are. They're also less prone to the intense, cutthroat aggressiveness that usually marks the successful research scientist or engineer" (Gelernter 1999).

12 See the literature discussed in UNESCO (2017).

13 Spatial abilities are sometimes highlighted in this area because the skills are positively correlated with standardized test scores, declarations for STEM majors in education, and the number of enrollments in science courses (Gold et al. 2018).

ENTRENCHED BIAS AT THE TERTIARY LEVEL PERPETUATES GENDER GAPS IN STEM

Echoing the findings in the literature on primary and secondary education, stereotypes and biases in tertiary education have been shown to influence women and men's fields of study and the resulting gender gaps in STEM. It is often difficult to isolate or rank these drivers. Moreover, these factors do not play out equally across STEM fields. For example, in a critical review of the evidence on the most commonly cited factors that underpin the variation in gender gaps across STEM fields, three domains have been identified to explain the larger gender gaps in participation in computer science, engineering, and physics, compared with the much smaller gaps in biology, chemistry, and mathematics (Cheryan et al. 2016). These are: (1) masculine cultures that signal a weaker sense of belonging among women than men; (2) a lack of sufficient early experiences with computer science, engineering, and physics; and (3) gender gaps in self-efficacy.

In terms of stereotypes, computer science, which is associated with particularly large gender gaps, is illustrative. Stereotypes about computer science in the United States include the idea that it is a masculine profession for white men with strong computer ability (Cheryan and Plaut 2010; Whitney et al. 2013). These geniuses are singularly focused on computers, socially awkward, lack interpersonal skills, and wear glasses (Schott and Selwyn 2000; Cheryan et al. 2013; Fisher 2003; Mercier, Barron, and O'Connor 2006). The field is also broadly characterized by isolation and a lack of communal goals, such as helping others and working with others (Diekman et al. 2010; Master, Cheryan, and Meltzoff 2016).

Popular stereotypes permeate society through the media. In a small experiment in the United States, researchers created two newspapers. One contained an article that reinforced current stereotypes about computer scientists that was entitled "Study finds computer science continues to be dominated

by ‘geeks’,” and the other dispelled these stereotypes (Cheryan et al. 2013). Following a randomly administered assignment among students, female students who had read the article filled with stereotypes reported less interest in pursuing computer science compared with female students who had read the other article. Men’s interest did not differ based on the article read.[14]

Bias among teachers exists not only in primary and secondary education, but also in tertiary education. Men and women professors in the United States both assigned lower ratings for competence to women among equivalent applications from science students for a laboratory manager position; they considered the women applicants less competent and suitable for the job and offered a lower salary and less mentoring (Moss-Racusin, Dovidio, and Brescoll 2012). In rating hypothetical doctoral graduates applying for a postdoctoral position in their fields, physics professors in the United States rated otherwise equivalent candidates as more competent and more employable if they were men (Eaton et al. 2020). Women candidates were rated more likeable than men candidates across physics and biology. However, physics professors rated Black women and Latinx women and men as the least hireable despite identical applications.

A small ICT study suggests that men and women may have preferences for website designs produced by the same sex. The relevant aesthetic considerations relate to typography, color. and the use of shapes. This could result in implicit biases when mostly male ICT teachers evaluate the work of their students (Moss and Gunn 2009).

Studies on peer groups by sex at U.S. universities have found biases. Male students disproportionately identified their male peers as knowledgeable about biology even relative to female students who perform better in the subject area and at rates that are much higher than the corresponding rates among female students (Grunspan et al. 2016). Undergraduates in studies in the United States believe that successful scientists share personality characteristics more readily with men than with women (Carli, Alawa, and Lee 2016).

Women undergraduates in the United States who associate men with science are less likely to identify themselves with science and have fewer scientific aspirations; science stereotypes by sex and identification with science explain approximately 35 percent of the difference in science career aspirations among women (Cundiff, Vescio, and Loken 2013). A sense of belonging in STEM classes is a predictor of interest in STEM classes, and this is also true in non-STEM fields (Thoman et al. 2013). Perceptions of what is and is not feminine are used to explain the variation in gender gaps across STEM areas. The perception that biology is a more feminine subject than physics and that engineering is not feminine is posited to explain the underrepresentation of women in engineering and the concentration of women engineers in subfields such as biological engineering (Schreuders, Mannon, and Rutherford 2009).

Female students who choose to pursue STEM studies at universities report that they face greater discrimination and stereotype threat than men in male- or female-dominated academic areas or than women in academic areas characterized by the greater participation of women, such as the arts, education, the humanities, and the social sciences; this may contribute to attrition among women in STEM (Steele, James, and Barnett 2002; Kost-Smith, Pollock, and Finkelstein 2009; Kost-Smith, Pollock, and Finkelstein 2010; Diekman et al. 2010; Deemer et al. 2014; Thoman, Arizaga, and Smith 2014).[15]

14 Stereotypes associated with STEM also appear in film. Among the few characters in STEM jobs in a review of popular films, the vast majority were men (88 percent vs 12 percent) (Smith, Choueiti, and Pieper 2014).

15 Stereotype threat is a situation in which people worry about confirming a negative stereotype about their identity group. Thus, women might feel threatened by negative gender stereotypes according to which they are not as capable as men (Lockwood 2006).

Data on first-year university students in the United States track the influence of parental occupation on career choices of the students. In engineering, the mother-daughter role-model effect has become stronger between 1971 and 2011—described as a promising development—though the gender gap in engineering will require more time to close than this effect carries (Jacobs, Ahmad, and Sax 2017).

A lack of confidence can influence the education pathway after the start of university studies. Calculus I has emerged as a juncture in the critical leaks in the educational pathway to STEM careers. Female students have been shown to be much less likely to continue to Calculus II (thereby exiting STEM) than male peers (Ellis, Fosdick, and Rasmussen 2016). While both men and women lose confidence over the course of a semester, female students start courses at a markedly lower confidence level than male students. Among new students who enter engineering at tertiary institutions, female students exhibit less confidence in their own ability to be successful as professionals and are more unsure about fitting in. This lack of professional role confidence predicts their attrition from engineering as a field of study (Cech, Rubineau, and Silbey 2011). Another study considered the possibility that the gender gap in STEM fields may exist not only because women unreasonably lack confidence because their past performance may be as good as or better than the performance of male students, but also because men overestimate their performance in mathematics. This is referred to as positivity bias. The overestimation by male students of their own performance has been shown to contribute to the stronger intention to pursue mathematics of men compared with women (Bench et al. 2015).

Female STEM students may not always have lower self-efficacy. This is a conclusion of a study among male and female engineering majors in the United States (Concannon and Barrow 2009). Another U.S. study found that more women than men had positive perceptions of their engineering abilities (Jones, Ruff, and Paretti 2013). However, male students were more likely to endorse the stereotypical idea that men possess greater engineering ability than women, suggesting that a climate exists that reinforces the stereotype of the dominance of men in engineering departments. Even if self-efficacy decreases because of, say, the stereotype threat, this may not affect the aspiration for science careers (Deemer et al. 2014).

Given the lack of a systemic gender skills gap in mathematics and science in secondary education, it has been argued that the large gap by field of study in tertiary education is essentially a reflection of choice and preference rather than a failing in ability or qualification. It is difficult, perhaps impossible, to disentangle the extent to which the gap in choice of field of study is the result of the cumulative impact of stereotypes and bias along the education path versus a matter of fit. Several studies find that women have a strong preference for communal social work, such as helping people and working with people, while men prefer working with objects, though the size of the effects is small (Konrad 2000; Lippa 1998; Schwartz and Rubel 2005; Diekman et al. 2010). Because STEM professions are not typically perceived as those that advance collaborative aspirations, differences in the relevant preferences between men and women may explain a part of the gender gap in STEM (Diekman et al. 2010).

Another dimension of choice relates to differences in personal academic strengths. In most countries, girls do as well as or better than boys in mathematics and science. At the same time, girls perform better than boys in reading by a large margin. Among men and women with a comparable outstanding aptitude in mathematics, women are likely to outperform men in verbal ability (Park, Lubinski, and Benbow 2008). Such differences or proximal factors may explain the STEM gaps to the extent that a personal choice to study STEM is a choice based on intrapersonal skills (as discussed in box 2). In the United States, students with high mathematics and verbal skills were found to be less likely to pursue STEM careers than were those with strong mathematics capabilities, but moderate verbal skills (Wang, Eccles, and

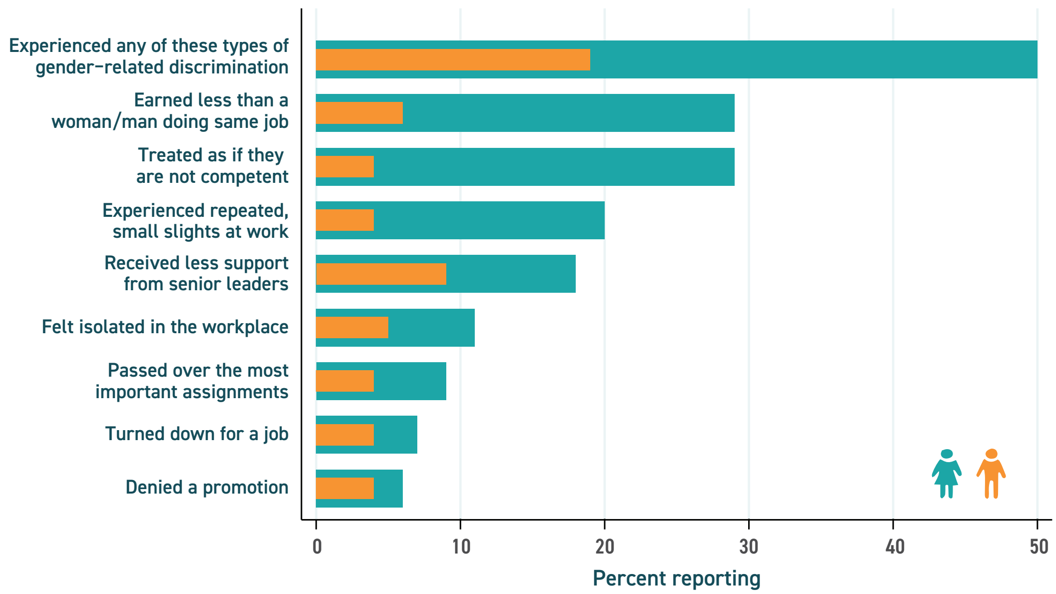
Kenny 2013). Their relative strength may afford women a greater range of career choices than men as well as an opportunity to consider non-STEM fields (Ceci and Williams 2010).

FROM SCHOOL AND INTO STEM CAREERS

As women and men transition from education into careers, even if they do study STEM, women are more likely than men to shift out of STEM careers once in the labor market. An added factor underpinning the lack of women in STEM jobs is the overall lower labor force participation among women. So, in many ways, STEM jobs are not unique with respect to gender gaps. A multitude of factors disadvantage women in the workplace worldwide, including disproportionate childcare responsibilities in the home, mobility restrictions because of safety concerns and sexual harassment, discriminatory labor laws, and a range of social norms in the workplace that create hostile work environments, unequal pay, and a lack of opportunities for professional advancement. The focus of this section is the evidence on factors specific to gender gaps in STEM fields and careers. Achieving parity in the STEM labor market will require a focus not only on specific STEM-related drivers, but also on the myriad factors that drive global gender gaps in the workplace.

A range of workplace attributes are associated with STEM gender gaps. In STEM jobs in the United States, women are much more likely than men to report workplace discrimination by sex (50 percent and 19 percent, respectively) (figure 9). They are also much more likely to report such discrimination than women in non-STEM jobs (41 percent). Evidence suggests that it is the domination by men in many STEM fields rather than the nature of the work in some STEM jobs, such as the use of equipment, laboratories, and fieldwork in engineering, that limits the participation of women in certain STEM careers and drives greater attrition among women. Women in male-dominated STEM jobs report higher rates of discrimination based on sex, 78 percent compared with 44 percent in STEM jobs with an evenly balanced mix by sex (Funk and Parker 2018). The gender gaps in exit rates in engineering are similar to the corresponding gaps in economics and finance, two male-dominated non-STEM areas (Hunt 2016). There is also a lack of mentoring and networks, as well as discrimination by managers and coworkers as drivers of differential attrition among women in engineering.[16]

FIGURE 9. STEM jobs are associated with more discrimination to the disadvantage of women



Source: Funk and Parker 2018.

In male-dominated STEM environments, biases in the workplace can send the message that women do not belong. When women engineering students gain early exposure to the workplace through internships and summer jobs, they often report encountering a sexist culture in which they do not gain equal access to learning opportunities (Seron et al. 2015; Sibley 2016). Social norms may create unwelcoming workplaces. For example, in engineering, where women are considerably underrepresented, studies in the United Kingdom and the United States find that men engineers often resort to fraternal salutations, such as man, mate, or lad in addressing men colleagues, which serve to encourage male bonding. But, while working with women engineers, men tend to be silent. Similarly, men tend to shake hands with their men colleagues, but not with women colleagues even if they are friendly with the women. These practices may not seem significant, but, cumulatively, they may create workplace dynamics that are siloed and potentially inhospitable for women. Women also report that they are mistaken for support staff instead of engineers (Faulkner 2009a, 2009b).

16 There is no difference in the share of women who say they have experienced sexual harassment at work (22 percent) between women in STEM and women in non-STEM jobs. But women in STEM jobs report sexual harassment as a problem in their industry at higher rates than women in non-STEM jobs (55 percent and 47 percent, respectively).

Other factors also come into play. For instance, in their first professional encounters, women find that the engineering field, in their experience, is not as devoted to tackling social challenges, a key motivator for women engineering students, and they begin to revise their career plans (Seron et al. 2015; Sibley 2016). Because of their limited membership in the profession in both numbers and status, women may sometimes undergo a loss of confidence and professional self-esteem, compromising their career retention and progression (Faulkner 2009a, 2009b).

Researchers have noted that there are unintended consequences of boosting women's representation in engineering management roles, resulting in segregation within the engineering field and increasing the challenge in the entry of women into these jobs (Cardador 2017). In the United States, about half the women in engineering are on a management track, and about three-quarters of those who left the profession between 2008 and 2012 were on a management path. Because technical roles are regarded as more valuable than management roles, women who take on more coordination and people-management duties are no longer viewed as real engineers, further entrenching gender bias on the entry into these jobs.

Employer bias is not unique to STEM. There is a wide-ranging literature, which is mostly drawn from high-income countries (see, for example, the summaries and discussions in Azmat and Petrongolo 2014; Baert 2017; Bobbitt-Zeher 2011; Davison and Burke 2000; Koch, D'Mello, and Sackett 2015). Stereotypes about differences by sex in mathematics skills emerge with respect to STEM jobs. Men and women employers both have been shown to exhibit a bias toward hiring men candidates to perform tasks calling for mathematics (Reuben, Sapienza, and Zingales 2014). Even if employers are given an opportunity to update their hiring decisions based on information about past performance, they continue to prefer men candidates.

It has been argued that the leaky pipeline from STEM studies to STEM careers among women is driven by differences in expectations about family formation between men and women specific to STEM. But differences in marriage and fertility plans do not explain gender gaps in the United States. Even women who study STEM and plan to delay marriage and limit the number of children do not benefit from the same employment opportunities in STEM as their men peers (Sassler et al. 2017).

4 What works in closing gender gaps in STEM?

The data show a stark gender gap in mindset and aspirations, but not necessarily capabilities, in primary and secondary schooling. By tertiary, a large gender gap in STEM studies emerges. The STEM gender gap in university studies increases in countries assessed as having greater gender equality, as measured by several alternative country gender equality indices (box 2). This so-called gender equality paradox with regards to STEM underscores the need for intentional efforts along the education path, even in seemingly gender-equal countries.

This section explores the scant evidence on effective methods to close STEM gender gaps. In their systematic review of experimental and quasi-experimental studies of the participation of women in STEM, Henninger, Muñoz Boudet, and Rodriguez-Chamussy (2019) initially identify 2,100 articles, which drop to 256 after application of a first filter, of which 21 are included in the final review based on a measurement of impacts or the existence of an associated impact evaluation.[17] Few studies focus on low- or middle-income countries, and studies on high-income countries sometimes rely on small samples. Here, a less stringent approach is adopted to the evidence and promising avenues of intervention, even if they have not yet been thoroughly tested. The analysis includes interventions that have been rigorously evaluated as part of a randomized control trial and quasi-experimental studies as well as qualitative peer-reviewed studies in areas where rigorous quantitative evidence does not exist. The analysis draws on the main areas that emerge in the wider literature, while noting the need for more rigorous evidence.

SOLUTIONS ON THE PATH TO TERTIARY EDUCATION

Encouraging the participation of boys and girls in STEM activities in preprimary and primary education is considered important in building interest and developing relevant skills in STEM studies and careers. Engaging young girls in spatial play may help address the gender gap in the ability among young children to reason about space (Jirout and Newcombe 2015). The way learning is delivered also matters. If young children are taught science in a traditional classroom setting, boys show greater interest than girls. Interparticipatory approaches designed to promote active learning can contribute to shrinking the gap by raising the interest and enjoyment of girls in science (Patrick, Mantzicopoulos, and Samarapungavan 2009).

Extracurricular activities, such as museum visits, competitions, clubs, and robotics and coding camps, offer promise in fostering interest in STEM among both boys and girls (Dabney et al. 2012). This extends to secondary education, in which extracurricular science activities may positively influence the science

17 These 21 studies are grouped into four categories of outcomes of interest: interest and aspirations, achievement and performance, participation and representation, and attitudes and beliefs.

identity of girls, foster positive attitudes, and inspire greater confidence (Gonsalves, Rahm, and Carvalho 2013; Bhattacharyya, Mead, and Nathaniel 2011). Because they take place outside the classroom, these activities offer a less formal space wherein girls are free of the fear of judgment and where nontraditional pedagogical methods may be applied, such as making, building, and focusing on the personally relevant nature of science and the ability of science to serve as a tool in solving everyday problems (Riedinger and Taylor 2016; (Watermeyer 2012; Lou et al. 2011; Peterman et al. 2016). Extracurricular activities that employ problem-based strategies may be beneficial not only in boosting the interest of secondary-school girls in science, but also in diagnosing specific challenges (Williams, Iglesias, and Barak 2008; Lou et al. 2011; Heaverlo 2011). Such programs are sometimes run as public-private partnerships, for example, the Women in Science (WiSci) Girls' Science, Technology, Engineering, Arts & Design, Mathematics Camps.[18]

Combining efforts, such as mentoring initiatives and outreach activities, including contests and professional development programs, can be effective in dispelling stereotypes about who can do STEM and what may result from STEM studies and careers (Jeffers, Safferman, and Safferman 2004; Fiske, Dasgupta, and Stout 2014) (box 3).

BOX 3. Addressing the leaky pipeline in technology with tech entrepreneurship programs for girls

Technovation Girls is the world's largest technology entrepreneurship program for girls ages 10–18 (Technovation 2016). It runs across more than 100 countries and is supported by the Peace Corps, UNESCO, and UN Women. Through Technovation, girls work with female mentors, identify a community problem that may be addressed with technology, develop a mobile application, and launch a start-up. Developed in 2010 in response to a decline in the number of women entering computer science over the previous 30 years, Technovation enables girls to learn how to create technological solutions to everyday problems.

Over the past nine years, about 32,000 girls in more than 100 countries have developed mobile applications and start-ups to confront diverse challenges, including food waste, lack of nutrition, and women's safety issues. After participating in the program, 78 percent of students reported that they had become more interested in computer science; 70 percent were more interested in entrepreneurship; and 67 percent were more interested in business leadership than when they started the program. Around 58 percent of alumnae subsequently enroll in computer science courses.

Numerous studies have documented the gender bias in STEM curricula and learning materials. Although there is little evidence that addressing this bias would close gaps, one could argue that such evidence is not needed to justify supporting change. The Gender Model Readers Project in Zimbabwe finds that biographies of women who have succeeded in male-dominated fields can alter the career aspirations of girls from traditional to nontraditional careers, but with no effect on boys (Nhundu 2007). In Israel, children assigned sex-neutral reading textbooks identify more activities as appropriate for both women and men relative to their peers with reading books that reflect stereotypes (Karniol and Gal-Disegni 2009). These children also identified more traditionally women's activities as appropriate for either sex.

18 See "Women in Science (WiSci)," Girl Up, Washington, DC, accessed October 18, 2019, https://www.girlup.org/wisci/#sthash.5VeflzyM.xrY3N1b5.dpbs.

Large-scale initiatives to rewrite textbooks and change curricula are costly and may not be implemented quickly within countries. Scholars have proposed less expensive and more rapid alternatives. Sadker and Zittleman (2009) highlight different forms of bias and propose practical steps to tackling bias, including exercises in which teachers ask students to search for examples of bias in textbooks and suggest ways to remove the bias.

Diagnosing and tackling gender bias in the classroom to avoid STEM stereotypes may increase the interest of girls in STEM education. Experimental studies in the United States find female students are more likely than male students to choose a non-stereotypical computer science class (68 percent vs. 48 percent, respectively) (Master, Cheryan, and Meltzoff 2016). The option of a non-stereotypical classroom increased by a factor of three the number of young women who expressed an interest in computer science class. Such an approach should be part of a broader effort to improve teaching practices (box 4). An anti–gender bias manual can be integrated into the materials used for in-service teacher training (Blumberg 2008). Providing teachers with information on women as role models in engineering and raising their awareness of these women's contributions to society appear to help overcome stereotypical conceptions of engineering (Hoh 2009).

BOX 4. Diagnosing and tackling gender bias within the classroom

Building on a robust evidence base, the World Bank recently developed *Teach*, a free classroom observation tool that aims to support analysis of the quality of teacher practices that help develop the socioemotional and cognitive skills of students in low- and middle-income countries (Molina et al. 2018). One of the four components of the tool measures whether the teacher creates a culture that is conducive to learning by treating students with respect, responding to their needs, and challenging stereotypes. It measures the extent to which the teacher does not exhibit gender bias and does challenge gender stereotypes in the classroom.

Measuring teaching practices is a first step toward improving teaching practices. To address findings in the *Teach* assessment, the World Bank is developing *Coach*, a new program to foster good teaching practices. The plans include addressing and challenging gender stereotypes and biases in the classroom in training materials for teachers.

Few interventions target parents, although they influence children's achievements and aspirations. Even a one-day event that engages parents of girls in STEM can contribute to reshaping parental attitudes toward the participation of girls in engineering. A randomized experiment informing parents about the benefits of opting for STEM courses in secondary school by providing brochures and a website positively affected the perception among mothers of the importance of STEM courses. Students also enrolled in a greater number of STEM courses as a result of the intervention, though there were not significantly different results by sex.

Evidence has shown that mentoring can boost girls' interest, confidence, and intent to pursue STEM (Dasgupta 2011; Cheryan, Drury, and Vichayapai 2012; Stout et al. 2011). Role models provide examples of the kind of success that one may achieve ("I can be like her") and often also supply a template of the behaviors that may be needed to achieve success. By supporting improvements in the social, emotional, and behavioral domains, furnishing information about STEM professions, and offering academic and career guidance, mentors can demonstrate to girls how technology and engineering can be personally meaningful and address community needs (Karcher 2005; Kekelis and Gomes 2009). In France, one-hour sessions with women role models who speak of science-related careers and experiences in the field increased by 30 percent the probability that a girl in grade 12 would enroll in a male-dominated STEM track in tertiary education the following year (Breda et al. 2018). An online mentoring program has been found to increase girls' knowledge of university studies and jobs in STEM, intention to pursue STEM studies, and also helped maintain their self-efficacy (self-efficacy decreased for the control group). These effects were still evident at the end of the one-year program (Stoeger et al. 2013).

Female science and mathematics instructors might serve as role models for girls interested in STEM. In Korea, matching with a female middle-school teacher increases the likelihood that a female student will enroll in STEM-related tracks in high school and aspire to pursue a STEM major (Lim and Meer 2019). The likelihood that female students will declare for and graduate with a STEM major in college increases if the students had female mathematics and science teachers in high school (Bottia et al. 2015; Paredes 2014; Muralidharan and Sheth 2016; Lim and Meer 2017).[19]

19 Not specific to STEM pursuits, but related evidence from India and Korea suggests that matching by sex may help improve the performance of femaie students (Muralidharan and Sheth 2016; Lim and Meer 2017; Paredes 2014). Teacher quality is also important. Female teachers with limited mathematics skills have been found to lower mathematics scores among girls in disadvantaged neighborhoods (Antecol, Eren and Ozbeklik 2015).

Interest in STEM can be fostered before tertiary enrollment through collaborations between primary and secondary schools and STEM departments at universities (Fiske, Dasgupta, and Stout 2014). This could entail bringing young students to university labs for scientific demonstrations or science workshops at their schools, ideally including female faculty and graduate students from STEM programs.

The private sector can play a role, by bringing financial support to initiatives (such as, for example, the corporate partners for Girls who Code in the U.S. which has raised over $100 million), facilitating exposure to female role models (such as supporting STEM employees to volunteer in classrooms or the "She Can STEM" campaign in the U.S.), and internship opportunities targeting secondary school girls.

SOLUTIONS IN TERTIARY EDUCATION SYSTEMS

One key area identified for closing STEM gender gaps at universities is exposure to female experts, faculty, and peers to increase social belonging (Fiske, Dasgupta, and Stout 2014). Studies on tertiary education point to the importance of mentors and role models to women's participation in STEM. In the United States, faculty mentorship predicts the development of a science identity and deeper interest in science and promotes persistence in science fields among female undergraduates (Hernandez et al. 2017). Also in the United States, mentorship matched by sex or race enhances women's sense of belonging in the field, motivation, retention, and postcollege engineering aspirations (Dennehy and Dasgupta 2017). In Lebanon, matching with a woman rather than a male science mentor in the first year of college substantially reduces the gender gap in STEM enrollments and graduation, mainly in the case of students with advanced mathematics ability (Canaan and Mouganie 2019). In contrast, the sex of a mentor in a nonscience department had no effect on the choice of major among students.

Faculty mentorship positively influences the interest of female students in science and academic performance in STEM subjects, provided that the students look up to the faculty mentors as role models and relate to them (Carrell, Page, and West 2010). Female students with a female professor they perceive as a role model show a stronger connection to science, are less likely to stereotype science as a man's domain, and have more serious intentions to pursue STEM careers (Carrell, Page, and West 2010; Young et al. 2013; Tropp and Pettigrew 2005; Stout et al. 2011).

Other approaches also influence performance by changing women's mindsets. For example, when a calculus test included introductory text stating that males and females have performed equally well in the past, women in the treatment group outperformed men in both groups as well as women in the control group (Good, Aronson, and Harder 2008). And, interventions designed to improve social belonging and resilience among women engineering students raised their grade point averages, eliminating existing gender gaps in performance (Walton et al. 2015).[20]

Female peers also matter. The presence of more female peers in classrooms might help reduce women's implicit bias that engineering is a man's field and help women feel more confident about their own STEM abilities (Dasgupta, Scirle, and Hunsinger 2015). In the United States, a multiyear longitudinal field experiment (2011–15) brought together 58 peer mentors (female and male) and 158 female mentees once a month for one year. When female undergraduates were paired with female mentors they maintained a sense of belonging and positive self-efficacy (Dennehy and Dasgupta 2017). Women without mentors and women with male mentors reported a sharp decline in their sense of belonging and their self-efficacy

20 The social belonging intervention highlighted that both men and women shared concerns about belonging in engineering and being treated with respect at first but that these issues went away in time. Quotations from students were included to reinforce these points. The second "affirmation-training" intervention underscored that both female and male students learned to manage stress and find balance over time.

over the course of their first year, although the male mentors were perceived as equally supportive. At the end of the first year of the study, all women with female mentors remained in engineering, compared with only 82 percent of the women with male mentors and 89 percent of the women without mentors (Porter and Serra 2020). [21]

University and professional associations are key forms of support in university and during professional life. These organizations provide access to mentors, networks, and a range of other services (box 5).

BOX 5. University and professional associations can support women in STEM

University associations can foster an inclusive environment and provide opportunities for leadership and peer mentoring. For example, at Harvey Mudd College in the United States, the annual Women Engineers and Scientists for Tomorrow Workshop with senior faculty presents opportunities in engineering and science-related careers to participant secondary-school students, parents, and teachers. Outreach programs at the University of Michigan include partnerships with local secondary schools and community colleges to recruit students in grades 7–8 to participate in the Girls in Science and Engineering Summer Program (Trautvetter 2018). Arizona State provides *CareerWISE*, an online training portal on problem-solving, coping and resilience. When women in STEM doctoral programs used the website for at least five hours, they demonstrated improvements across these domains (Bekki et al. 2013).

As part of reforms in education in engineering, the Pontifical Catholic University of Chile developed the Women in Engineering Program to increase engineering degrees. Activities include a bootcamp to provide female students with tools for leadership and self-awareness to face entry into professional life, training students as ambassadors to inspire and engage secondary-school students, and organizing an annual gathering of outstanding female engineers to showcase and celebrate the successes of female engineers.

Professional associations are also important in building networks, providing structured mentorship, sharing job opportunities, accessing scholarships, and establishing professional skills. These organizations may have a national, regional, or global reach. They also focus not only on technology and engineering, but other male-dominated sectors as well. The Society of Women Engineers is the largest association for women in engineering and technology. It provides scholarships, hosts youth outreach events, and disseminates new research related to gender gaps in STEM fields. Other examples include Women in Power, the Global Women's Network for Energy, Women in Cleantech and Sustainability, the Women's Infrastructure Network, and the National Society of Black Engineers.

Beyond peer networking, role models and mentoring, as with the pre-tertiary educational pathway, there are potential avenues for addressing STEM gender gaps in pedagogy. Female students with instructors who use student-centered methods and emphasize professional skills in their courses report that they acquire better engineering skills (Ro and Knight 2016). Observational data suggest that women in

21 This effect has been found in economics, a non-STEM field dominated by men. Exposing students enrolled in classes on the principles of economics to charismatic women economists who studied at the same university greatly increased the probability that female students intended to major in the field and enroll in economics classes, but did not affect man students (Porter and Serra 2020).

male-dominated fields are more likely to drop out after experiencing setbacks or competitive pressure early in their careers (Fischer 2017). Focusing on absolute performance rather than framing academic assessments as competitions or providing relative feedback, such as rankings, might contribute to closing the gap in the willingness to compete and encourage students to make choices that are sex and gender neutral (Buser and Yuan 2019). Specialized training programs can be useful (box 6).

BOX 6. Specialized training programs as an alternative path to jobs for women in technology

Skills training programs might offer opportunities to reduce the gender gap in STEM by encouraging participants to defy norms and stereotypes about male- and female-appropriate occupations. Experimental evidence from Nigeria indicates the potential for training to support employment in emerging sectors despite an initial lack of sector-specific skills. ICT training, combined with soft skills (cultural sensitivity, stress and time management) and opportunities to connect with potential employers, resulted in a 26 percent greater likelihood that female graduates would be working in ICT. The program increased aspirations among women who initially held implicit biases against associating women with professional attributes. These women were also more likely to crossover into the ICT sector after the training program (Croke, Goldstein, and Holla 2017).

The World Bank Group's Decoding Bootcamps Program gathered insights from 25 coding bootcamps and 7 digital skills programs across 22 countries on good practice approaches to recruiting and retaining women in advanced technology skills training programs. Profiling female role models in the local technology sector, leveraging women's networks to find interested applicants, and engaging with families and communities, especially in contexts with restrictive social norms, appeared to be promising recruitment tools. Consideration of the constraints and responsibilities that affected women, such as childcare, transportation, and costs, was especially important in retaining women in skills training for technology jobs. Actively integrating socioemotional and life skills and boosting self-efficacy were also key. To help connect women to technology jobs after their skills training, structured programs focused on mentorship. Job placement and building professional networks were also promising. World Bank teams are now rigorously testing these insights in a range of country contexts (Hammond, Mulas, and Nadres 2018).

Financial incentives may be another important option for bringing more women into STEM studies. This is particularly critical given that higher parental educational attainment and higher household income are often associated with the level of children's engagement and performance in science (Betancur, Votruba-Drzal, and Schunn 2018). Results-based financial support through loan repayment assistance for female students has a positive effect on retention and completion of undergraduate degrees in engineering (Yang and Grauer 2016).

Efforts aimed at giving college students Information about the differential returns to STEM might matter, though there are no studies available. Though, in Kenya informational sessions on the returns to vocational education (with a video about successful female mechanics) increased women's enrollment in male-dominated trades (Hicks et al. 2015).

CLOSING STEM GENDER GAPS IN WORKPLACES

Women face a variety of barriers once they have completed STEM studies and seek to enter and advance in the labor market. First, they encounter obstacles in recruitment and hiring. Second, once they are hired, the environment is often less inclusive and presents barriers to career progression. Third, women struggle to balance work and family life, especially caring for children, which has a major impact on career progression. These are not challenges unique to STEM jobs.

There are a wide range of options to create inclusive and more equitable workplaces, which are not relevant only to STEM jobs. This includes well-known areas such as parental leave policies, flexible work, employer-supported childcare, and anti-sexual harassment policies, to name a few. Other avenues include initiatives focused on monitoring gender equity in the workplace, including collecting and making available data on gender pay gaps (also called pay transparency; see Bennedsen et al. 2018; Castilla 2015), and gender equality outcomes more generally at firms (such as EDGE certification) (Fitzsimmons, Yates, and Callan 2020). Policies including salary history bans (Hansen and McNicols 2020); joint evaluations (Bohnet, van Geen and Bazerman 2016) and, in some cases, anonymizing applications (Fiske, Dasgupta, and Stout 2014; Rinne 2018) can equalize opportunities in hiring and starting pay. To broaden the pool of applicants considered for jobs, efforts to address "gendered wording" in job post descriptions has been advocated (Gaucher, Friesen, and Key 2011) although more research is needed.[22] Another approach is to set a quota with respect to the sex composition of candidates to interview to increase the share of females hired than may otherwise result in a process with no quota.[23]

Evidence on measures that are effective in mitigating STEM gender gaps in workplaces and careers is mostly focused on academic settings (often applying more generally to research careers than STEM) and in engineering. And this evidence is often qualitative and based on case studies.[24]

Qualitative insights from British female engineers point to various types of support that enabled the women to succeed (Fernando, Cohen, and Duberly 2018). First, the care and peer support of women and men colleagues and managers, including direct guidance on how to handle difficult situations, helped counteract the exclusion and isolation that women often experience in the sector. Second, feedback about performance that was personalized and constructive helped women build their technical skills and confidence. Third, opportunities to take on greater responsibilities were invaluable, these included invitations from managers or other senior colleagues to become involved in high-profile projects that helped women's career progression. Although a less direct form of support, colleagues who exemplified the balance between work and life, especially senior women, also served as role models who showed how combining engineering and parental responsibilities effectively was possible.

Given the pervasive gender bias that has been documented in STEM workplaces particularly, approaches to changing gender bias among peers and management warrants exploration. Some experiments have focused on changing gender biases to improve the behavior of employees and the workplace climate to promote gender equality and foster women's career progression. Faculty participants at a workshop at

22 See, for example, https://www.hiremorewomenintech.com/.

23 This is known in the U.S. as the Rooney Rule – established by the U.S. National Football League in 2003 and named after the former owner of the Pittsburgh Steelers. It was not intended to pertain to hiring women but with regards to ethnic-minority candidates in coaching and senior league jobs, though it is now used more generally in the private sector. It was found to increase the share of ethnic-minority coaches in the NFL (DuBois 2016).

24 To illustrate the lack of an evidence base on what works, in the review of interventions to address STEM gender gaps in Europe and Central Asia, Muñoz Boudet et al (2019) focus on the education path and do not discuss any pertaining to the labor market. This is similar with Fiske, Dasgupta, and Stout (2014) which focuses on these gaps in the U.S.

the University of Wisconsin-Madison focused on reducing gender bias had a boost their motivation, their perception of benefits, and self-efficacy to engage behaviors promoting gender equality (Carnes et al. 2015).

Oregon State University in the United States engaged in an institutional transformation by making staff more aware of the barriers women face in advancing within the institution (Shaw et al. 2019). The program involved a two-week seminar centered on (1) analyses of the systems of power with special attention on gender and (2) the design of plans for participants to contribute through concrete actions to change institutional policies within their areas of influence. The results of the evaluation indicate that the intervention substantially affected the university's hiring practices, promotion, retention, and institutional culture. For example, the College of Engineering increased the share of women in tenured faculty from 15 percent in 2014 to 20 percent in 2017. As of 2018, the number of female faculty has more than doubled in that college.

More research is needed on the most effective and sustainable ways to address such bias. A systematic review of interventions designed to reduce implicit bias reveals that approaches that focus on engaging with the perspectives of others—imagining how people feel and think—are not effective in the short term, while exposure to non-stereotypical behavior through positive examples appears more promising (FitzGerald et al. 2019). In most cases, the effects on behavior of interventions aimed at tackling gender bias are small and fade quickly. This may be understandable in that bias is formed and maintained through culture (Forscher, Lai, and Axt 2019).[25]

A second area of gender inequality especially relevant to STEM jobs is the role of mentoring in the workplace, including the importance of mentoring by men because there are few women in many STEM fields.[26] Some studies of women working in male-dominated nontraditional sectors have highlighted the role of male mentors or role models (Goldstein, Gonzalez, and Papineni 2019; Alibhai et al. 2017). For example, a study from Uganda shows that female entrepreneurs with male mentors were up to 22 percent more likely to own businesses in male-dominated sectors, such as metalworking, electricals and carpentry (Campos et al. 2015). Today, research focused specifically on women's underrepresentation in STEM highlights the importance of female role models in increasing aspirations and building female self-efficacy. Further research is needed to examine the influence of male mentors in tackling the STEM gender gaps in workplaces.

Mentoring can be particularly relevant among women early in their careers. In the United States, the Committee on the Status of Women in the Economics Profession, a standing committee of the American Economic Association, established the CeMENT Program to facilitate encounters between women assistant professors and successful female role models. Economics, as discussed earlier, is atypical among the social sciences in being male dominated. A randomized control trial found that the program increased publication rates and grant funding substantially in favor of female assistant professors (Blau et al. 2010). The program also supported their retention and increased the likelihood that they would get tenure at a top tier institution (Ginther et al. 2020).

Combining mentoring with complementary interventions increases job satisfaction and self-confidence and reduces the sense of isolation among women in male-dominated STEM fields (Carpenter and O'Neal 2013). These other interventions included professional development and training to prevent a hostile workplace, creating male advocates and allies programs; and developing publicity materials to increase the visibility of female faculty on university campuses.

25 Though, some research does show that gender norms can and do change through interventions (Dhar and Jayachandran 2018; Bursztyn et al. 2018; La Ferrara, Chong, and Duryea 2012; Banerjee, La Ferrara, and Orozco 2019).

26 Compared with male lawyers with senior male mentors, female lawyers with male mentors exhibit greater career progress satisfaction and were more likely to be partners or senior executives (Ramaswami et al. 2010).

5 Conclusion

This report set out to undertake a global, comprehensive review of the evidence focused on both the drivers and the solutions related to participation of women and girls in STEM.

Along the education path, we find, as many others have, a lack of a systematic gender gap in math and science at primary and secondary levels. In most countries, girls do as well or better than boys, on average. Yet, in tertiary, women are significantly less likely to enroll in most (not all) STEM fields, although they are more likely than men to pursue post-secondary education. Moreover, this challenge may not be resolved through broad shifts to gender equality: countries with more gender equality have greater STEM gender gaps in terms of field of study at the tertiary level.

In the labor market, where there is notably less systematic data, women are underrepresented in STEM careers, paid less than male counterparts, and more likely to leave STEM jobs. This pattern—higher attrition rates among girls and women in STEM from primary to tertiary education and into jobs—is commonly called the leaky pipeline in STEM.

The large literature that examines the drivers of why women do not pursue STEM studies is mostly from high-income countries, comes from small samples, does not use experimental or quasi-experiment approaches. Furthermore, samples are typically composed of white students—a more inclusive and intersectional approach is needed.

Stereotypes and biases play a role. Drilling down, this includes gender bias in education materials, among teachers, among parents, and among peers, which result in lower self-confidence (and higher anxiety) regarding STEM among schoolgirls and lower interest and aspirations. Consequently, female enrollment in STEM at the tertiary level is lower than their male peers. Once in the labor market, evidence shows that women face more challenges than their male colleagues, especially in male-dominated STEM fields, which may discourage them from applying for STEM jobs and resulting in women leaving these jobs at higher rates than men.

The leaky STEM pipeline is path dependent, starts at early ages and is not addressed at any single entry point or single intervention. Many proposed and pursued approaches have yet to be rigorously tested, though arguably some warrant support regardless of the evidence (such as removing biases in textbooks). Moreover, underrepresentation of women is not the case for every STEM field. For example, the share of female students and those with careers in computer sciences/IT, physics and engineering is much lower than women in life sciences. Still, even within engineering subfields, the gaps differ with a notably higher share of women in bioengineering than electrical engineering. Finally, this is not a problem simply attributed to country development paths, since gaps in some dimensions are higher in high-income countries.

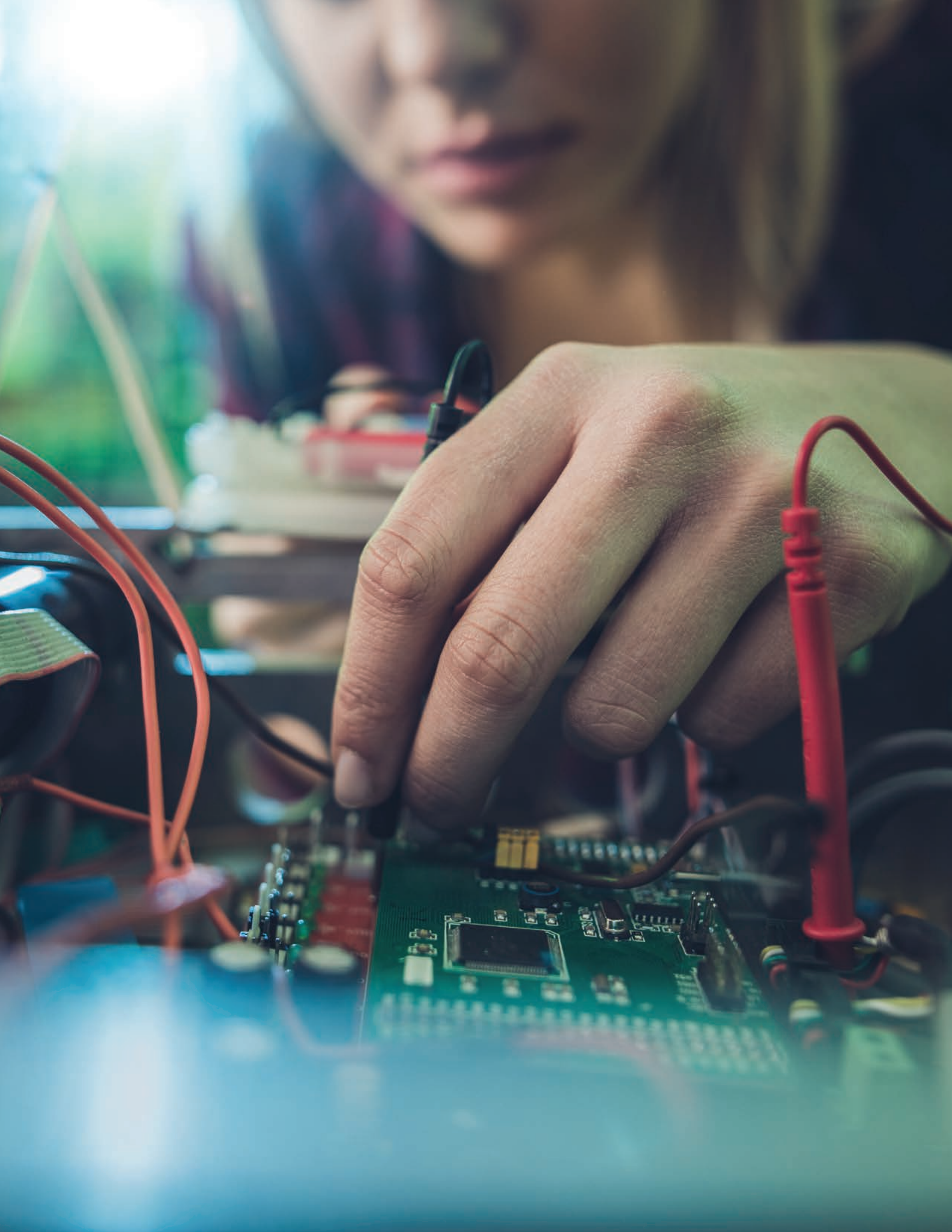
Further research is needed to understand both the existing STEM gaps in education and careers and what works to close these gaps. Knowledge gaps are especially large for low and middle-income contexts and using rigorous methodologies and large sample sizes.

Starting from basics, more sex-disaggregated, and comparable test score and enrollment (by field of study) data across countries, at all education levels, is essential, including comparable global data on the STEM labor market. Agreement on broad guidance to defining a STEM job globally would be of value, at least for systematically coding labor force surveys.

An important challenge is to disentangle preferences and choices from the influence of social norms. Pursuing careers outside of STEM (especially in high-income countries, as noted in the discussion of the gender equality paradox and STEM gaps in box 2) may represent women using their agency to act on their preferences. Yet, it is difficult to disentangle an innate interest or preference from socialization that has been strongly influenced by gender roles and norms.

Innovative not-at-scale initiatives need testing and impact evaluation. Interestingly, some recent studies have found that in some male-dominated sectors, male role models help women enter higher-paying industries. However, in the case of STEM, the emphasis has been on female role models who help girls and women overcome negative gender stereotypes. More testing on the relative influence of female versus male role models would enhance the evidence base, as would experiments that seek to influence parents (mothers or fathers) to shift their aspirations for their sons and daughters in regards to STEM.

Finally, greater coordinated engagement with the private sector will be pivotal, both for funding initiatives and other support to get girls into STEM studies but also to understand what works in largely private sector STEM careers.



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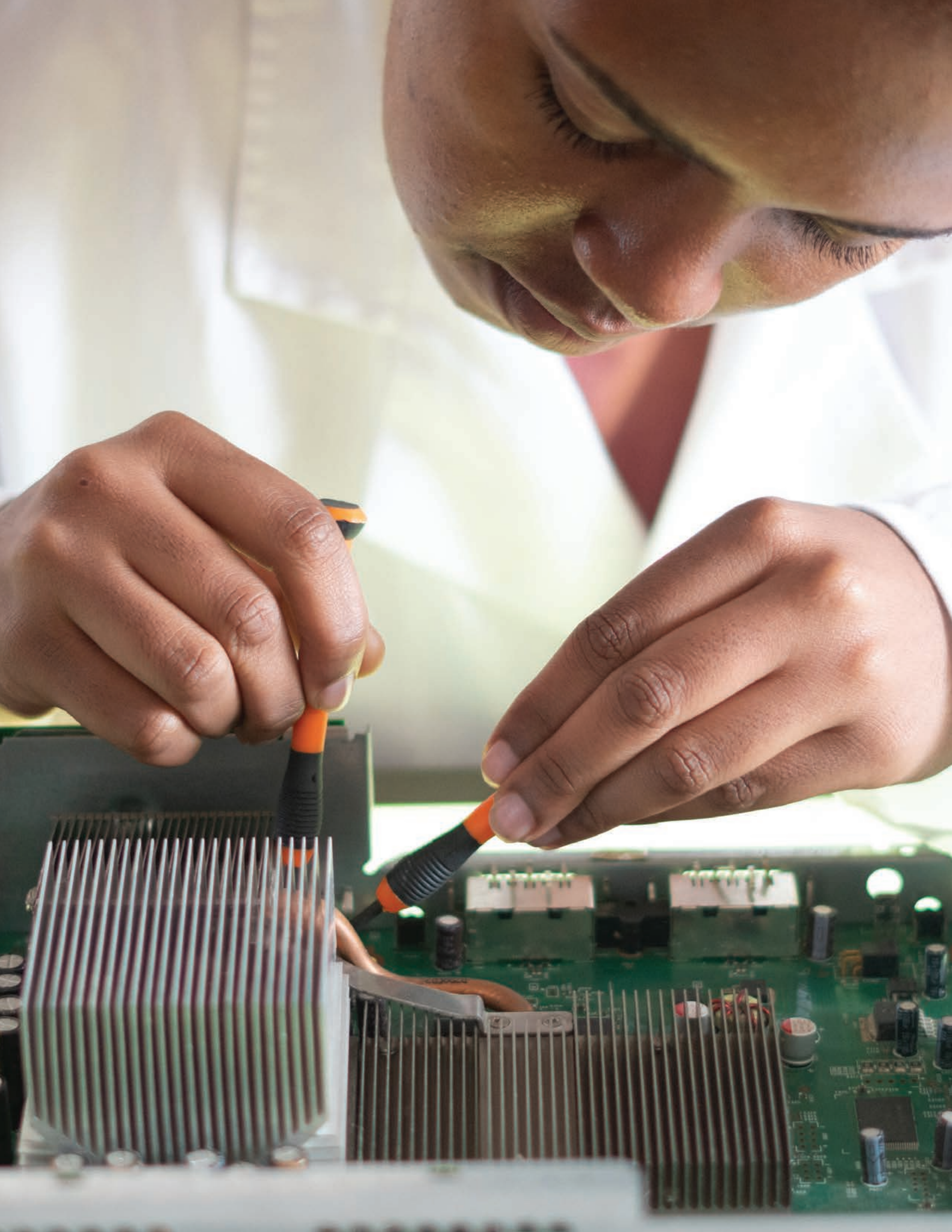

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