United Nations Educational, Scientific and Cultural Organization

Sustainable Development Goals

Cracking the code:

Girls' and women's education in science, technology, engineering and mathematics (STEM)

Education 2030

Cracking the code:

Girls' and women's education in science, technology, engineering and mathematics (STEM)

UNESCO Education Sector
Education is UNESCO's top priority because it is a basic human right and the foundation on which to build peace and drive sustainable development. UNESCO is the United Nations' specialized agency for education and the Education Sector provides global and regional leadership in education, strengthens national education systems and responds to contemporary global challenges through education with a special focus on gender equality and Africa.

The Global Education 2030 Agenda
UNESCO, as the United Nations' specialized agency for education, is entrusted to lead and coordinate the Education 2030 Agenda, which is part of a global movement to eradicate poverty through 17 Sustainable Development Goals by 2030. Education, essential to achieve all of these goals, has its own dedicated Goal 4, which aims to *"ensure inclusive and equitable quality education and promote lifelong learning opportunities for all."* The Education 2030 Framework for Action provides guidance for the implementation of this ambitious goal and commitments.

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Foreword

Only 17 women have won a Nobel Prize in physics, chemistry or medicine since Marie Curie in 1903, compared to 572 men.

Today, only 28% of all of the world's researchers are women.

Such huge disparities, such deep inequality, do not happen by chance.

Too many girls are held back by discrimination, biases, social norms and expectations that influence the quality of education they receive and the subjects they study.

Girls' under-representation in science, technology, engineering and mathematics (STEM) education is deep rooted and puts a detrimental brake on progress towards sustainable development.

We need to understand the drivers behind this situation in order to reverse these trends. *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics* provides a global snapshot of this under-representation, the factors behind it and examples of how to improve the interest, engagement and achievement of girls in these fields.

Both education and gender equality are an integral part of the 2030 Agenda for Sustainable Development, adopted by the United Nations General Assembly in 2015, as distinct Sustainable Development Goals (SDGs) but also as catalysts for the achievement of all other SDGs.

Science, technology and innovation are also key to the SDGs: in how we address the impact of climate change, in how we increase food security, improve healthcare, manage limited freshwater resources and protect our biodiversity.

Girls and women are key players in crafting solutions to improve lives and generate inclusive green growth that benefits all. They are the greatest untapped population to become the next generations of STEM professionals – we must invest in their talent.

This matters for human rights, for inclusion, for sustainable development.

We need to understand and target the particular obstacles that keep female students away from STEM. We need to stimulate interest from the earliest years, to combat stereotypes, to train teachers to encourage girls to pursue STEM careers, to develop curricula that are gender-sensitive, to mentor girls and young women and change mindsets.

In 2016, Member States adopted a decision on the role of UNESCO in encouraging girls and women to be leaders in STEM, including arts and design. This report directly responds to this request. It is also a contribution to UNESCO's Global Partnership for Girls' and Women's Education which promotes gender equality to, in and through education.

By providing evidence and examples from research and practice, this report is a solid reference for policy-makers, practitioners and other stakeholders to engage more girls in STEM education.

Most of all, this report has been written for girls and women around the world. It champions their right to a quality education, and a better life and better future.

Irina Bokova
UNESCO Director-General

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Executive summary

Despite significant improvements in recent decades, education is not universally available and gender inequalities persist. A major concern in many countries is not only limited numbers of girls going to school, but also limited educational pathways for those that step into the classroom. This includes, more specifically, how to address the lower participation and learning achievement of girls in science, technology, engineering and mathematics (STEM) education.

STEM underpins the 2030 Agenda for Sustainable Development, and STEM education can provide learners with the knowledge, skills, attitudes and behaviours required for inclusive and sustainable societies. Leaving out girls and women in STEM education and careers is a loss for all.

This report aims to 'crack the code', or to decipher the factors that hinder or facilitate girls' and women's participation, achievement and continuation in STEM education, and what can be done by the education sector to promote girls' and women's interest in, and engagement with, STEM.

Gender differences in STEM education participation at the expense of girls are already visible in early childhood care and education (ECCE) and become more visible at higher levels of education. Girls appear to lose interest in STEM subjects with age, and lower levels of participation are already seen in advanced studies at secondary level. By higher education, women represent only 35% of all students enrolled in STEM-related fields of study. Gender differences also exist in STEM disciplines, with the lowest female enrolment observed in information, communication and technology (ICT); engineering, manufacturing and construction; and natural science, mathematics and statistics. Women leave STEM disciplines in disproportionate numbers during their higher education studies, in their transition to the world of work and even during their career cycle.

Cross-national studies of learning achievement (measuring knowledge acquisition or knowledge application) from more than 120 countries and dependent territories present a complex picture. In middle- to high-income countries for which trend data are available, data gaps to girls' disadvantage are closing, particularly in science. In addition, in countries where girls do better than boys on curriculum-based assessments, their score difference can be up to three times higher than when boys do better. There are significant regional differences, however. For example, girls outperform boys in many countries in Asia while the score difference between boys and girls in science achievement is particularly strong in the Arab States, with girls significantly outperforming boys.

More countries demonstrate gender differences to boys' advantage in mathematics achievement, with boys' score differentials as compared to those of girls often increasing between early and late primary education. Regional differences exist also in mathematics; girls are particularly disadvantaged in Latin America and sub-Saharan Africa. Differences also exist between assessments that measure learning against the curriculum-based compared to those that measure students' ability to apply knowledge and skills to different situations. Boys performed better in two-thirds of the 70 countries measuring applied learning in math at age 15.

Education systems and schools play a central role in determining girls' interest in STEM subjects and in providing equal opportunities to access and benefit from quality STEM education.

Research on biological factors, including brain structure and development, genetics, neuroscience and hormones, shows that the gender gap in STEM is not the result of sex differences in these factors or in innate ability. Rather, findings suggest that learning is underpinned by neuroplasticity, the capacity of the brain to expand and form new connections, and that education performance, including in STEM subjects, is influenced by experience and can be improved through targeted interventions. Spatial and language skills, especially written language, are positively correlated with performance in mathematics and can be improved with practice, irrespective of sex, especially during the earlier years of life.

These findings highlight the need to look at other factors to explain gender differences in STEM. Studies suggest that girls' disadvantage in STEM is the result of the interaction of a range of factors embedded in both the socialisation and learning processes. These include social, cultural and gender norms, which influence the way girls and boys are brought up, learn and interact with parents, family, friends, teachers and the wider community, and which shape their identity, beliefs, behaviour and choices. Self-selection bias, when girls and women chose not to pursue STEM studies or careers, appears to play a key role. However, this 'choice' is an outcome of the socialisation process and stereotypes that are both explicitly and implicitly passed on to girls from a young age. Girls are often brought up to believe that STEM are 'masculine' topics and that female ability in this field is innately inferior to that of males. This can undermine girls' confidence, interest and willingness to engage in STEM subjects.

Evidence shows that girls' self-efficacy and attitudes related to STEM are strongly influenced by their immediate family environment, especially parents, but also the wider social context. Parents' own beliefs, attitudes and expectations are themselves influenced by gender stereotypes, which can cause differential treatment of girls and boys in care, play and learning experiences. Mothers, more than fathers, appear to have a greater influence on their daughters' education and career choices, possibly due to their role-model function. Parents with higher socio-economic status and higher educational qualifications tend to have more positive attitudes towards STEM education for girls than parents with lower socio-economic status and education, of immigrant status and ethnic minority background or single parents. Media representations of women, and the status of gender equality in society also has an important influence, as it influences the expectations and status of women, including in STEM careers.

Education systems and schools play a central role in determining girls' interest in STEM subjects and in providing equal opportunities to access and benefit from quality STEM education. Teachers, learning contents, materials and equipment, assessment methods and tools, the overall learning environment and the socialisation process in school, are all critical to ensuring girls' interest in and engagement with STEM studies and, ultimately, STEM careers.

Teaching quality and specialisation in STEM subjects are essential for good quality STEM education. The sex of STEM teachers appears to make a difference too. Female STEM teachers have a positive influence on girls' performance and engagement with further STEM studies and careers. Girls also appear to perform better when teaching strategies take into consideration their learning needs, and when teachers have high expectations of them in STEM subjects and treat them equally. In contrast, girls' learning experience in STEM is compromised when teachers hold stereotypical beliefs about sex-based STEM ability or treat boys and girls unequally in the classroom.

Learning contents and materials also impact on girls' performance in STEM. Curricula that are gender-balanced and take account of girls' interests, for example, linking abstract concepts with real-life situations, can help increase girls' interest in STEM. Evidence also suggests that hands-on activities, for example in laboratories, can enhance girls' interest. In view of the increasing role of information, communication and technologies (ICT) in the STEM workplace, more attention is needed to ensure that girls have equal opportunities to quality ICT education, addressing stereotypes therein.

Assessment contents, tools and processes can affect girls' learning outcomes in STEM subjects. Psychological reactions to competition or testing, such as mathematics anxiety, which is more common among female learners, and teachers' own biases, may further compromise girls' performance. Like all aspects of education, the way STEM learning is assessed needs to be free from gender bias.

Supportive learning environments can increase girls' self-confidence and self-efficacy in STEM. Exposure to real-world learning opportunities, such as through extra-curricular activities, field trips, camps and apprenticeships, can help inspire and retain girls' interest. Mentoring appears to be particularly beneficial for girls, enhancing their confidence and motivation and improving their understanding of STEM careers.

Getting more girls and women into STEM education and careers requires holistic and integrated responses that reach across sectors and that engage girls and women in identifying solutions to persistent challenges. Doing so moves us all towards gender equality in education where women and men, girls and boys can participate fully, develop meaningfully, and create a more inclusive, equitable and sustainable world.

Introduction

Introduction

STEM education and the 2030 Sustainable Development Agenda

The 2030 Agenda for Sustainable Development,[1] adopted by the United Nations (UN) General Assembly in September 2015, calls for a new vision to address the environmental, social and economic concerns facing the world today. The Agenda includes 17 Sustainable Development Goals (SDGs), including SDG 4 on education and SDG 5 on gender equality.

UNESCO recognises that achieving the 2030 Agenda requires the cultivation of transformative, innovative and creative thinking and skills, and competent and empowered citizens.[2] For education to achieve its potential, urgent changes are needed. This includes steps to eliminate persistent disparities in education access and achievement, to improve educational quality, and to provide learners with the knowledge, skills, attitudes and behaviours to ensure inclusive and sustainable societies.

Science, technology, engineering and mathematics (STEM) education has a vital role to play in this transformation as it underpins the 2030 Agenda (Box 1). Advances in STEM have already brought about improvements in many aspects of life, such as health, agriculture, infrastructure and renewable energy. STEM education is also key for preparing students for the world of work, enabling entry into in-demand STEM careers of tomorrow.

Box 1: STEM in international commitments and agendas

STEM and innovation feature prominently in the *2030 Sustainable Development Agenda*. They are also a means to achieve other SDGs, such as ending hunger and tackling climate change.[3] Of particular relevance to this report are SDG 4, on inclusive and equitable quality education and lifelong learning, and SDG 5, on gender equality and girls' and women's empowerment. These SDGs include specific targets for countries to enhance access to STEM education and technologies, and to reduce gender disparities. The *Incheon Declaration and Framework for Action*[4] for the implementation of SDG 4 notes that the focus on quality and innovation "will require strengthening STEM" and "particular attention should be given to providing girls and women with scholarships to study in the STEM fields." *The Addis Ababa Action Agenda*[5], which provides a global framework for financing sustainable development, calls on countries to "scale up investment in science, technology, engineering and mathematics education... ensuring equal access for women and girls".

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Why focus on girls' and women's education in STEM?

Ensuring girls and women have equal access to STEM education and ultimately STEM careers is an imperative from the human rights, scientific, and development perspectives. From a human rights perspective, all people are equal and should have equal opportunities, including to study and work in the field of their choice. From a scientific perspective, the inclusion of women promotes scientific excellence and boosts the quality of STEM outcomes, as diverse perspectives aggregate creativity, reduce potential biases, and promote more robust knowledge and solutions.[6-8] Women have already demonstrated their abilities in STEM fields, having contributed, for example, to advancements in the prevention of cholera and cancer, expanded understanding of brain development and stem cells, and other discoveries.[9] Maximizing the catalytic role of STEM requires drawing on the widest pool of talent to promote excellence and leaving out women is a loss for all.[10]

From a development perspective, gender inequalities in STEM education and employment perpetuate existing gender inequalities in status and income. Gender equality in STEM will ensure that boys and girls, men and women will be able to acquire skills and opportunities to contribute to and benefit equally from the benefits and assets associated with STEM.[11]

The gender gap in STEM education participation and achievement has been the subject of extensive research over many decades.[12-14] While gender differences in science and mathematics achievement appear to have decreased in recent years in many countries, as shown in large-scale cross-national surveys,[15,16] they have not been eliminated.[17,18] Moreover, while more women are entering the STEM workforce than ever before, women are still significantly under-represented in STEM occupations in many countries.[19-22]

What is the purpose of this report?

This report is part of UNESCO's efforts to promote gender equality[23] and empower girls and women through education. It is also a direct response to UNESCO's Member States decision calling on UNESCO to further encourage girls and women to be leaders in STEM, including arts and design.[24]

The report is intended to stimulate debate and inform STEM policies and programmes at global, regional and national levels. Specifically, it aims to: i) document the status of girls' and women's participation, learning achievement, and progression in STEM education; ii) 'crack the code', i.e., decipher the factors that contribute to girls' and women's participation, achievement and progression in STEM education; and, iii) identify interventions that promote girls' and women's interest in and engagement with STEM studies.

The first section presents statistics on girls' and women's participation and achievement in STEM subjects at different levels of education. The second section provides an ecological model to identify individual-, family-, school- and societal-level factors influencing girls' participation, achievement and progression in STEM education. The third section identifies interventions that can be undertaken at these different levels of the ecological model, including promising examples from around the globe. The final section includes conclusions and a set of key recommendations.

The report is based on a desk review of national data, peer-reviewed literature, results of standardised cross-national surveys (Annex 1) and other sources. It also draws on an experts meeting held in Paris in 2016 and an expert peer review process.

It will be a useful resource for education sector stakeholders in Ministries of Education, Science and Labour, especially decision-makers and planners, curriculum developers, and practitioners and institutions providing STEM education, including teachers and teacher training institutions. It is also expected to be useful for civil society practitioners, including NGOs engaging girls in STEM, and others with an interest in this field, including employers in STEM sectors.

iStock.com/Andrew Rich

There are several limitations to this report. First, while it includes data from more than 120 countries and dependent territories, the depth and comparability of information is limited. Regional, sub-regional or national variations might exist that have not been captured. Moreover, there are limited evaluations or published studies on programme experience outside of the US, indicating a gap in more diversified cultural contexts. Second, the review drew largely on materials published in English, therefore research and programme experience published in other languages may have been missed. Third, some of the research accessed identified contradicting conclusions regarding the factors affecting girls' participation in STEM education, making definitive observations difficult. There is a need for further research and factor analysis that consider differences by context, age, socio-economic, geographical or cultural background, and other related variables. Finally, research on the effect of various biological factors on human behaviour, including educational performance, is still in its initial stages with preliminary or inconclusive findings. As such, UNESCO sees this report as a living document that can be updated as further research is made available.

1. Current status of girls and women in STEM education

1. Current status of girls and women in STEM education

This section provides an overview of girls' and women's access, participation, and learning achievement in STEM education at primary, secondary and higher education levels. Cross-national and regional surveys reveal gender differences in STEM fields of study and learning achievement, particularly at higher levels of education and in specific subjects.

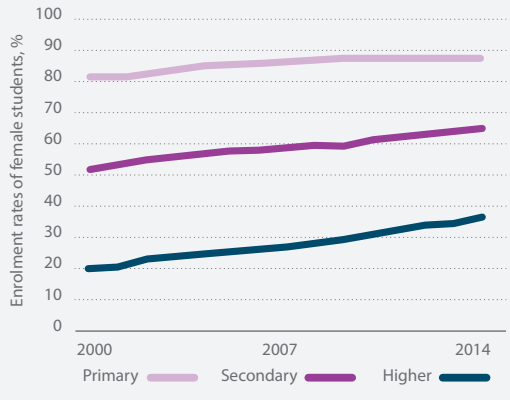
1.1 Overall education trends: access, participation and progression

Girls' and women's participation in STEM education needs to be considered in the context of their overall access to, and participation in, education. While access to education for girls and young women has globally improved, important disparities persist both among and within regions and countries.

Significant progress has been made with respect to girls' participation in education in recent decades. Trends show a small but consistent increase in female students' enrolment rates at all levels of education since 2000 (Figure 1). Globally, in 2014, gender parity was achieved in primary, lower secondary and upper secondary education. Significant progress has been made in higher education, where the enrolment of female students almost doubled between 2000 and 2014, with young women constituting the majority of students at Bachelor's and Master's degree levels globally. However, the percentage of female students who continue with doctoral degrees drops by more than 7% compared to those enrolled at Master's level.[25] Despite the positive global trends, there are significant disparities across regions and countries, and among specific groups within countries. The global achievement of gender parity in access to primary education, for example, masks important disparities in many regions and countries.[26] In secondary education, gender disparities are more diverse, with considerable regional differences. For example, more boys than girls complete lower and upper secondary education in South and West Asia, sub-Saharan Africa and the Arab States (Figure 2), while the opposite is true in Latin America and the Caribbean.[27]

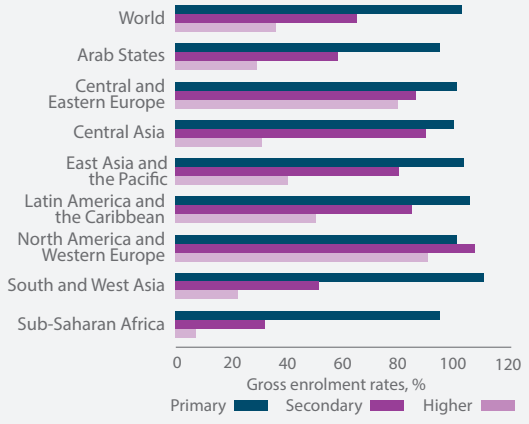
Despite gains in access, socio-economic, cultural and other obstacles still prevent female learners from completing or benefiting fully from good quality education of their choice in many settings. These barriers increase in adolescence, when gender roles for girls become more entrenched and gender discrimination more pronounced. Barriers include household and care responsibilities, early marriages and pregnancies, cultural norms that prioritise boys' education, inadequate school sanitation facilities, parental concerns about girls' safety on the way to and from school, and school-related gender-based violence.[28,29] Adolescent girls from rural or disadvantaged areas are at a higher risk of educational exclusion.[25]

Figure 1: Enrolment rate* of female students, by level of education, world average



Girls' enrolment in education is increasing globally, especially in higher education. *Note: Net enrolment rates for primary and secondary, gross enrolment ratio for higher education.
200 countries and dependent territories. Data source: UIS 2015[25]

Figure 2: Girls' gross enrolment ratio* from primary to higher education in 2014, world and regional averages



Regional variations in girls' enrolments, especially in higher education.
*Note: Gross enrolment ratios can exceed 100% because of late entry and/or grade repetition.
200 countries and dependent territories. Data source: UIS 2015[25]

1.2 Participation and progression in STEM education

This section considers girls' participation, subject choice, and progression in STEM education. Gender differences in STEM education, are present at all levels of education. In many parts of the world, the gender gap is to the disadvantage of girls, but in certain contexts and subjects, the gender gap is in their favour. Gender differences in STEM education participation are more apparent as soon as subject selection becomes available, usually in upper secondary education, and become worse as the level of education increases.

Children can be exposed to learning opportunities in science and mathematics from a young age, including during ECCE.[30,31] While all children at this age should have equal opportunity to instruction and educational play opportunities, some studies have found differential access to boys' advantage.[32,33] Early educational experiences have been found to have a positive effect on students' choice of mathematics and science courses later as well as their career aspirations.[30,31,34,35]

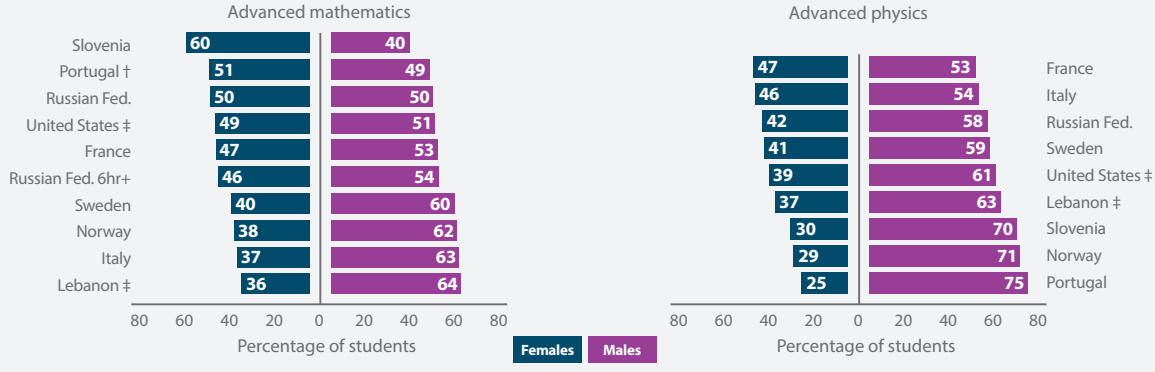
In primary education, science and mathematics are part of the core curriculum globally and it is expected that both girls and boys have the same exposure to these subjects, although the amount of time differs widely between regions and countries.[36] In many contexts, sex-role stereotyping is reinforced at this age range.[34] Teachers have been found to evaluate girls' ability in mathematics at a lower rate than boys' ability, even when they are performing at similar levels.[38,39]

The gender gap in STEM participation becomes more apparent in lower secondary education. This is when specialisation begins and students make choices about which subjects to study.[40-42] Furthermore, in many contexts, girls appear to lose interest in STEM subjects with age and more than boys do.[6] A study in the United Kingdom (UK) found that, at age 10-11 years, boys and girls were almost equally engaged with STEM, with 75% of boys and 72% of girls reporting that they learned interesting things in science. By the age of 18, this proportion fell to 33% for boys and 19% for girls, as measured by participation in STEM advanced studies. Here, boys began dropping out of STEM subjects as they approached their advanced level studies, whereas girls decided to drop out much earlier in secondary school.[43] A longitudinal study with Swedish youth also found that their career aspirations were largely formed by age 13, and that it would be progressively more difficult to engage students in science after that age.[44]

Those who have studied STEM subjects at advanced levels in upper secondary are more likely to move on to STEM-related degree programmes in higher education.[21] Regardless of the level of studies, exposure to STEM and intentions do not always guarantee the continuation of STEM studies. For example, girls may consider not to choose educational pathways that lead to occupations where few women are employed or to occupations perceived to be difficult to combine with family life.[45]

Although global comparable data on subject selection in secondary education is limited,[46] data from the Trends in International Mathematics and Science Study (TIMSS) Advanced 2015[18] show that in most countries, the majority of students taking advanced courses in both mathematics and physics were boys (Figure 3).

Figure 3: Percentage of students that take advanced courses in mathematics and physics, by sex, Grade 12

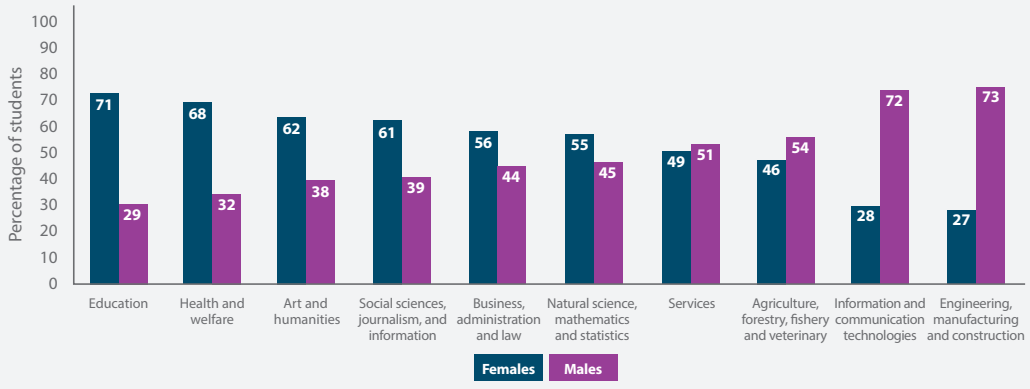


More boys than girls take advanced courses in mathematics and physics in secondary education in Grade 12.
Note: † Met guidelines for sample participation rates only after replacement schools were included, ‡ Did not satisfy guidelines for sample participation rates. The Russian Federation 6hr+ results are for a subset of the Russian Federation students. This subset of students are in an Intensive stream that have at least 6 hours of mathematics lessons per week.
9 countries.

Data source: TIMSS Advanced 2015[18]

A clear gendered pattern emerges in higher education. Male students are the majority of those enrolled in engineering, manufacturing and construction and information and communication technology studies, and to a lesser extent in other disciplines (Figure 4). Female students are the majority in education, arts, health, welfare, humanities, social sciences, journalism, business and law fields. Women now account for a higher proportion of students studying natural sciences, mathematics and statistics than men, due to significant increases in enrolments between 2000 and 2015.[25]

Figure 4: Share of female and male students enrolled in higher education, by field of study, global average

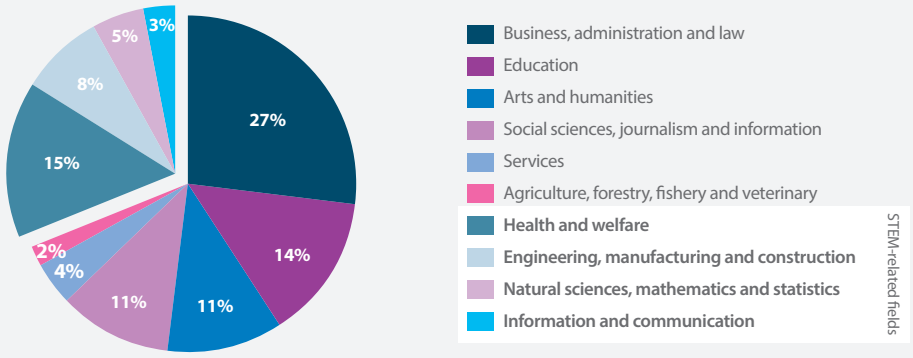


Significant gender differences in higher education enrolments by fields of study.
115 countries and dependent territories.

Data source: UIS 2014-2016[25]

Within the female student population in higher education globally, only around 30% choose STEM-related fields of study (Figure 5). Differences are observed by disciplines. Female students' enrolment is particularly low in ICT (3%), natural science, mathematics and statistics (5%) and engineering, manufacturing and construction (8%); the highest is in health and welfare (15%) studies.

Figure 5: Distribution of female students enrolled in higher education, by field of study, world average

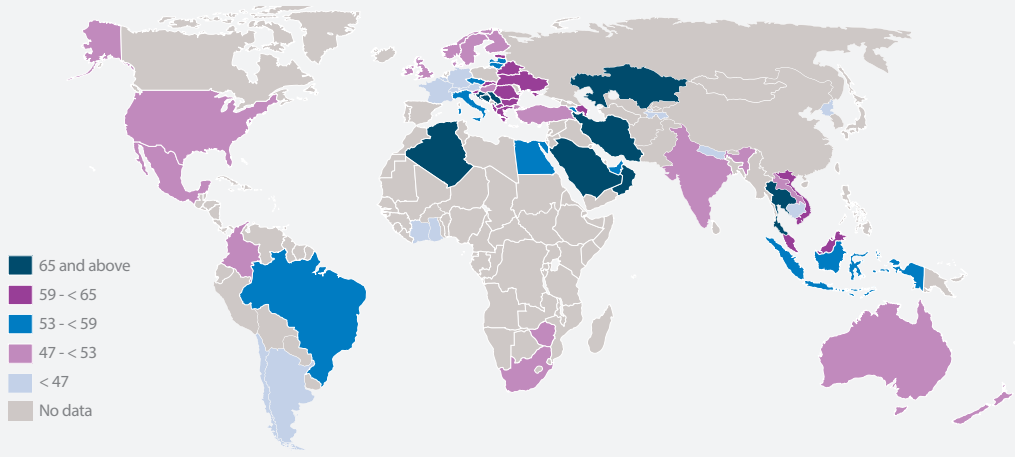


Only around 30% of all female students select STEM-related fields in higher education.
110 countries and dependent territories.

Data source: UIS 2014-2016[25]

Global averages mask significant regional and country differences. For instance, the proportion of female students enrolled in natural science, mathematics and statistics studies ranges significantly, from 16% in Côte d'Ivoire to 86% in Bahrain (Figure 6). High proportions of female students are enrolled in engineering, manufacturing and construction in South-East Asia, the Arab States, and some European countries, while lower proportions are found in sub-Saharan Africa, North America and Europe (Figure 7).[47]

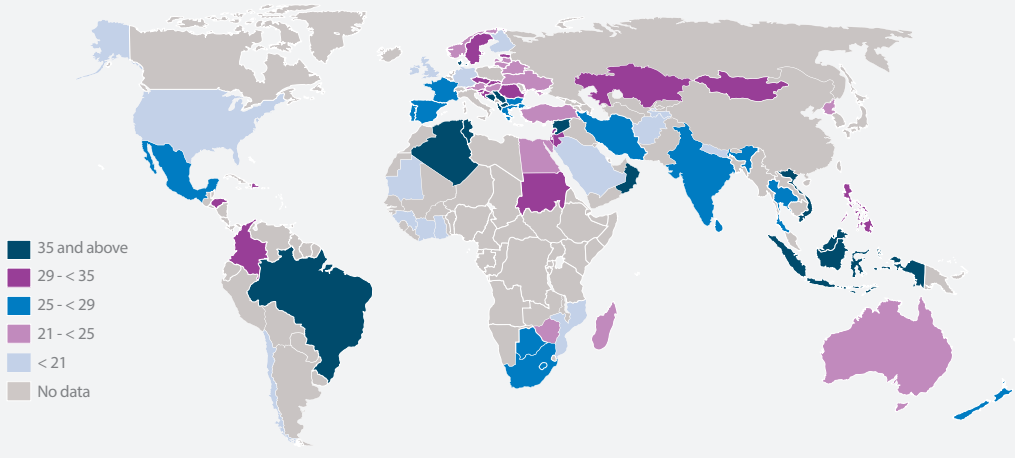
Figure 6: Percentage of female students enrolled in natural science, mathematics and statistics programmes in higher education in different parts of the world



Note: This map has a different scale to map below. They are not to be compared directly.
82 countries.

Data source: UIS 2015[25]

Figure 7: Percentage of female students enrolled in engineering, manufacturing and construction programmes in higher education in different parts of the world



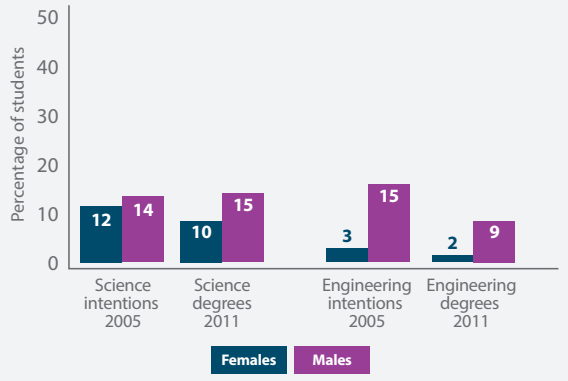
Note: This map has a different scale to map above. They are not to be compared directly.
103 countries.

Data source: UIS 2015[25]

Not only is female participation in STEM education and employment low, the attrition rate is particularly high. Women leave STEM disciplines in disproportionate numbers during their studies, during transition to the world of work and even during their career cycle.[11] For example, a US study showed a gap between students' intentions to study science and engineering and those graduating with degrees in these subjects (Figure 8). A large gender gap was observed in science, with more girls opting out than boys, while boys and girls seemed to change their mind about engineering at similar rates. Similar findings were observed in a study of engineering undergraduates in the Republic of Korea.[48]

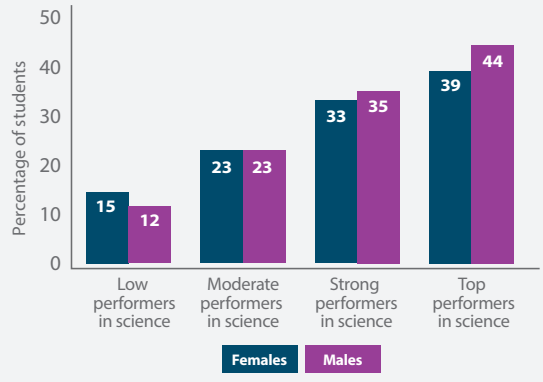
PISA 2015 also found that, in OECD countries, higher levels of science achievement were associated with higher expectations to work in science-related fields (Figure 9). For example, more than 39% of the top-performing girls have career expectations in science, compared to 15% among the lowest performers.[17]

Figure 8: First-year students' intentions and final degrees in engineering and science, by sex, National Science Foundation



Gap between science and engineering study intentions and obtained degrees in the US.
Data source: US, 2013[49]

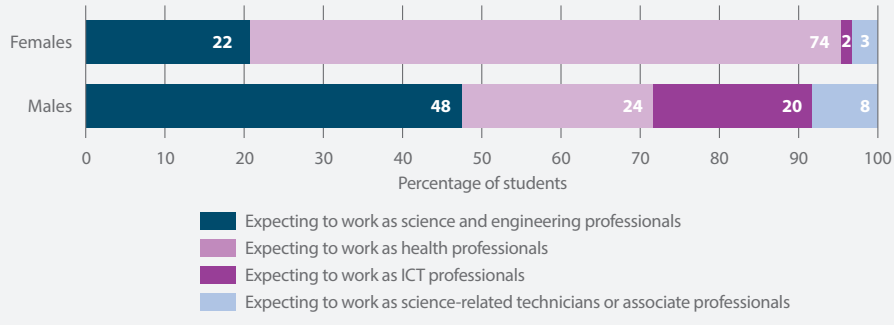
Figure 9: Percentage of students who expect to work in science-related occupations and their level of proficiency in science, 15-year-olds



Girls' and boys' career expectations are affected by their level of proficiency in science.
35 OECD countries.
Data source: PISA 2015 (OECD countries)[17]

Overall, PISA 2015 found no gender difference in science-related career expectations, with 24% of girls and 25% of boys in the 35 participating OECD countries expecting a career in science. However, differences in career aspirations were observed within science-related fields. For example, girls were three times more likely than boys to see themselves working in health professions, while boys were twice as likely as girls to see themselves working in engineering (Figure 10).[17, 50] This is in line with the enrolment statistics within STEM-related fields presented earlier.

Figure 10: Student expectations on science careers, by sub-field of study, out of those who choose science careers, 15-year-olds

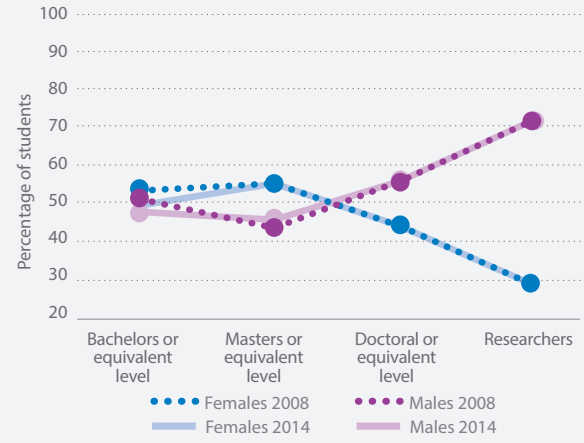


Most 15 year-old girls intending to pursue science careers expect to work as health professionals.
35 OECD countries.
Data source: PISA 2015 (OECD countries)[17]

UNESCO's STEM and Gender Advancement (SAGA) project has found that the gender gap in science widens significantly in the transition from Bachelor's to post-graduate levels (e.g. Master's or Doctorate levels) and into research and careers (Figure 11). The highest level of attrition can be found at post-doctoral level as women do not take up careers in their fields of study, despite the large amount of time invested in education prior to employment.[11]

There are many factors that influence women's transition into STEM careers, including perceived compatibility of certain STEM fields with female identity, family obligations, the working environment and conditions. While acknowledging the importance of these factors for female participation in STEM careers, this is beyond the scope of this review, which focuses on education. The key factors that influence female students' participation and achievement in STEM subjects are presented and analysed in the second section of this report.

Figure 11: Proportion of women and men in higher education and research, world average



Gender gap widens significantly among science researchers.
226 countries. Data source: UNESCO 2008-2014[11]

Key messages

- Gender differences in STEM education participation at the expense of girls begin as early as ECCE in science- and math-related play, and are more visible at higher levels of education.
- Girls appear to lose interest in STEM subjects with age, particularly between early and late adolescence. This lowered interest affects participation in advanced studies at secondary-level.
- Gender gaps in STEM education participation become more obvious in higher education. Female students represent only 35% of all students enrolled in STEM-related fields of study at this level globally. Differences are also observed by disciplines, with female enrolment lowest in engineering, manufacturing and construction, natural science, mathematics and statistics and ICT fields.
- Significant regional and country differences in female representation in STEM studies can be observed, suggesting the presence of contextual factors affecting girls' and women's engagement in these fields.
- Women leave STEM disciplines in disproportionate numbers during their higher education studies, in their transition to the world of work and even in their career cycle.

1.3 Learning achievement in STEM education

Data from national education assessments and regional and international surveys can be used to understand learning achievement in STEM subjects, in particular science and mathematics at primary and secondary education levels. This section presents data on girls' learning achievement in science, mathematics, and computer and information literacy, drawing on international and regional surveys from more than 120 countries and dependent territories (Annex 1). Data are presented by subject and level of education, including assessments of trends over time, where available.

Data from regional and international surveys reveal gender differences in STEM learning outcomes. In contrast to the data on participation in STEM-related fields of study, which clearly show a lower participation rate for female students, data on learning achievement based on sex vary significantly across studies, either in favour of boys or in favour of girls, making it difficult to identify gender patterns. This suggests contextual factors that affect girls' and boys' learning achievement in STEM differently. These differences can also be attributed to data collection methodologies used in each study (e.g, geographical coverage and context, students' age, subject and content assessed, assessment methodologies applied, or other).

1.3.1 Science achievement

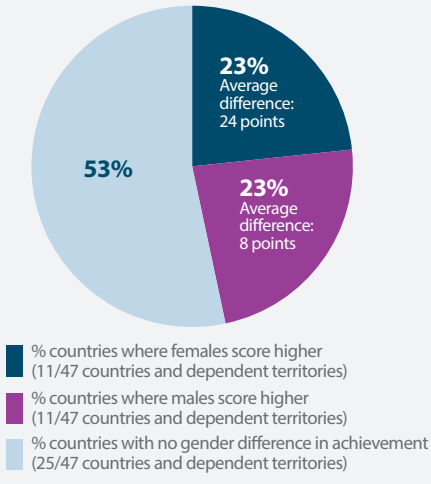
Primary education

Global comparative data on achievement in science at primary education level is limited. Results are available for 47 countries participating in TIMSS 2015 for Grade 4 students, and 15 Latin American countries participating in the Third Regional Comparative and Explanatory Study (TERCE) 2013 in Latin America and the Caribbean for Grade 6 students. There are significant data gaps for sub-Saharan Africa, Central Asia, and South and West Asia.

Data from TIMSS 2015 in science achievement in Grade 4 show no gender differences in more than half of the participating countries (Figure 12). In the remaining countries, gender differences are equally split either to boys' or girls' advantage. Where girls outperform boys, the average score difference is significantly higher (24 points) than where boys outperform girls (8 points).

CRS PHOTO/Shutterstock.com

Figure 12: Gender difference in science achievement, Grade 4

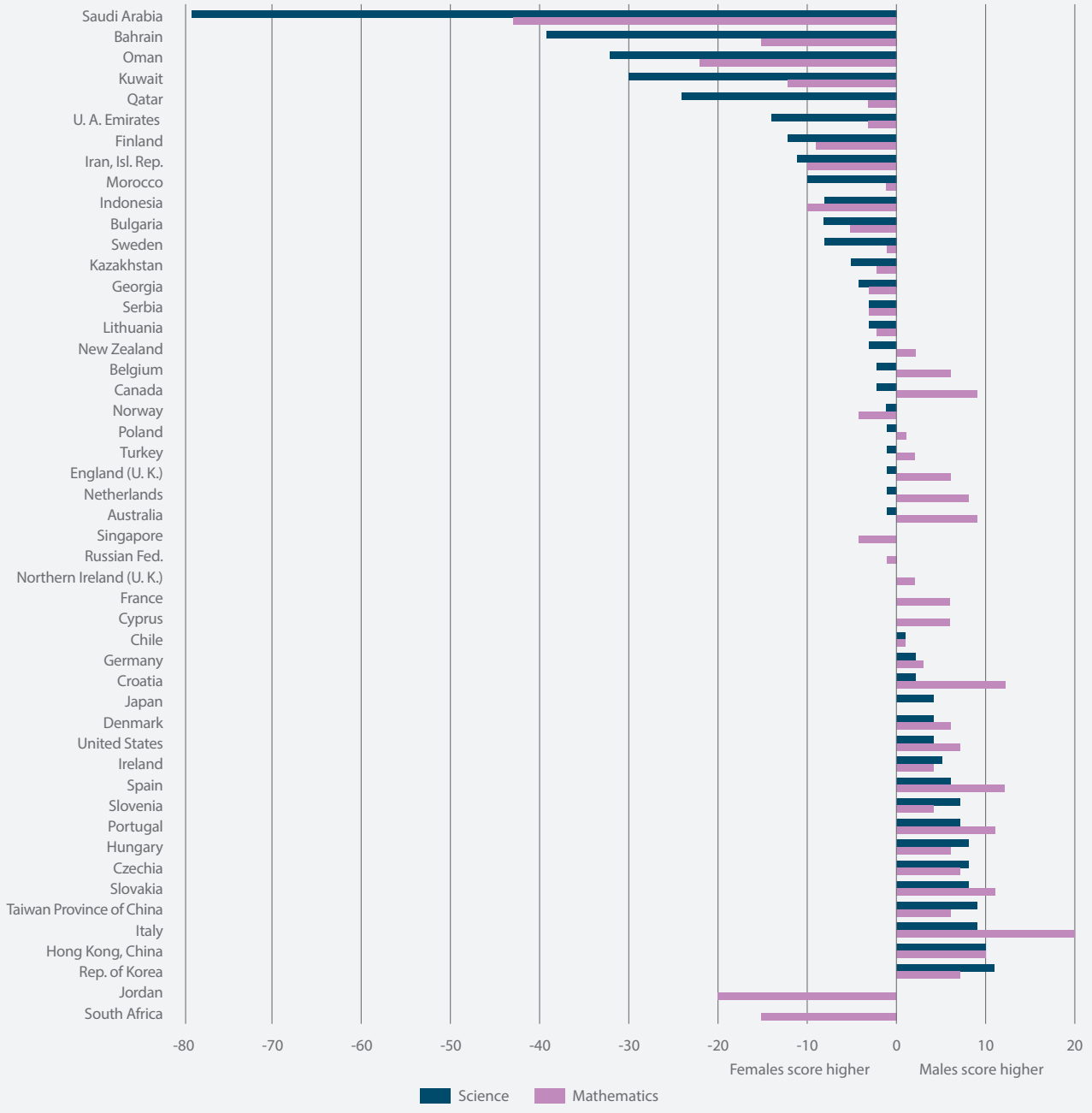


Notes: Average score difference is calculated as average achievement score points of boys minus that of girls, or vice-versa. See Annex 1 for participating countries and dependent territories. 47 countries and dependent territories.

Data source: TIMSS 2015[16]

Significant regional and national variations can be observed in science achievement (Figure 13, includes mathematics). The largest score difference in boys' favour was observed in the Republic of Korea (11 points), with a similar pattern in other countries in Asia and also in Europe. The largest difference in girls' favour was in Saudi Arabia (79 points), with a similar pattern observed in other countries in the Arab States. The reasons behind this difference merit further research. For example, gaps in learning outcomes at the expense of boys have also been found in other subjects in secondary education in the Arab States,[51] with young women in this region seeking and succeeding in higher education at higher rates than young men, suggesting greater engagement overall with education.[52,53] Another possible interpretation could be that the single-sex learning environments present in the region allow greater time for teacher interaction and opportunities for inquiry for girls. Targeted qualitative studies would be able to shed more light into such a wide gender score differential in STEM achievement in this region.

Figure 13: Distribution of score difference in science and mathematics achievement between girls and boys in primary education, Grade 4

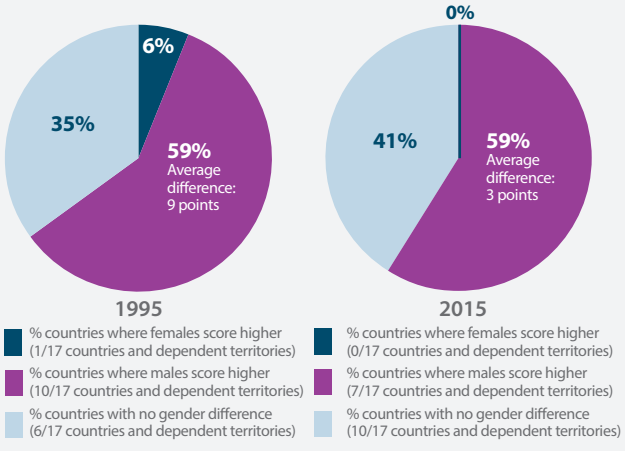


Larger score differentials are observed where girls outperform boys in science and mathematics in Grade 4, particularly in the Arab States.
47 countries and dependent territories in science and 49 countries and dependent territories in mathematics. Data source: TIMSS 2015[16]

Trend data from a smaller subset of 17 TIMSS participating countries demonstrate that patterns of earlier gender disadvantage at the expense of girls appear to be closing between 1995 and 2015 (Figure 14). Among these trend countries, Cyprus, the Czech Republic, Japan, the Netherlands, New Zealand, Norway and the US show the largest improvements in girls' science achievement during this period.

Data on science achievement among Grade 6 students from the TERCE 2013 study show statistically significant gender differences in science achievement in eight of the 15 participating Latin American countries, with the gender advantage shared equally. In Argentina, Chile, Paraguay, Panama this was in girls' favour, and in Costa Rica, Guatemala, Nicaragua and Peru in boys' favour (Figure 15). Factors provided to explain this difference include parental expectations, mothers' education, teacher practices, student retention, reading habits and study time.[54] As in the Arab States, girls in Latin America also stand an equal or better chance than boys overall in continuing to the upper grades of primary school.[55]

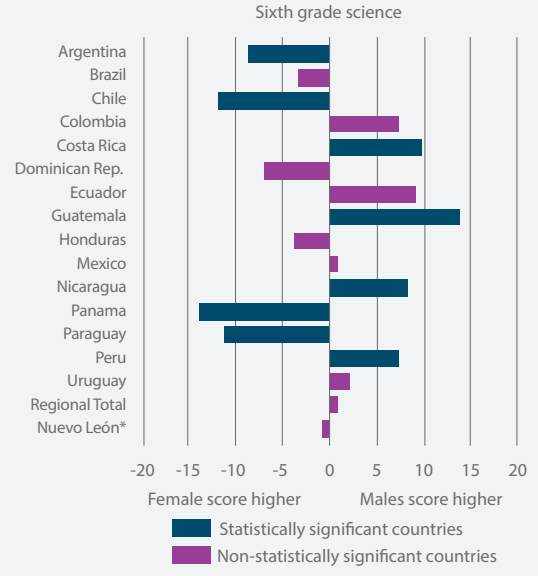
Figure 14: 20-year trends in science achievement, Grade 4



Notes: Average score difference is calculated as average achievement score points of boys minus that of girls. Score differentials are not available when girls outperform boys. Countries and dependent territories for which trend data are available: Australia, Cyprus, Czechia, England (U. K.), Hong Kong (China), Hungary, Iran, Isl. Rep., Ireland, Japan, Rep. of Korea, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovenia, and the United States.

Data source: TIMSS 1995 -2015[16]

Figure 15: Science achievement score difference between girls and boys, Grade 6



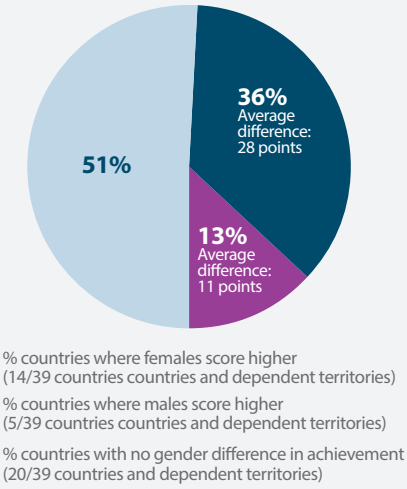
Gender differences in science achievement in Latin America in Grade 6.
*Note: Nuevo León is one of the 32 Federal Entities of Mexico.
15 countries. Data source: TERCE 2013[56]

Secondary education

A larger body of data is available to examine gender disparities in science achievement at secondary education levels. In addition to the 39 countries with TIMSS 2015 data for Grade 8, data are available for 70 countries participating in the Programme for International Student Assessment (PISA) 2015, for slightly older student cohorts (aged 15). As in the case of primary education, data about science achievement in secondary education are limited for sub-Saharan Africa, Central Asia, and South and West Asia.

TIMSS 2015 finds similar proportions of countries with no gender difference in achievement in Grade 8 as in Grade 4. However, in Grade 8 girls outperform boys in a larger proportion of countries, again with a larger average score differential (28 points compared to 11 points for boys) (Figure 16).

Figure 16: Gender difference in science achievement, Grade 8

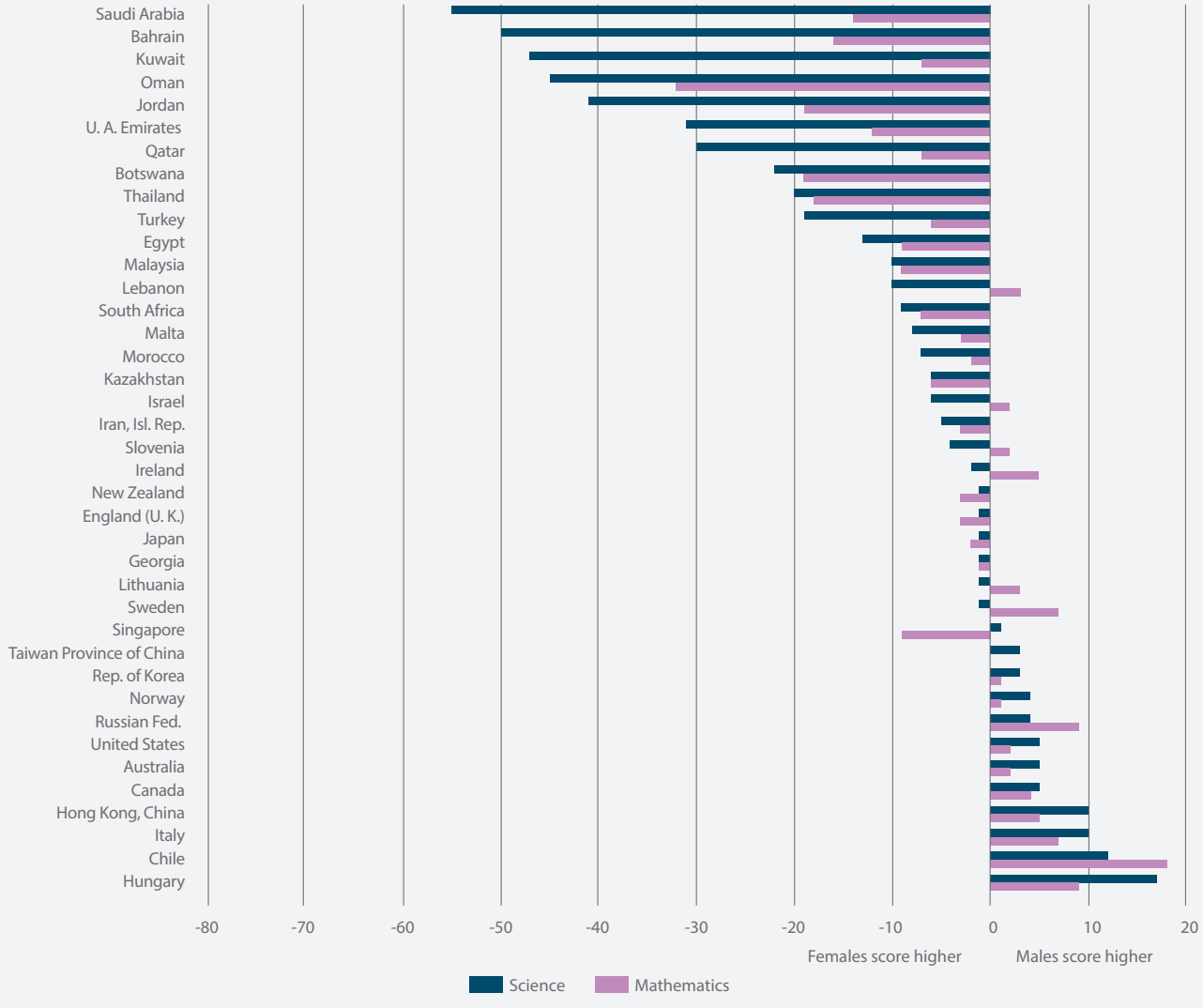


Notes: Average score difference is calculated as average achievement score points of boys minus that of girls, or vice-versa. See Annex 1 for participating countries and dependent territories.
39 countries and dependent territories. Data source: TIMSS 2015[16]

As in the case of Grade 4, regional differences are observed in Grade 8, with the largest score difference in science achievement in girls' favour, again observed in Saudi Arabia (55 points) and in other countries in the Arab States (Figure 17, includes mathematics).

The findings from PISA 2015 and TIMSS 2015 cannot be directly compared, as their measurement parameters are not the same. TIMSS measures learning achievement against the curriculum, while PISA focuses less on curriculum content and more on applying knowledge and skills in different situations.

Figure 17: Distribution of score difference in science and mathematics achievement between girls and boys in secondary education, Grade 8



Girls outperform boys in both science and mathematics in secondary education in Grade 8.
39 countries and dependent territories.

Data source: TIMSS 2015[16]

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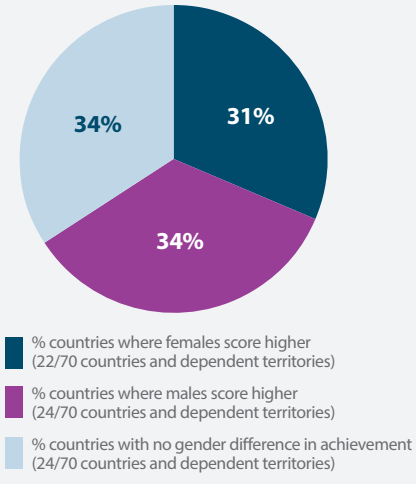
A country participating in both studies could therefore have different findings. Additionally, there are differences in the number and profile of participating countries (income, region), and the age of students (PISA focuses on 15-year-olds, TIMSS focuses on Grade 8, corresponding to 12-13-year-olds).

Results from 70 countries participating in PISA 2015 reveal a mixed picture. In about 1 in 3 participating countries, there are no gender differences (34%) in science achievement. In the remaining countries, the gender gap is shared almost equally either in boys' (34%) or girls' (31%) favour (Figure 18).

Regional score differentials found in PISA are less marked than those observed in TIMSS. The largest score differentials in girls' favour are observed again in countries in the Arab States (see Figure 19, page 29). While countries participating in both surveys generally show similar findings in terms of overall gender differences in favour or at the expense of girls, some differences can be observed.

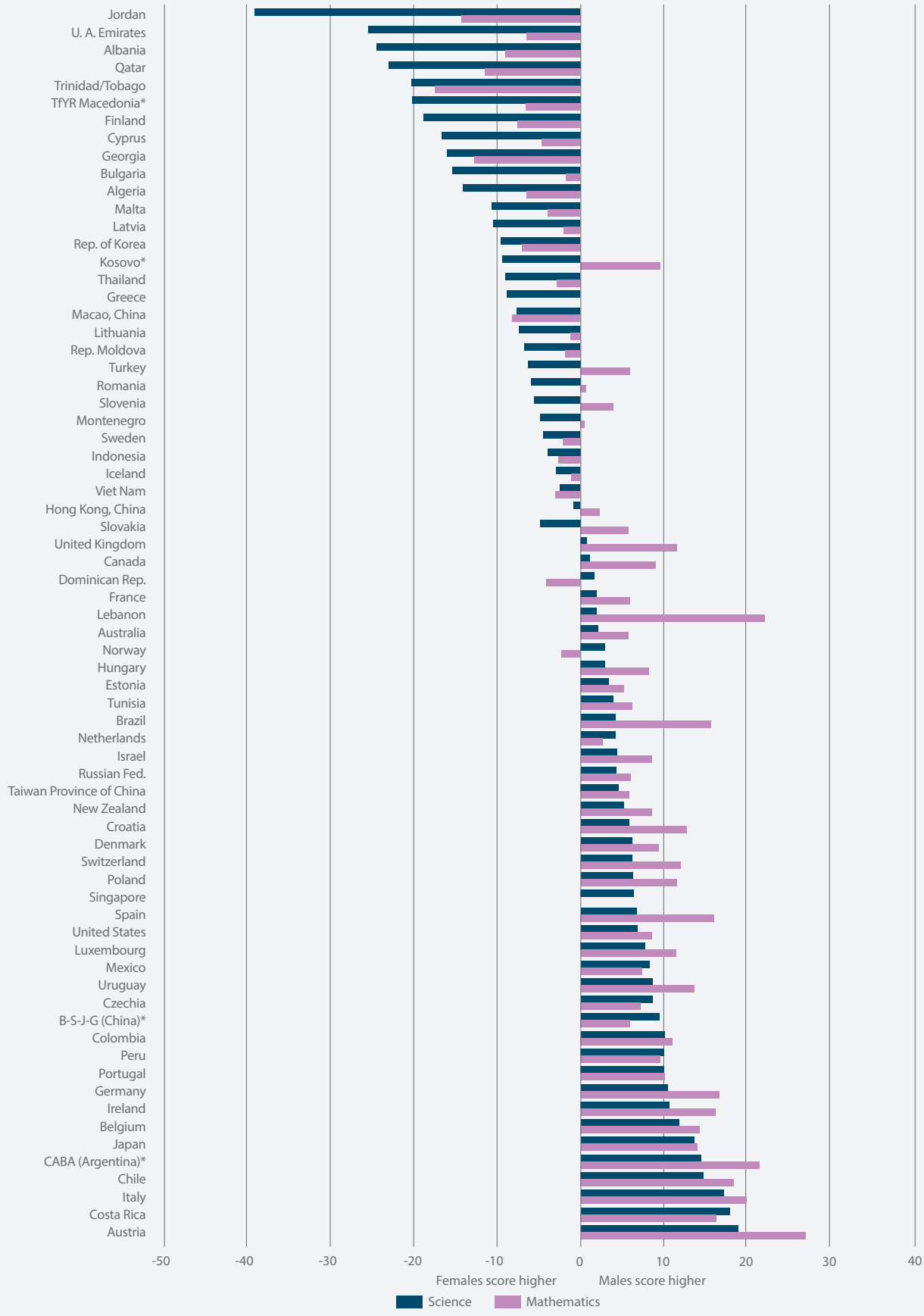
Figure 18: Gender difference in science achievement, 15-year-olds



Notes: Average score difference is not available for the full sample of participating countries and dependent territories. See Annex 1 for participating countries and dependent territories.

Data source: PISA 2015[17]

Figure 19: Distribution of score difference in science and mathematics achievement among 15-year-old girls and boys



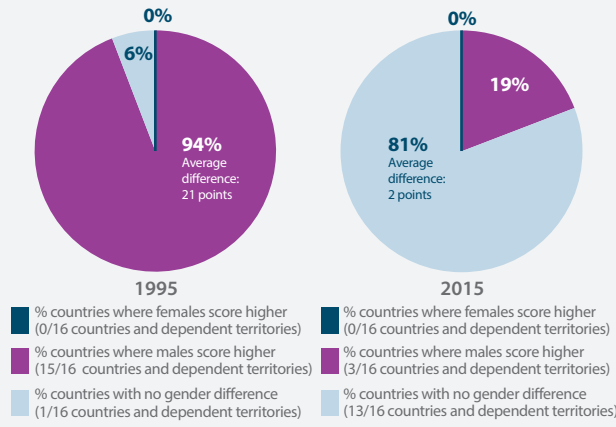
Boys outperform girls in about 60% of countries in both science and mathematics, 15-year-olds.
*Note: References to Kosovo shall be understood to be in the context of the UN Security Council resolution 1244 (1999). B-S-J-G (China): Beijing-Shanghai-Jiangsu-Guangdong (China).
70 countries and dependent territories: TfYR Macedonia refers to The former Yugoslav Republic of Macedonia. CABA (Argentina) stands for Ciudad Autonoma de Buenos Aires (Buenos Aires, Argentina)
Data source: PISA 2015[17]

Some additional observations can be made on findings from TIMSS and PISA as relates to boys' and girls' science achievement. First, TIMSS 2015 found that girls tend to do significantly better in certain content domains than boys, including biology at primary and secondary levels, and chemistry at secondary education level. Boys' advantage is smaller in other content areas (e.g. physics and earth sciences) (Figure 20). Second, the PISA 2015 study found that boys comprised the majority of 'top performers' in science in 33 countries. These students are judged to be sufficiently skilled in and knowledgeable about science to creatively and autonomously apply their knowledge and skills to a wide variety of situations, including unfamiliar ones. Finland was the only participating country with more girls than boys among top performers in science in PISA 2015.[17]

Finally, both PISA and TIMSS have trend data available for secondary education, although at different time scales and with different sets of countries. Significant changes can be seen in Grade 8 in the 17 countries that participated in both the 1995 and the TIMSS 2015 survey (Figure 21). The gender disadvantage at the expense of girls has been significantly reduced in most countries, with only a 2 point score differential between boys and girls remaining in just three countries. Nevertheless, girls did not outperform boys in any of the 17 countries in 2015.

Among the Organization for Economic Cooperation and Development (OECD) trend countries participating in PISA 2006 and 2015, the number of countries where boys scored higher than girls in science doubled. However, the score differential remains low, at only 4 points (Figure 22) and girls scored higher in a similar proportion of countries.

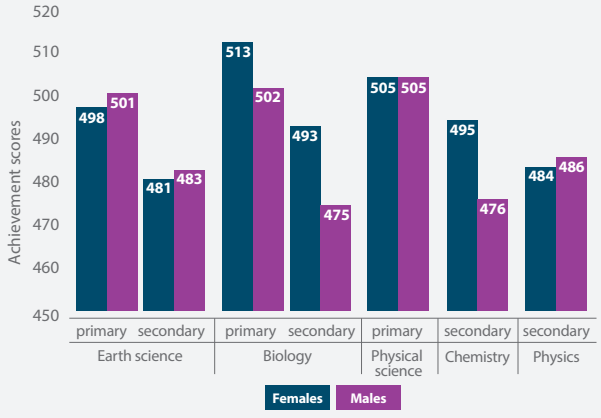
Figure 21: 20-year trends in science achievement, Grade 8



Notes: Average score difference is calculated as average achievement score points of boys minus that of girls. Countries and dependent territories for which trend data are available: Australia, England (U. K.), Hong Kong (China), Hungary, Iran, Isl. Rep., Ireland, Japan, Rep. of Korea, Lithuania, New Zealand, Norway, Russian Fed., Singapore, Slovenia, Sweden, and the United States.

Data source: TIMSS 1995 -2015[16]

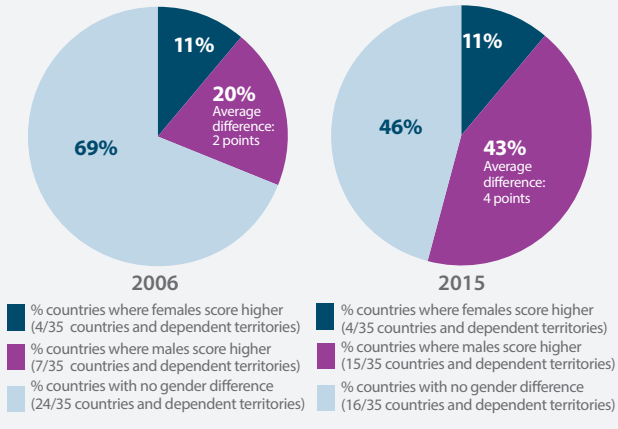
Figure 20: Female and male student achievement in science sub-topics in primary and secondary education, Grades 4 and 8



Gender differences in science sub-topics topics at primary and secondary education.
Note: 'Life science' in primary education = 'Biology' in Secondary Education, while 'Physical science' in primary education = 'Chemistry' and 'Physics' in SE.
47 countries and dependent territories at primary level and 39 countries and dependent territories at secondary level.

Data source: TIMSS 2015[16]

Figure 22: 9-year trends in science achievement, 15-year-olds



Notes: Average score difference is calculated as average achievement score points of boys minus that of girls. Score differentials are not available when girls outperform boys. Countries and dependent territories for which trend data are available: Australia, Austria, Belgium, Canada, Chile, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Rep. of Korea, Latvia, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States.

Data source:PISA 2006 -2015 (OECD countries)[17]

1.3.2 Mathematics achievement

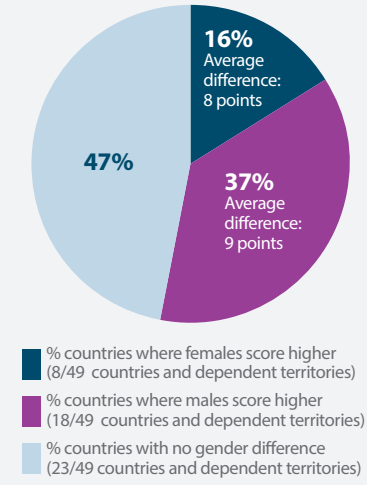
Primary education

There is a larger body of evidence on mathematics achievement in primary education than for science. This includes 49 countries in TIMSS 2015 for Grade 4 students, 15 countries in Latin America in TERCE 2013 for Grade 3 and 6 students, 10 countries from West and Central Africa in the Programme d'Analyse des Systèmes Educatifs des Pays de la Conférences des Ministres de l'Education des Pays Francophones (PASEC) 2014, and 15 countries in Eastern and Southern Africa in the Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ) 2007. Significant gaps remain in our understanding of the situation in primary education in Central Asia, and South and West Asia due to lack of data.

Compared to science, data on mathematics in primary education from TIMSS 2015 show a larger proportion of countries where boys score higher than girls. However, average score differences show similar trends with more significant score differentials in countries where girls score higher than boys (Figure 23). There are similar regional patterns, with again the largest score differential observed in Saudi Arabia, among Arab States (see Figure 17, page 27). Where girls outperform boys in mathematics, average differences are lower than in science achievement.

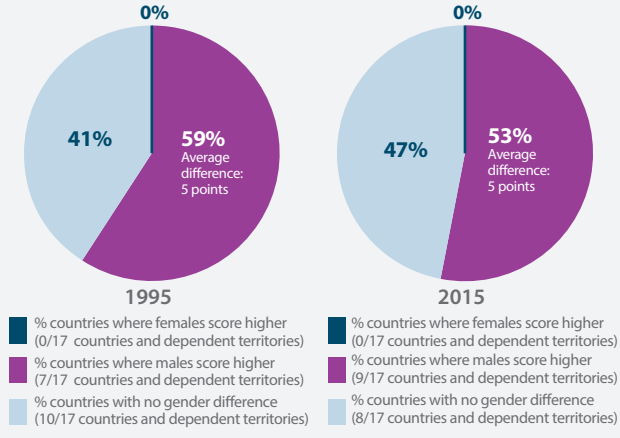
Trend data from a smaller subset of countries (17) demonstrate slight improvements in reducing gendered differences in learning achievement between TIMSS 1995 and 2015, including reductions in average score differentials between boys and girls (Figure 24). However, in several countries and territories, including Australia, Hong Kong (China) and Portugal, the gender gap in achievement widened during this period at the expense of girls.

Figure 23: Gender difference in mathematics achievement, Grade 4



49 countries and dependent territories Data source: TIMSS 2015[16]

Figure 24: 20-year trends in mathematics achievement, Grade 4



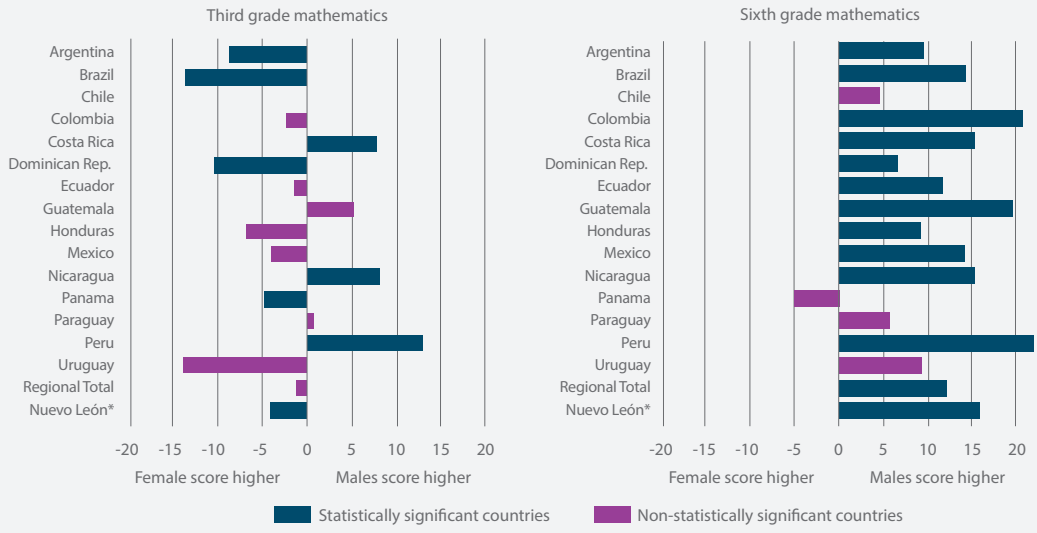
Notes: Average score difference is calculated as average achievement score points of boys minus that of girls. Countries and dependent territories for which trend data are available: Australia, Cyprus, Czechia, England (U. K.), Hong Kong (China), Hungary, Iran, Isl. Rep., Ireland, Japan, Rep. of Korea, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovenia, and the United States.

Data source: TIMSS 1995 -2015[16]

Data on mathematics achievement in the 15 Latin American countries participating in TERCE 2013 find a mixed picture in mathematics achievement in Grade 3, with statistically significant advantages in achievement in girls' favour in five countries (Figure 25).

Gender differences emerge significantly in boys' favour in the large majority of participating countries. Researchers suggest that socio-cultural factors may play a role[56] such as cultural values, gender beliefs, bias and stereotypes.

Figure 25: Average score difference in mathematics achievement between girls and boys, Grades 3 and 6

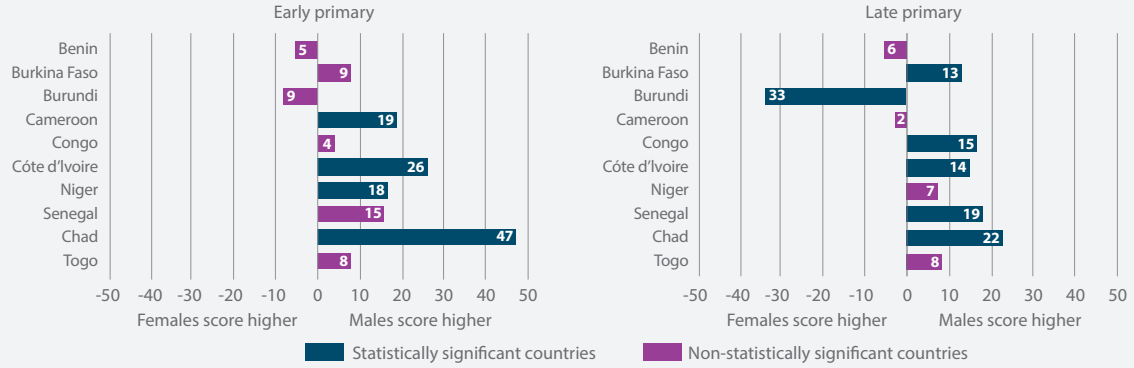


Girls do better than boys in mathematics in most Latin American countries in Grade 3 but lose their advantage by Grade 6.
*Note: Nuevo León is one of the 32 Federal Entities of Mexico
15 countries.

Data source: TERCE 2013[56]

A very different picture emerges in the 10 Francophone African countries participating in PASEC 2014 (Grade 2 and Grade 6). Here, boys' advantage in mathematics achievement is present in the majority of countries in both early and late primary education, with score differentials increasing in some countries between levels and decreasing in others (Figure 26). Burundi is an outlier, with significant differences in scores in girls' favour at late primary by a wide margin, meriting further attention as to the factors of success. Girls' disadvantage in STEM-related subjects in sub-Saharan Africa cannot be disassociated with the wider socio-economic and cultural obstacles girls face in education in general in this region, such as poverty, early marriage, sexual abuse at school, or social norms valuing boys education more. Furthermore, the overall education quality remains a challenge for Francophone African countries and does not always respond to girls' learning needs.[57]

Figure 26: Average score difference in mathematics achievement between girls and boys, early and late primary education, Grades 2 and 6

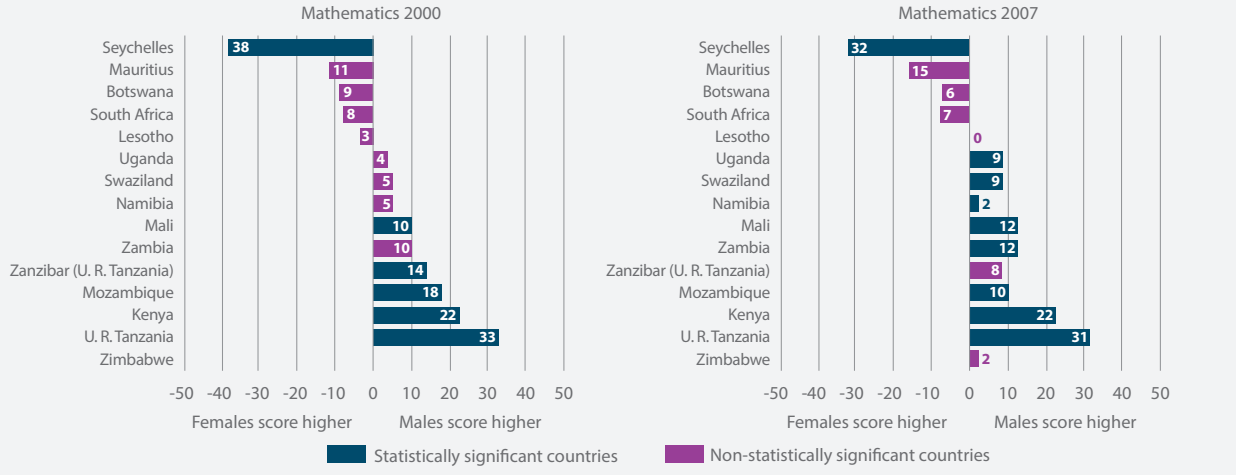


Boys are doing better than girls in mathematics in primary education in Francophone African countries.
10 countries

Data source: PASEC 2014[57]

In Southern and Eastern Africa, data from the SACMEQ III 2007 study (latest available) finds boys' advantage in mathematics in the majority of countries, and little change between the 2000 and 2007 studies. The largest differences in achievement in 2007 were observed in the Seychelles, where girls outperformed boys by 32 points, and in the United Republic of Tanzania, where boys outperformed girls by 31 points (Figure 27).

Figure 27: Average score difference in mathematics achievement between girls and boys, Grade 6



7-year trends in mathematics achievement in Southern and Eastern Africa in Grade 6.
15 countries

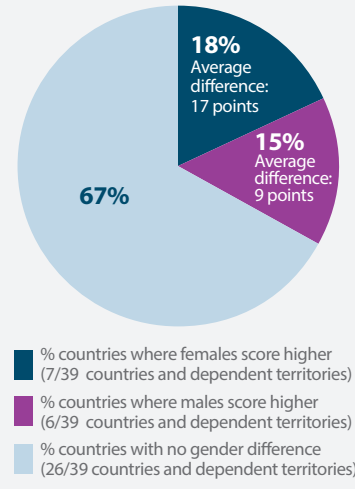
Data source: SACMEQ 2000-2007[58]

Secondary education

Data on gender disparities in mathematics achievement at secondary education levels is available from 39 countries participating in TIMSS 2015 for Grade 8, and 70 countries participating in PISA 2015 among slightly older cohorts (15-year-olds). Data are limited for sub-Saharan Africa, Central Asia, and South and West Asia. Regional surveys providing data for primary education level mathematics for certain countries do not cover secondary education.

TIMSS 2015 found a smaller proportion of countries with gender differences in mathematics achievement at secondary level than at primary level (Figure 28), and a larger proportion of countries for which gender disadvantage was in girls' favour. As is the case for primary education, regional differences are observed (see Figure 17, page 27) with the largest difference in mathematics achievement in girls' favour observed in Oman (45 points). Smaller score differentials are seen, overall, in mathematics than in science.

Figure 28: Gender difference in mathematics achievement, Grade 8

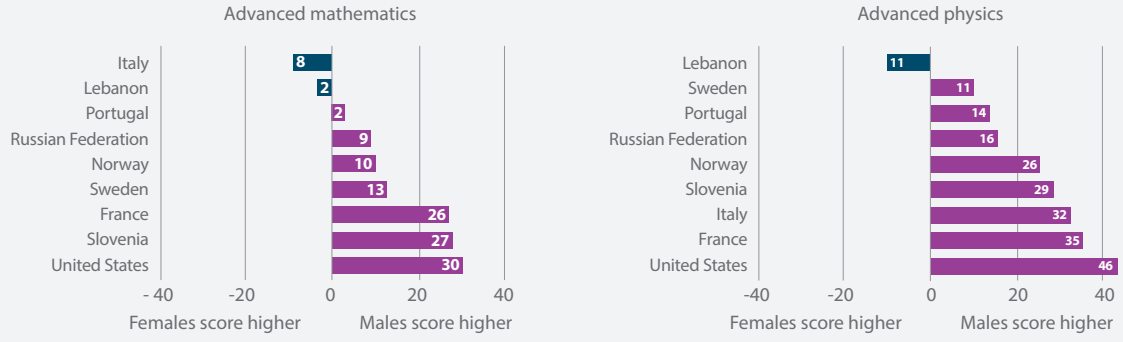


Note: Average score difference is calculated as average achievement score points of boys minus that of girls, or vice-versa. See Annex 1 for participating countries and dependent territories.

Data source: TIMSS 2015[16]

In TIMSS Advanced 2015, boys had higher achievement in mathematics than girls in seven out of the nine participating countries (Figure 29). Only two countries, Italy and Lebanon, had no statistically significant difference between boys' and girls' achievement. Similarly, in physics, boys had higher achievement than girls in all the TIMSS Advanced 2015 countries, except Lebanon, where girls did better than boys. It is critical to promote positive formative experiences at this age, to stimulate girls' interest and engagement with STEM fields, such as, for example, by raising awareness about STEM employment possibilities and prospects.

Figure 29: Average score difference in advanced mathematics and science achievement between girls and boys, Grade 12

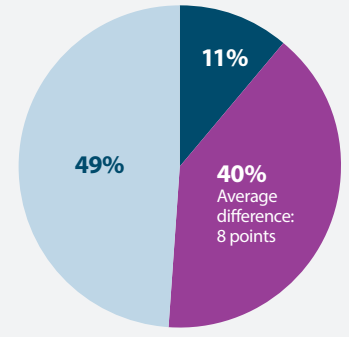


Boys score higher than girls in advanced mathematics and physics in Grade 12.
9 countries

Data source: TIMSS Advanced 2015[18]

Where gender differences exist in mathematics achievement, they are more likely to be in boys' favour in PISA 2015 participating countries (Figure 30). This is a much different picture than in science achievement (see Figure 15, page 26) where a more mixed pattern emerged. Fewer regional patterns can also be observed in mathematics achievement (see Figure 19, page 29.) Some additional observations can be made on TIMSS 2015 findings as they relate to boys' and girls' mathematics achievement. TIMSS 2015 found that girls tend to do better in certain content domains while boys perform better in others. For example, in Grade 8, boys have higher achievement scores in the sub-topic 'number' and girls do better in 'algebra' and 'geometry' (Figure 31). Figure 32, on page 35, presents the number of countries where gender differences were observed in sub-topics.

Figure 30: Gender difference in mathematics achievement, 15-year-olds

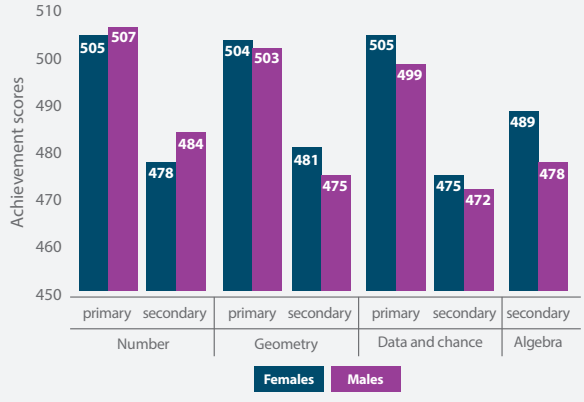


% countries where females score higher (8/70 countries and dependent territories)
% countries where males score higher (28/70 countries and dependent territories)
% countries with no gender difference (34/70 countries and dependent territories)

Note: Average score difference is calculated as average achievement score points of boys minus that of girls. Score differentials are not available when girls outperform boys. See Annex 1 for participating countries and dependent territories.

Data source: PISA 2015[17]

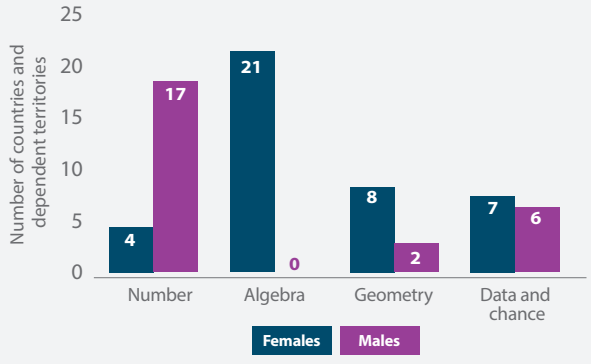
Figure 31: Girls' and boys' achievement in mathematics sub-topics in primary and secondary education, Grades 4 and 8



Gender differences in mathematics achievement scores by sub-topics in both primary and secondary education.
Note: Algebra is only available at secondary level.
49 countries and dependent territories at primary, and 39 countries and dependent territories at secondary

Data source: TIMSS 2015[16]

Figure 32: Gender difference in achievement in the content domains in mathematics, in secondary education, Grade 8

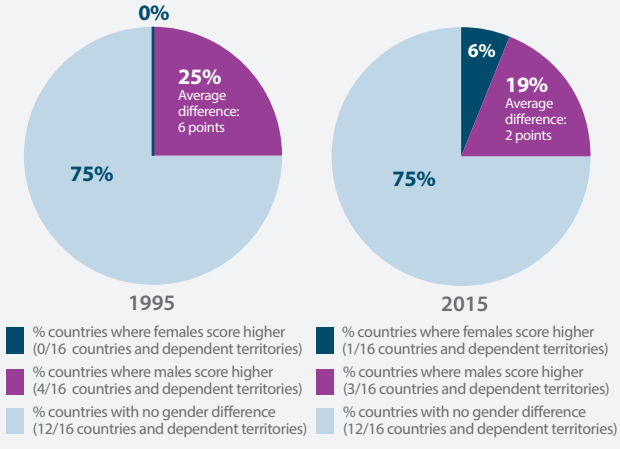


Data source: TIMSS 2015[16]

Secondary education

Both TIMSS and PISA have trend data available for mathematics in secondary education, although at different time scales, with different sets of countries, and different measurement parameters. There is limited change in gender difference in mathematics achievement in the 16 countries participating in both the 1995 and 2015 TIMSS surveys (Figure 33), as compared to differences in science achievement trends (Figure 14, on page 26). In the 2015 TIMSS, three countries closed gender gaps in score differentials (Iran, Islamic Republic of, Japan and the Republic of Korea), but three countries (Hungary, the Russian Federation and Sweden) developed gender advantage in boys' favour. In TIMSS 2015, girls outperformed boys in only one country, Singapore, where there was no gender difference in mathematics achievement in 1995. Some improvements were made in closing the gender gap in mathematics achievement among OECD countries participating in PISA 2003 and 2015 (Figure 34). However score differentials remain in boys' favour in the majority of the participating countries.

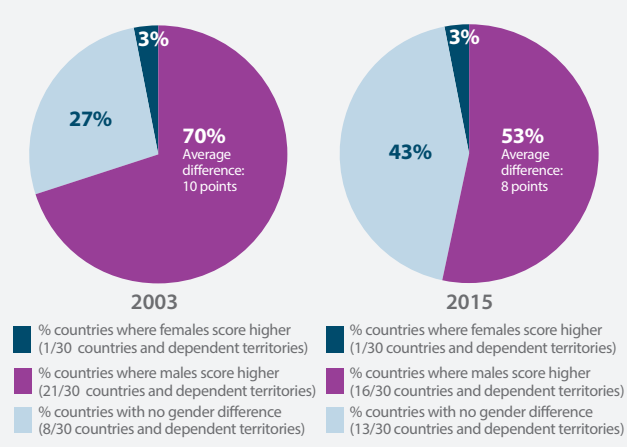
Figure 33: 20-year trends in mathematics achievement, Grade 8



Note: Average score difference is calculated as average achievement score points of boys minus that of girls. Score differentials are not available when girls outperform boys. Countries and dependent territories for which trend data are available: Australia, England (U. K.), Hong Kong (China), Hungary, Iran, Isl. Rep., Ireland, Japan, Rep. of Korea, Lithuania, New Zealand, Norway, Russian Fed., Singapore, Slovenia, Sweden, and the United States.

Data source: TIMSS 1995 -2015[16]

Figure 34: 12-year trends in mathematics achievement, 15-year-olds



Note: Average score difference is calculated as average achievement score points of boys minus that of girls. Score differentials are not available when girls outperform boys. Countries and dependent territories for which trend data are available: Australia, Austria, Belgium, Canada, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Rep. of Korea, Latvia, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, and the United States.

Data source: PISA 2003 -2015 (OECD countries)[17]

1.3.3. Computer and information literacy achievement

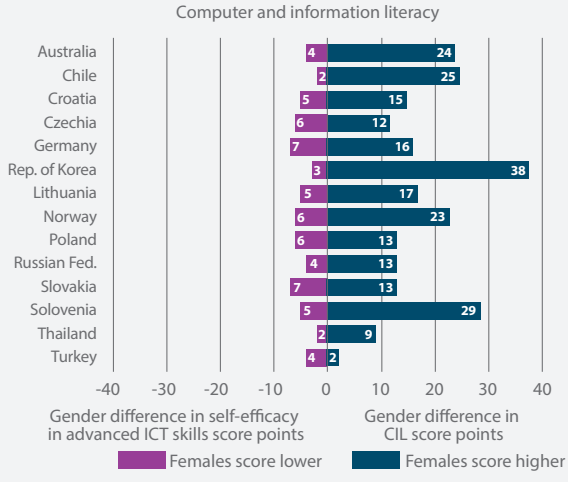
Not only is ICT a distinct STEM career path, it is also increasingly used as a working tool in STEM education and careers.[59] It is estimated that by 2020, 98% of STEM-related jobs will require ICT skills and there will be around 1 million vacant posts in computing because of a lack of skilled personnel.[60] Women are significantly under-represented in ICT, accounting for only 3% of ICT graduates globally. In Europe, only 29 out of 1,000 female graduates have a degree in computing in 2015, and only four went on to have ICT careers.[20]

The only international assessment of students' achievement in computer and information literacy available is the International Computer and Information Literacy Study (ICILS), which was developed by IEA. To-date it has been implemented only once, in 2013, among Grade 8 students in 14 countries. The survey sheds light on the contexts and outcomes of ICT-related education programmes, and the role of schools and teachers in supporting students' computer and information literacy achievement.

ICILS 2013 found that in Grade 8, girls scored better than boys in all participating countries in computer and information literacy, with an average difference of 18 points. However, their perceived self-efficacy in advanced ICT skills was significantly lower (Figure 35). For example, in the Republic of Korea where the highest score differential (38 points) was observed in favour of girls, girls' self-efficacy was lower than boys' by 3 points.[61]

ICILS 2018 is in the pipeline, and will enable countries participating in the previous cycle to monitor changes over time in computer and information literacy achievement and teaching and learning contexts, and new countries to participate. ICILS 2018 will also report on the computational thinking domain, understood as the process of working out exactly how computers can help us solve problems.[62]

Figure 35: Average score difference between girls' and boys' achievement in computer and information literacy and self-efficacy in advanced ICT skills, Grade 8



Girls' achievement in computer and information literacy (CIL) was higher than boys' yet their confidence was lower in Grade 8.
14 countries. Data source: ICILS 2013[61]

Key messages

- Data on gender differences in learning achievement present a complex picture, depending on what is measured (subject, knowledge acquisition against knowledge application), the level of education/age of students, and geographic location.
- Overall, there is a positive trend in terms of closing the gender gap in STEM-related learning achievement in girls' favour, but significant regional variations exist. For example, where data are available in Africa, and, Latin America and the Caribbean, the gender gap is largely in favour of boys in mathematics achievement in secondary education. In contrast, in the Arab States, girls perform better than boys in both subjects in primary and secondary education. As with the data on participation, national and regional variations in data on learning achievement suggest the presence of contextual factors affecting girls' and women's engagement in these fields.
- Girls' achievement seems to be stronger in science than mathematics and where girls do better than boys, the score differential is up to three times higher, than where boys do better. Girls tend to outperform boys in certain sub-topics such as 'biology' and 'chemistry' but do less well in 'physics' and 'earth science'.
- Impressive improvements have been observed over time in reducing the gender gap in science in secondary education among TIMSS trend countries. 14 out of 17 participating countries had no gender gap in science in 2015, compared to only one in 1995. However, the limited number of countries does not allow for the generalization of these findings.
- The gender gap is slightly bigger in mathematics but improvements over time in girls' favour are also observed in certain countries, despite the important regional variations and the overall gender gap in boys' favour. Gender differences are observed within mathematic sub-topics with girls outperforming boys in topics such as 'algebra' and 'geometry' but doing less well in 'number'.
- Girls' performance is stronger in assessments that measure knowledge acquisition than those measuring knowledge application. This difference might suggest that although girls' knowledge in science has increased, they might need to work more on the application of their knowledge and skills in these fields.
- Country coverage in terms of data availability is quite limited while data is collected at different frequency and against different variables in the existing studies. There are large gaps in our knowledge of the situation in low- and middle-income countries in sub-Saharan Africa, Central Asia, and South and West Asia, particularly at secondary level. There is a need for a broader set of internationally comparative data that covers more countries across all regions.

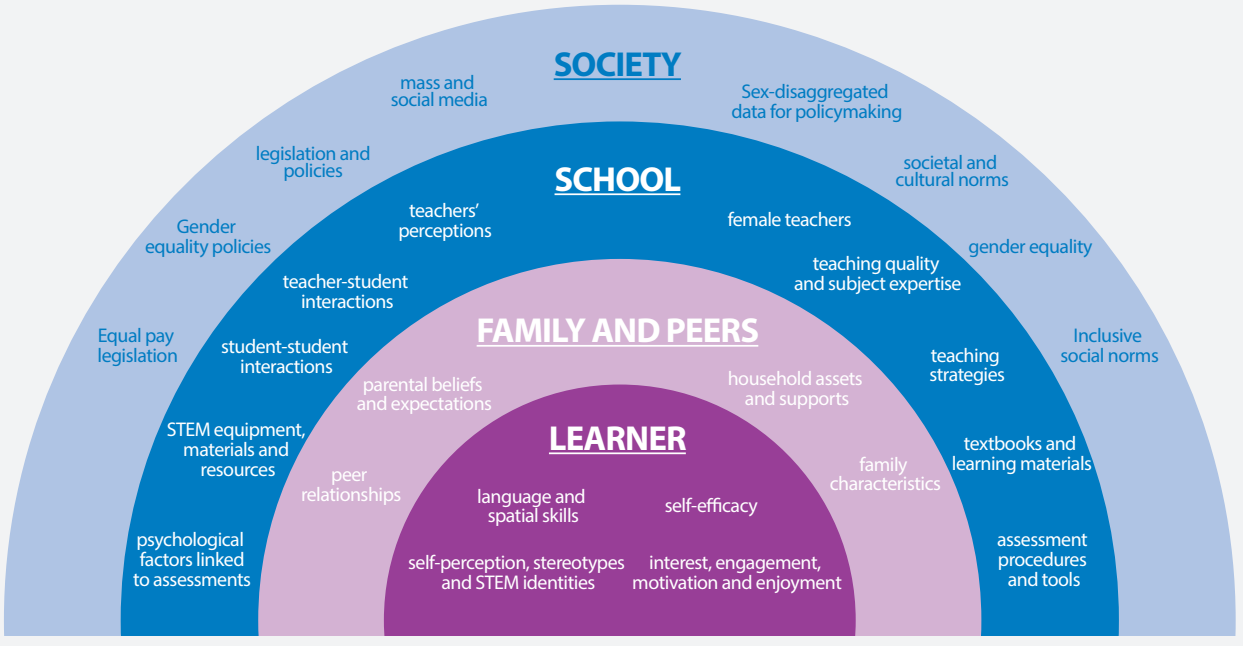
2. Factors influencing girls' and women's participation, progression and achievement in STEM education

2. Factors influencing girls' and women's participation, progression and achievement in STEM education

There are multiple and overlapping factors which influence girls' and women's participation, achievement and progression in STEM studies and careers, all of which interact in complex ways. In order to better explain these factors and understand the interrelations among them, this section suggests an ecological framework which compiles and presents these factors at the individual, family, institutional and societal levels (Figure 36): [40-42, 63-66]

- **Individual level:** biological factors that may influence individuals' abilities, skills, and behaviour such as brain structure and function, hormones, genetics, and cognitive traits like spatial and linguistic skills. It also considers psychological factors, including self-efficacy, interest and motivation.
- **Family and peer level:** parental beliefs and expectations, parental education and socio-economic status, and other household factors, as well as peer influences.
- **School level:** factors within the learning environment, including teachers' profile, experience, beliefs and expectations, curricula, learning materials and resources, teaching strategies and student-teacher interactions, assessment practices and the overall school environment.
- **Societal level:** social and cultural norms related to gender equality, and gender stereotypes in the media.

Figure 36: Ecological framework of factors influencing girls' and women's participation, achievement and progression in STEM studies



2.1 Individual-level factors

2.1.1 Biological factors

Many studies have considered the biological factors that underpin learning, cognitive ability and behaviour. This section presents key findings in these areas relating to STEM studies.

Brain structure and function

Neuroscience research has demonstrated some differences in brain structure and functions between men and women;[67] however, few reliable differences have been found between boys' and girls' brains relevant to learning or education.[68] For example, studies have found that the basic brain mechanisms of learning and memory do not differ between men and women. Similarly, studies on the neural basis of learning have not found that boys and girls master calculation or other academic skills differently and that no difference in brain composition can explain gender differences in mathematics achievement.[40]

Other evidence suggests that there are no or only small differences in boys' and girls' cognitive abilities, communication and personality variables.[69-71] Studies using functional magnetic resonance imaging (MRI) may help expand understanding of neuroprocessing, but results are not conclusive to support differences in abilities based on different brain structures or functions by sex.[72] Girls and boys appear to develop equally well in early cognitive skills that relate to quantitative thinking and knowledge of objects in the environment.[71,73] These findings suggest that there are more differences in basic cognitive, emotional and self-regulatory abilities among individuals within each sex than between men and women.

Research highlights the malleability of the brain and the importance of environmental influences in the learning process.[40] Evidence from neuroscience shows that neuroplasticity – the brain's ability to create new connections – is the foundation of any kind of learning and that the brain is more malleable during childhood than at any other stage in life.[74] Furthermore, children who are aware of brain neuroplasticity and who are told that their performance can improve by working hard have higher test scores.[68] In addition, students who believe that their abilities can be changed are more open to learning new material, mastering more difficult content and responding to challenges with increased effort.[75]

Language and spatial skills

Research on the cognitive predictors of STEM learning in children suggests that written language (awareness of phonetics, knowledge of letters and vocabulary) and spatial skills (ability to understand problems that relate to physical spaces, shapes, and forms) can predict competence in mathematics.[76] For example, children with stronger written language and spatial skills have stronger competence in mathematics in Grade 1 and advance more rapidly over time. Spatial ability also appears to predict STEM careers.[77]

Boys are considered to have better spatial skills than girls, but this is probably due to the family environment which provides boys with greater opportunities to practice these skills.[78] Although not all studies on this topic confirm sex-based variations in language and spatial skills,[76] researchers support that linguistic, spatial and number skills – as with other cognitive abilities – are flexible and can be significantly improved through early experiences.[76,79]

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Genetics

Genetic studies have found that cognitive skills, including education performance, are influenced by genetic factors.[80,81] There is no evidence of genetic differences in cognitive ability between the sexes, however, and genetic influences are neither deterministic nor static. They are influenced by, and interact with, environmental factors. In particular, the family, classroom or the wider education system, may determine the extent to which genes influence cognitive ability.[80,81]

The number and combination of genetic factors,[81] as well as the way in which the environment interacts with each individual's genetic types, may cause different patterns in motivation, learning, ability and achievement.[82] Genes may also be manifested differently, depending on an individual's environment and developmental stage, and their influence tends to become stronger with age.[81] Furthermore, the same genes, so called 'generalist genes', affect different abilities. This means that genes associated with one learning ability, such as reading, are very likely to be associated with other learning abilities, for example, mathematics.[80] This contradicts the stereotype that 'girls are good in reading and boys are good at math'.

Hormones

Research on the role of hormones on brain development shows that increased pre-natal exposure of girls to testosterone affects their post-natal behaviour. This includes, for example, showing a preference for objects that move in space, or expressing physical aggression rather than empathy, which is related to lower exposure to testosterone.[83,84] Although higher exposure to testosterone has not been found to influence mathematical or spatial abilities,[83] some suggest it can influence girls' likelihood of choosing careers considered 'typically male' and which require risk-taking and competition.[85] Other research finds girls who have earlier menarche lean more towards STEM subjects in higher education.[86] Additional research is needed to confirm the role of hormones and early menarche in the pursuit of STEM studies.

Key messages

- No differences are observed in the neural mechanism of learning based on sex. While some sex differences may be observed in certain biological functions, they have little or no influence on academic ability, including in STEM subjects.
- Genetic factors may influence academic ability but research suggests that differences in cognitive ability are likely to be larger among individuals than between men and women and that genetic ability interacts with, and is highly influenced by, the environment.
- Neuroplasticity – the brain's ability to create new connections – is the foundation of any kind of learning. The brain is more malleable during childhood than at any other stage in life. Children who are aware that cognitive ability can improve with practice perform better.
- Stronger written language and spatial skills are associated with higher ability in mathematics. These skills are flexible and can be influenced by targeted interventions, especially during early childhood.
- Hormones affect human behaviour but more research is needed to conclude how pre-natal hormonal exposure and hormone changes during adolescence might affect cognitive ability and behaviour.

2.1.2 Psychological factors

Girls' decisions about their studies and careers are influenced to a great extent by psychological factors, which affect their engagement, interest, learning, motivation, persistence and commitment in STEM.

PISA 2015 reports that engagement in science is determined by two factors – the way that girls and boys perceive themselves, i.e. what they are good at and what is good for them, and their attitudes towards science, i.e. if they think science is important, enjoyable and useful.[17] Both factors are closely linked to the social environment and the socialisation process rather than to innate, biological factors. This section presents key findings on psychological factors that impact on girls' STEM studies and career aspirations.

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Self-perception, stereotypes and STEM identities

A significant amount of research has focused on the need to develop girls' science and mathematics identities and self-perceptions of their potential in STEM studies and professions.[87-89] Self-selection bias is considered to be the major reason for girls opting out of STEM,[90-93] as girls often do not consider STEM professions to be compatible with their gender.

Studies have shown that stereotyped ideas about gender roles develop early in life, even in families promoting gender equality.[94] For example, it is found that girls and boys often have different toy preferences by the end of the first year of their lives, they understand gender stereotypes and want to behave like others of the same sex by as early as age two, and they learn to adjust their behaviour according to internalised gender stereotypes by age four.

Gender stereotypes about STEM are prevalent throughout the socialisation process, during which girls learn and develop gender roles. There are two predominant stereotypes with relation to gender and STEM – 'boys are better at maths and science than girls' and 'science and engineering careers are masculine domains'.[91]

Gender stereotypes about perceived higher-level intellectual ability among boys in general, and specifically in mathematics and science, are acquired early. A recent US study found that stereotypes associating high-level intellectual capacity and 'genius' with males are internalised by children as young as six years old.[95] Other studies have found that the belief that men are better than women at mathematics negatively influences girls' career aspirations and learning achievement from an early age.[95-97] Women have been found to be under-represented in fields where it is believed that innate talent is the main requirement for success and where women are stereotyped as not possessing this talent.[98-101]

Explicit or implicit gender stereotypes that communicate the idea that STEM studies and careers are male-dominated can negatively affect girls' interest, engagement and achievement in STEM and discourage them from pursuing STEM careers.[91,94,102,103] When asked to draw or describe STEM professionals, many studies have found adolescents have gender-stereotyped perceptions of scientists as being a male (as well as unattractive, socially awkward, and middle-aged/elderly).[104-108] The *For Girls in Science* programme of the L'Oréal Foundation in France (see Box 11) also found that students in secondary education held stereotypical views about science studies and professions.[109] Many identified science subjects to be masculine, demanding innate ability, and isolated, and women in science studies and professions unattractive in appearance.

Even if girls do not endorse these stereotypes themselves, knowing that people in their immediate environment hold such beliefs can undermine girls' confidence and, consequently, their performance and intention to pursue STEM careers.[91,110,111]

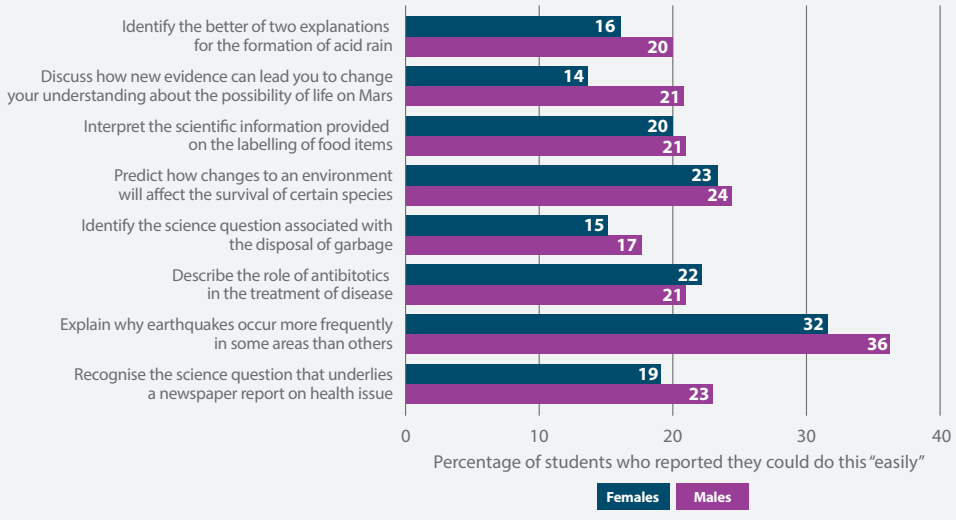
The need for belonging and identifying with the study field one pursues is also found to lead to better outcomes and engagement, but females report finding it more difficult to identify with STEM than males, and some feel their academic identity in STEM is incompatible with their gender identity.[64,112] For instance, a longitudinal UK study found that it was not 'thinkable' for girls, especially for those from lower socio-economic backgrounds and minority groups, to imagine themselves within the 'masculine' world of science.[66] The need for belonging also appears to lead many girls into programmes with a more supportive academic climate.[113] Lack of support, encouragement and reinforcement is detrimental to girls' intention to study STEM.[114]

Self-efficacy

Self-efficacy affects STEM education outcomes and aspirations for STEM careers, as well as performance.[115-118] PISA 2012 found that it led to a performance difference of 49 score points in mathematics and 37 score points in science – the equivalent of half to one additional school year.[119] PISA 2015 confirmed that girls have lower self-efficacy in science and mathematics than boys (Figure 37), a difference that has remained largely unchanged since 2006. Gender differences in science self-efficacy in boys' favour were particularly large in Denmark, France, Germany, Iceland and Sweden. Girls who assimilate gender stereotypes have lower levels of self-efficacy and confidence in their ability than boys.[120,121]

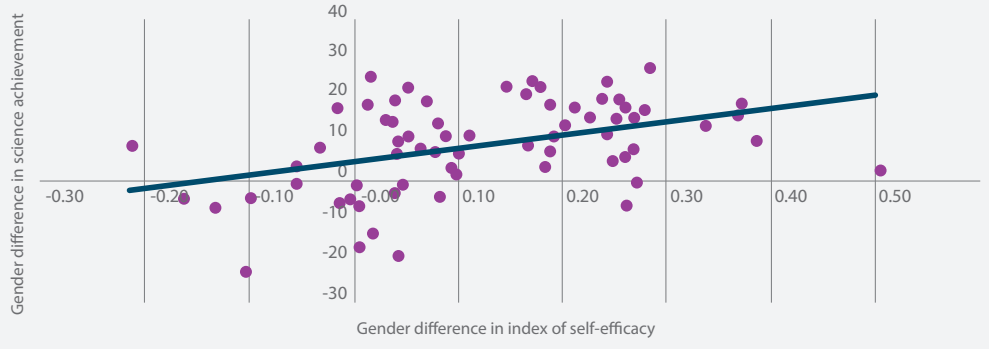
PISA 2015 also reported that there is a relationship between the gender gap in science self-efficacy and the gender gap in science performance, particularly among high-achieving students (Figure 38). In countries where the 10% top-performing boys score significantly above the 10% top-performing girls in science, there tends to be a larger gender gap in self-efficacy in boys' favour.[17] Although moderate, this correlation suggests that differences in self-efficacy can explain some of the variation in science performance observed across countries. It also suggests that awareness of differences in science performance may influence self-efficacy.

Figure 37: Percentage of students who reported that 'they could easily do' certain tasks in science, 15-year-olds



Girls have lower self-efficacy in science than boys, except in health-related topics.
70 countries and dependent territories.
Data source: PISA 2015 (OECD countries)[17]

Figure 38: Self-efficacy and science achievement among top-performing students, 15-year-olds



Self-efficacy is related to science achievement among top-performing students.
Note: Gender difference in science achievement is calculated as average achievement score points of top-performing boys minus that of top-performing girls; gender difference in self-efficacy is calculated as index of self-efficacy of boys minus that of girls.
70 countries and dependent territories.
Data source: PISA 2015 (OECD countries)[17]

Studies examining girls' self-efficacy in ICT, including ICILS, have found lower levels of confidence among girls even in contexts where they are outperforming boys. A study in Viet Nam found that girls enter ICT with the perception that programming is difficult, but upon overcoming this perception, they improve in programming and often outperform boys.[122] More attention is needed to attract more girls in ICT and to dilute girls' anxiety and misconceptions about sex-based ability in these fields.

Interest, engagement, motivation and enjoyment

Interest plays an important role in girls' engagement in STEM at school, their subject choices in higher education and their career plans. A meta-analysis of gender differences in occupational interests, synthesising more than 40 years of evidence, suggests that interest plays a critical role in gender differences in occupational choices.[63] The study showed that consistently over time and across age groups, men prefer working with things and women prefer working with people. As already presented earlier in this report, girls' interest in STEM is closely linked with their perception of self-efficacy and performance and is heavily influenced by their social context, including parents' expectations,[17] their female peers,[120,123] stereotype threat,[91,94,124] and the media.[106] Further explored in the next section, interest is also influenced by girls' overall learning experience in school,[26] especially at earlier grades,[125] including the influence of STEM teachers[121,120,127] and their teaching strategies,[119,125,128] the curriculum[125] as well as opportunities for practice[129] and exposure to role models and mentorship opportunities.[130] No innate factors were found to influence girls' interest in STEM although, as presented earlier, emerging research on hormones suggests that girls' pre-natal exposure to androgens might affect their behaviour and career preference.[83-86] Further research is needed however to be able to understand if, how, and to which extent, this affects girls' interest in STEM careers.

Some studies found that female students reported more negative science attitudes and lower perceived competence than male students[131] and that their career aspirations in science could be predicted by their knowledge and attitudes towards mathematics, science and engineering.[132] Other studies found that, in upper secondary education, boys showed greater interest in engineering and girls showed greater interest in health and medicine,[132] and that boys had greater technology-related career goals than girls.[133] Research among adolescents in North American and European countries has found that boys are somewhat more likely than girls, on average, to value mathematics, physical sciences, computers and technology.[134]

Motivation is important for increasing students' participation in STEM. Systematic review of studies targeting students' motivation showed that certain interventions had positive effects on both motivation and academic outcomes, for example, targeting students' beliefs about value, interest, or intrinsic motivation or how to deal with success or failure.[135] It was also suggested that women may benefit more from such interventions as they are more affected by gender stereotypes about their abilities in these fields. On the other hand, women who have firmly internalized such stereotypes might be less receptive to motivation interventions.

Enjoying learning science and performance in science are also positively related to expectations of future careers in this field. PISA 2015 found that boys enjoy science more than girls in the majority of the participating countries (29 of 47). The differences in boys' favour were particularly wide in Taiwan Province of China, France, Germany, Japan and the Republic of Korea. Girls were more likely than boys to report enjoying and being interested in science in only 18 of the 47 countries, particularly in Jordan and The former Yugoslav Republic of Macedonia. The relationship with enjoyment is stronger among higher-achieving students.

Socio-economic status also matters as more advantaged students are more likely to expect a career in science, even among students with the same enjoyment of learning science. These psychological factors need to be taken into consideration in interventions targeting girls since improving girls' confidence and self-belief can boost their achievements and increase their preference for study and career choices in STEM.

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Key messages

- Self-selection bias is the major reason for girls opting out of STEM. However, this 'choice' is influenced heavily by the socialisation process and stereotyped ideas about gender roles, including stereotypes about gender and STEM.
- Gender stereotypes that communicate the idea that STEM studies and careers are male domains can negatively affect girls' interest, engagement and achievement in STEM and discourage them from pursuing STEM careers. Girls who assimilate such stereotypes have lower levels of self-efficacy and confidence in their ability than boys. Self-efficacy affects both STEM education outcomes and aspirations for STEM careers to a considerable extent.
- Not all girls are deterred by gender stereotypes. Those who have a strong sense of self-efficacy in mathematics or science are more likely to perform well and to choose related studies and careers.
- Interest, which is linked to self-efficacy, and a sense of belonging play an important role in girls' engagement in STEM at school, their subject choices in higher education and their career plans. Some studies have shown that girls appear to lose interest in STEM subjects with age, suggesting that early interventions are needed to sustain girls' interest in these fields.

2.2 Family- and peer-level factors

Parents, the wider family, and peer groups play an important role in shaping girls' attitudes towards STEM, in encouraging or discouraging them from pursuing STEM-related studies and careers, as do other factors related to a child's household environment and assets. Parental and family beliefs and expectations about STEM are themselves influenced by their education level, socio-economic status, ethnicity and wider social norms.

Parental beliefs and expectations

Parents with traditional expectations of gender roles reinforce gendered behaviours and attitudes in children.[136] Differential treatment of girls and boys can reinforce negative stereotypes about gender and ability in STEM, deterring girls from these fields.[137] For example, in some contexts, parents have lower expectations of girls' ability in mathematics and place less value in girls' participation in science and mathematics.[138-140]

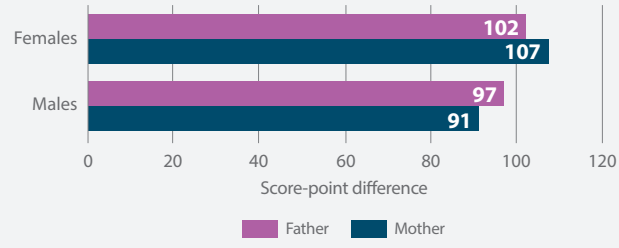
Parents also have a strong influence on the career choices of their children through the home environment, experiences and support they provide.[139,141,142] Some research suggests that girls' career choices are more influenced by their parents' expectations, whereas boys' career choices are more influenced by their own interests.[17] Parental beliefs, especially those of mothers, influence girls' beliefs about their ability and, hence, their education achievements and career options.[143,144] Mothers have been found to have a significantly stronger influence on their daughters' decisions to study STEM than on their sons' decisions in a number of settings.[17,145]

Parents' education and profession

The presence of family members with STEM careers has been shown to influence girls' pursuit of STEM studies.[146] Parents in STEM fields are likely to familiarise girls with STEM careers in ways that other role models cannot, and debunk the perception that STEM occupations are difficult to combine with family life.[45] Studies have shown that women scientists more frequently have parents who are scientists than their male colleagues.[102,139]

Parents' education is also an important factor. Many studies in industrialised countries have shown that children of more highly educated parents take more mathematics and science courses in upper secondary education and perform better.[17,147,148] In OECD countries, girls' science performance appears to be more strongly associated with mothers' higher educational qualifications, and boys' with their fathers' (Figure 39). Other studies comparing the multiple influences on children's mathematics achievement have found that mothers' education has the largest effect.[149,150]

Figure 39: Average score difference in science achievement between male and female students with parents with higher education qualifications, 15-year-olds



Parents, especially mothers, with higher education qualifications positively influence girls' achievement in science.
35 OECD countries. Data source: PISA 2015 (OECD countries)[17]

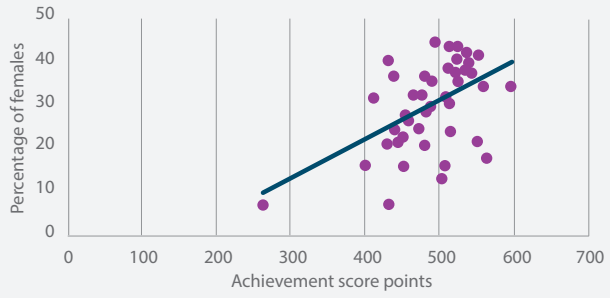
Household assets and support

Higher socio-economic status has also been shown to be associated with higher scores in mathematics for both boys and girls. PISA 2015 found that a one-unit increase in the PISA Index of Economic, Social and Cultural Status resulted in an increase of 38 score points in science and 37 in mathematics.[17] This may be related to parents providing additional learning support at school and at home, with higher academic expectations, and less conventional beliefs about gender roles and career paths in these settings.[139]

Children's interest and achievement in STEM can also be reinforced through parents' provisions for access to instructional support, including private tutoring. In Singapore, the top-performing country in TIMSS 2015 in both mathematics and science in Grade 8, 42% of parents reported engaging private tutors to support their child's mathematics studies.[151] A UNESCO study in Cambodia, Indonesia, Malaysia, Mongolia, Nepal, the Republic of Korea and Viet Nam found that more girls received private tutoring than boys across all subjects, including those related to STEM.[152]

Access to other learning materials and instructional support can also spark and maintain interest in STEM studies and affect achievement. For example, students who regularly use a computer or tablet at home have been found to perform better in science at secondary level, regardless of their sex (Figure 40).

Figure 40: Percentage of girls using computers at home and their science achievement scores, Grade 8



Girls' use of computers at home can positively affect their achievement in science in Grade 8.
42 countries and dependent territories. Data source: TIMSS 2011[165]

Lack of interest reported by girls in STEM studies in different settings is often believed to be linked to inequitable access to, and experience with, STEM-related educational activities at home and in other settings.[153] PISA 2012 reported that boys were more likely than girls to participate in science-related activities outside school, such as watching television programmes about science, visiting websites about science topics, or reading science articles in newspapers or magazines.[119] Families with limited resources may not have the funds, time or connections to promote mathematics and science learning for their children. This has been documented as a factor affecting girls' participation in engineering programmes in the Republic of Korea and the US, among other settings.[48,113]

Other family characteristics

Girls' experiences in STEM are also shaped by a number of factors related to the broader socio-cultural context of the family. Ethnicity, the language used at home, immigrant status and family structure may also have an influence on girls' participation and performance in STEM. For example, in a US study comparing Caucasian and Latino children, Caucasian boys were more likely to report that their parents were supportive and engaging than Latino boys, Latina and Caucasian girls, with the language and education of the parents playing an important role.[154]

Some studies have found that children of immigrant parents and of single parents are more academically disadvantaged.[139,155] PISA 2015 found that, in the majority of the 35 participating countries, first-generation and second-generation immigrant students tend to perform worse than their non-immigrant peers, although in some contexts, for example, Macao (China), Qatar and the United Arab Emirates, they outperformed them. However, despite lower performance, immigrant students are 50% more likely than non-immigrant students with the same science scores to expect to have a science-related career. No significant gender differences were observed, suggesting that these results were applicable to both boys and girls.

Peer influence

Girls' confidence, motivation and feeling of belonging are affected by the 'peer climate' in STEM education.[65] Peer relationships influence children's beliefs, behaviours, academic achievement and motivation, especially during adolescence.[90,156] Students with friends that value academic achievement are themselves more likely to value mathematics and science.[157-160] Similarly, girls might be discouraged from taking STEM subjects if their peers and immediate environment view these subjects as inappropriate for women.[90,161] Female peers, in particular, can significantly predict girls' interest and confidence in both mathematics and science.[120,123,163,164] For example, a US study found that girls' decisions to take advanced mathematics and physics courses were influenced by how well their female friends did in these subjects the year before.[65]

Key messages

- Parents, including their beliefs and expectations, play an important role in shaping girls' attitudes towards, and interest in, STEM studies. Parents with traditional beliefs about gender roles and who treat girls and boys unequally can reinforce negative stereotypes about gender and ability in STEM.
- Parents can also have a strong influence on girls' STEM participation and learning achievement through the family values, environment, experiences and encouragement that they provide. Some research finds that parents' expectations, in particular the mother's expectations, have more influence on the higher education and career choices of girls than those of boys.
- Higher socio-economic status and parental educational qualifications are associated with higher scores in mathematics and science for both girls and boys. Girls' science performance appears to be more strongly associated with mothers' higher educational qualifications, and boys' with their fathers'. Family members with STEM careers can also influence girls' STEM engagement.
- The broader socio-cultural context of the family can also play a role. Factors such as ethnicity, the language used at home, immigrant status and family structure may also have an influence on girls' participation and performance in STEM.
- Peers can also impact on girls' motivation and feeling of belonging in STEM education. Influence of female peers is a significant predictor of girls' interest and confidence in mathematics and science.

2.3 School-level factors

This section considers school-related factors that affect girls' participation, achievement and progression in STEM subjects. This includes the environment within which STEM education takes place, teachers, teaching strategies, the curriculum and learning materials, and assessments.

Teachers

The quality of teachers, including their subject expertise and pedagogical competence, can significantly influence girls' participation and learning achievement in STEM. Teachers' attitudes, beliefs and behaviours, as well as their interaction with students, can also affect girls' choice of future study and careers. Teachers' sex is also an influential factor, as female teachers can serve as role models for girls.

Teaching quality and subject expertise

The quality of teachers is considered to be the single most important in-school factor, at primary and secondary levels, in determining students' overall academic achievement.[164] In a meta-analysis of research in the US, students' higher achievement in science and mathematics was found to be related to teachers with more teaching experience, more confidence in science and mathematics teaching and higher overall career satisfaction.[165] In Poland, students attending a school with low teacher quality were 25% more likely to have a low math score and 34% to have a low science score, compared to students attending a school with high teacher quality.[166] Subject expertise is a key element of teaching quality.[167] There are shortages of STEM-specialised teachers in many contexts, particularly in remote and rural communities. This affects the quality of STEM instruction for all learners.[6]

While most of the research on teacher quality does not examine gender differences, some studies have found that teachers may have a particular influence on girls' participation and engagement in STEM education. For example, teachers were the only significant predictor of girls' interest and confidence in science (Grades 6-12) in one US study, compared to the influence of family, place of residence, ethnicity and extra-curricular involvement in STEM.[126]

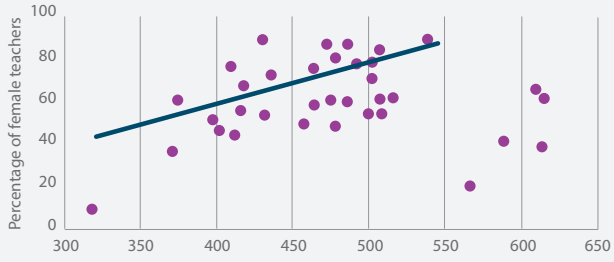
While good teaching can have a positive effect on STEM education, poor teaching can have the opposite effect. For example, in one US online study among youth aged 15 to 18, girls interested in pursuing a career in STEM were four times more likely than boys with similar aspirations to believe that their teachers were not preparing them well enough in STEM subjects.[168] Another study at a large engineering school in the US reported that poor teaching and advice was one of the three factors that significantly influenced students' decision, both males and females, to drop out of engineering.[169]

Investing in teacher training and professional development is critical for enhancing girls' interest and participation in STEM education.[167,170] It is insufficient alone, however, and needs to be matched with interventions that address other contextual factors and disadvantages facing girls.

Female teachers

The employment of female teachers has been associated with improved educational experiences and enhanced learning outcomes for girls in different contexts, across different subjects.[171] Female teachers have been found to positively influence girls' perceptions, interest and confidence in STEM subjects[120] as well as their STEM career aspirations.[127,172] The UNESCO 2016 GEM report found that girls do better in introductory mathematics and science courses and are more likely to follow STEM careers when taught by female teachers.[2] Similarly, TIMSS 2011 data shows a clear link between female teachers and girls' performance in mathematics in Grade 8 (Figure 41).[167] Female teachers can positively influence girls' education in STEM by dispelling myths about sex-based, innate abilities among boys, and by acting as role models for girls.[125, 127,173,174] They may also be more sensitized and have more positive attitudes towards gender equality in the classroom than their male colleagues, as found in a study in Spain.[175]

Figure 41: Percentage of female teachers and average achievement of female students in mathematics, Grade 8

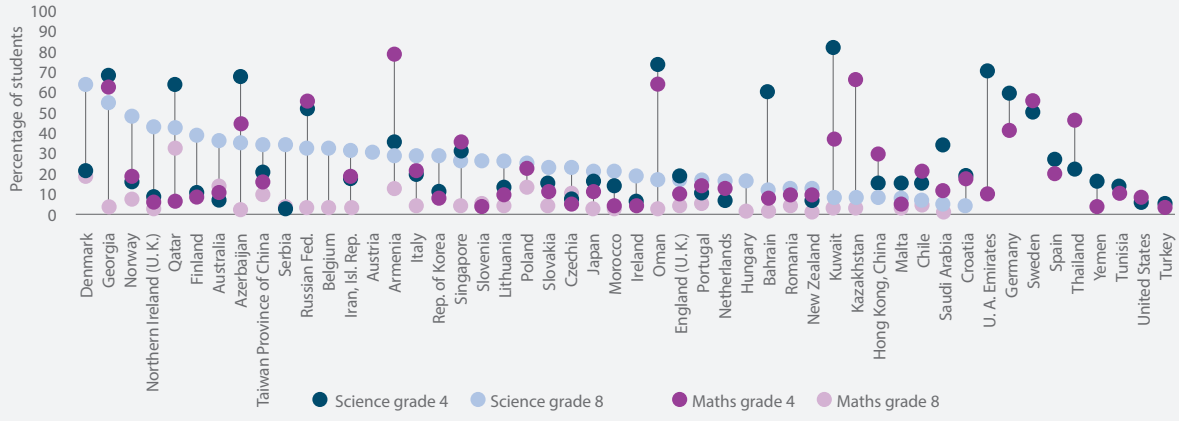


Female teachers positively affect girls' performance in mathematics in Grade 8.
42 countries and territories. Data source: TIMSS 2011[165]

Not all studies establish a clear correlation between female teachers and girls' STEM performance, indicating that other factors play a role.[176,177] These include specialisation, access to professional development and support, the age of teachers and learners, the broader learning environment and socio-economic context, as found in a study in Norway.[176] Nevertheless, even studies that did not establish a clear relationship between the presence of female teachers and girls' performance in STEM found that female teachers seem to have a positive influence on both girls and boys.

Despite their overall positive influence on STEM outcomes, few countries have significant proportions of female teachers with specialisation in science and mathematics (Figure 42). Female teachers are more likely to specialise in science than mathematics at both primary and secondary levels, but there are significant variations between countries. For example, a UNESCO study found that in secondary education, 90% of chemistry and biology teachers and 75% of mathematics, physics and ICT teachers in Mongolia were women, whereas only 20% of science teachers and 10% of mathematics teachers in Nepal were women.[154]

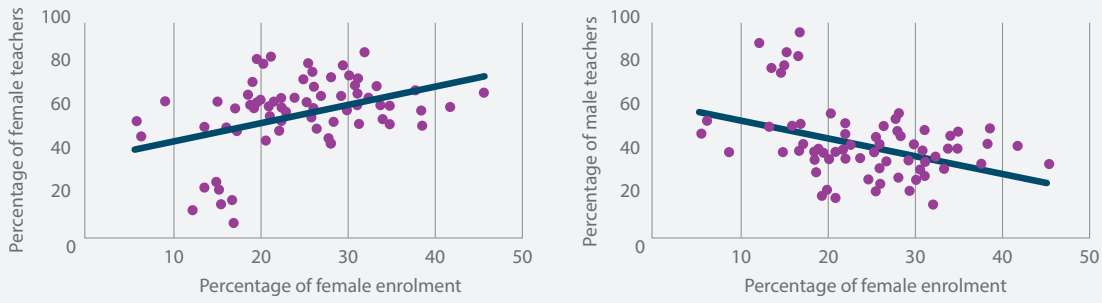
Figure 42: Percentage of students that are taught by female teachers specialized in science and mathematics in primary and secondary education, Grades 4 and 8



Few countries have significant proportions of female teachers with specialization in science and mathematics in Grades 4 and 8.
Grade 4: 50 countries and dependent territories, and Grade 8: 42 countries and dependent territories. Data source: TIMSS 2011[165]

Analysis of available data from 78 countries also shows a positive correlation between the presence of female teachers in secondary school and girls' enrolment in engineering, manufacturing and construction in higher education but a negative correlation with male teachers (Figure 43). The same correlation was not observed for science in higher education, suggesting that gender stereotyping might be less of an issue for science than for engineering, manufacturing and construction, which are traditionally considered to be more masculine subjects. It may also be due to the fact that female teachers are more likely to specialise in science than mathematics at both primary and secondary levels, as noted earlier, or the presence of other factors influencing girls' enrolment in science.

Figure 43: Percentage of female and male teachers in secondary education and girls enrolled in engineering, manufacturing and construction in higher education



Female teachers have a positive effect on girls' enrolment in engineering, manufacturing and construction but male teachers have a negative effect.
78 countries and dependent territories. Data source: UIS 2013[25]

Teachers' perceptions

Teachers' beliefs and attitudes, as well as their behaviour and expectations of both themselves and their students, including perceived ability, appear to have a profound effect on girls' academic interest and performance in STEM subjects.

Teachers' perceptions of sex-based ability can create an unequal environment in the classroom, and dissuade girls from pursuing STEM studies.[39,48,178] In Latin America, TERCE 2013 found that 8% - 20% of mathematics teachers in Grade 6 believed that mathematics is easier for boys to learn and that lower teacher expectations for girls had an impact on classroom interactions.[179] Similarly, a review of studies in the US found that teachers' expectations of ability in mathematics are often gender-biased and can influence girls' attitudes and performance in mathematics.[145,180] Teachers also had stereotypical views about other subjects, for example, about who is or can become an engineer,[176] and girls were less likely than boys to receive encouragement from teachers in physics lessons.[182]

Teachers can communicate messages about their attitudes without being aware of doing so or recognising that their attitudes might be biased. For example, a recent study in the United Kingdom and Ireland found that 57% of teachers held subconscious gender stereotypes in relation to STEM.[183] Teachers can pass on gender stereotypes to their students through instruction, as was found in a study of public schools in Switzerland.[184] Gender stereotypes can also intersect with and exacerbate other factors, such as girls' ethnicity.[185] For example, studies report that beliefs held by teachers, as well as by students, influenced mathematics outcomes for girls of African-American origin.[186,187]

Female teachers' perceptions of their own competence in teaching science and mathematics have a powerful effect on girls, and appear to decrease at higher levels of education. Studies have found that while female teachers are more confident than their male colleagues at primary school level, their confidence decreases significantly by secondary school.[167] Teachers' self-efficacy (as measured by levels of math or science 'anxiety') has been correlated to lower learning achievement and higher reported belief by girls that boys are innately better at math.[118,188] Similar effects have not been found for boys, which may be because girls are more influenced by same-sex teachers or because boys have greater confidence in their ability in mathematics.[118]

Teaching strategies

Effective teaching practices can cultivate a constructive learning environment that motivates and engages girls.[40] TIMSS 2011 found that the way in which the curriculum is taught in primary and lower secondary education significantly affects students' opportunities to learn mathematics and science.[167] PISA 2012 found that where teachers used cognitive-activation strategies in mathematics, which encourage students to think and reflect, use their own procedures to solve a problem, explore multiple solutions, learn from mistakes, ask for explanations and apply learning in different contexts, performance in mathematics improved.[119]

The quality of teachers, including their subject expertise and pedagogical competence, can significantly influence girls' participation and learning achievement in STEM.

In order to improve girls' performance, the teaching strategies within the classroom need to change,[189] to support female learners differently. Specific teaching strategies have been shown to particularly help girls and to reduce the gender gap in STEM achievement, while being beneficial for all students. These include, for example, student-centred, inquiry-based and participatory strategies, as well as strategies that improve girls' self-confidence and take account of their specific interests and learning styles.[119,125,128]

Teacher-student interactions

Studies show that interactions between teachers and students influence girls' engagement, self-confidence, performance and persistence in STEM studies.[176,190] Teacher interaction with students may create an unequal environment and reinforce gender stereotypes.[178] Classroom observations in some contexts have shown that girls have less instructional and discussion time, ask fewer questions, and receive less praise than boys.[126,191] This was found in one study in Asia, where 65% of all student-teacher interactions in mathematics classes were with boys, and 61% were with boys in science.[154] Differences were observed in the way girls and boys were treated in the classroom depending on the location

of the school. For example, in Nepal and Viet Nam, boys were more confident and received more teacher support in urban areas. In rural areas, however, girls received more teacher support and demonstrated higher levels of participation and confidence in both mathematics and science. There is no analysis behind this observation, which could be attributed to factors ranging from closer teacher-student relations in smaller rural communities to targeted programmes to promote gender equality in rural areas.

Furthermore, the way in which teachers manage social relationships and peer interaction within the classroom may encourage or hinder engagement in classroom activities.[192] Special attention must be paid to ensuring equitable and positive interactions between students. Collaborative group work is considered as an effective way to create positive attitudes toward instruction, boost achievement and self-esteem.[193] It can also create a more comfortable atmosphere for girls to ask questions, participate in activities and interact with teachers.[125] In some settings, girls appear to prefer collaborative learning environments than competitive or individual work.[129] However, on other occasions, group work can disadvantage girls and advantage boys.[194] For example, some studies have found boys may take leadership roles, argue and defend their views while girls may take stereotypical, secondary and more passive roles,[193] have less opportunity to speak in groups and avoid confrontation with their peers.[194] It is therefore important that teachers are aware of, and can manage, gender dynamics in classroom interactions, between teachers and students and among students themselves.

Curricula and learning materials

Other school factors that influence the learning process and girls' participation and performance in STEM include the curriculum, textbooks and other learning materials, as well as access to equipment and resources.

Textbooks and learning materials

The way male and female characters are represented in school textbooks conveys explicit and implicit messages to both boys and girls about male and female roles and abilities in STEM.[195] Such messages can reinforce gender stereotypes, and discourage girls from pursuing STEM careers.[196] Textbooks often fail to show female STEM professionals or, if they do, they often use language and images that portray women in subordinate roles, for example male doctors but female nurses.

A recent review by UNESCO of over 110 national curriculum frameworks in primary and secondary education in 78 countries found that many mathematics and science textbooks and learning materials conveyed gender bias.[197] For example, in India, more than 50% of the illustrations in mathematics and science textbooks at primary level portrayed only male characters, while just 6% showed only female ones. In mathematics textbooks, only men were depicted in commercial, occupational and marketing situations and no women were depicted as engineers, executives or merchants. In Indonesia, a Grade 7 science textbook only shows boys engaging in science (Figure 44), while in Cambodia, an illustration of the central nervous system in a Grade 9 textbook attributes more active and creative brain functions, such as thinking and exercising, to men, and more passive ones, such as smelling a flower or tasting food, to women (Figure 45).[154] Gendered curricula perpetuate gender bias and curb girls' future career aspirations.[198]

Figure 44: Indonesian science textbook depicts only boys in science, Grade 7[152]

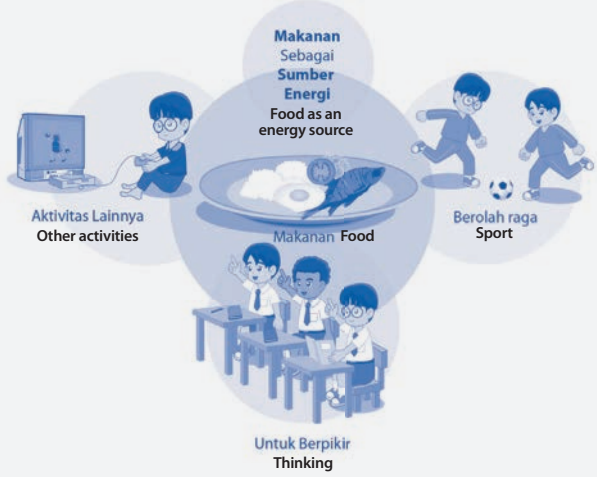
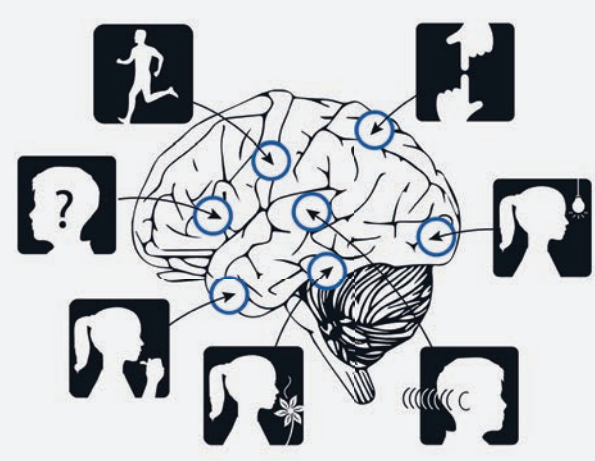


Figure 45: Cambodian textbook illustration associates more active and creative brain functions to men, Grade 9[152]



Improving girls' interest and achievement in STEM requires ensuring that the curriculum[125] accommodates girls' perspectives and avoids gender stereotypes.[128] PISA 2015 found that girls were more likely to be interested in how science can help prevent disease, whereas boys were more interested in topics such as energy or motion.[17] Nevertheless, many of the traditional STEM topics are more closely aligned to the interests of boys.[193] STEM curricula and textbooks need to consider girls' experience, learning style and interests. However, caution is needed when adapting curricula to try to attract girls to STEM subjects, as some researchers argue that changing curricula to reflect typical girls' and boys' interests may contribute to reinforcing gender stereotypes and reproducing the gender differences that the changes were intended to overcome.[199]

More demanding mathematics and science curricula appear to have a positive effect on girls' decisions to pursue STEM fields in higher education.[200] A strong upper secondary school curriculum in mathematics and science, providing opportunities for authentic learning experiences, can counteract the effects of negative gender steoretyping, which discourages girls' engagement in STEM fields. At the same time, STEM subjects and careers are often perceived as too difficult or as requiring more effort than students are willing to make.[135] It is therefore important to ensure a balanced curriculum in order not to deter students.

STEM equipment, materials and resources

The availability of equipment, materials and resources is essential to stimulate students' interest, and enhance learning, in STEM subjects. Access to resources for scientific experiments, in particular, has been associated with girls' achievement in science and interest in science subjects.[154] For example, in Cambodia, science laboratories were found to have a positive impact on student participation and helped to overcome preconceived beliefs about girls' low abilities in science. TIMSS 2011 found a positive correlation between the availability of science laboratories and girls' and boys' achievement in science (Figure 46 for girls' results).

iStock.com/Snowleopard1

Figure 46: Percentage of girls attending schools with a science laboratory and their achievement in science in secondary education, Grade 8

Females' achievement in science increases with the presence of a science laboratory, Grade 8.
42 countries and dependent territories Data source: TIMSS 2011[165]

Ensuring that there are enough materials for every student and avoiding competition over access to resources is also extremely important. For example, in some schools in Africa, a single mathematics textbook can be shared by three pupils on average.[201] This not only hinders learning but also increases the risk of boys monopolising the material and girls being observers.[193] In Slovenia, the lowest achieving girls were those with the least opportunity to conduct experiments during chemistry lessons.[202]

Virtual laboratories and ICT- based materials can be another source for learning and practice. Virtual experiments have been found to be equivalent to laboratory experiments in influencing students' attitudes and performance,[203] and could be used as alternative where physical laboratories are lacking. UNESCO microscience kits can also offer a cost effective alternative where laboratories are not available.[204]

The way computer science is taught and where, also affects girls' interest in STEM subjects and careers. Studies have shown that girls showed less interest when introductory computer science was taught in a traditional computer science classroom than when it was taught in a classroom that portrayed a new image of computer science, where they felt they belonged.[205] Opportunities to interact with technology has also been found to affect interest in science among both boys and girls.[206] Broader actions are also needed to close the digital divide, and expand access broadly to ICT for all learners. Particular attention is needed to close gender disparities in technology access, confidence and use (see Figure 31 on page 34).[45]

Finally, apprenticeship programmes and other training opportunities are a common feature of technical and vocational education and training (TVET) programmes, and can provide students with STEM-related learning and skills opportunities. Research in Viet Nam found that TVET institutions tend to reproduce the gender biases of the wider economy, channelling boys and girls into gender-stereotypical training opportunities.[207] Another study found that gender differences in upper secondary students' selection of physics courses reflected the gendered context of the local labour force.[208] The study also suggested that ensuring relevant and stimulating apprenticeship and learning opportunities, including in settings with more women in STEM occupations, may challenge societal gender stereotypes and assist in retaining girls in STEM studies.

Assessment

Performance in STEM-related assessments is not only influenced by students' cognitive skills but also by other non-cognitive factors, including assessment procedures and tools, teacher and student perceptions about ability, and psychological factors, including motivation and anxiety about testing, especially testing of mathematics.

Assessment procedures and tools

Gender differences in achievement scores in STEM subjects can be influenced by assessment procedures, including the construction of assessment tools and the way assessments are administered. Some studies have found that boys are more likely to perform better in multiple-choice mathematics assessments or standardised tests than girls.[195,209,210] The root causes for this are unclear, but have been attributed to boys' greater propensity for risk-taking and guessing on exams, compared to girls[211] and to differential response to competition.[212]

The way assessments are administered can also influence girls' outcomes. Girls have been found to have better mathematics scores in classroom tests, attributed to the social aspect of the classroom,[213] and perform slightly better in course work and 'essay-type' assessments.[195] PISA 2012 found that boys tend to do better in mathematics assessments using computer-based rather than paper-based formats, attributed to 'spatial reasoning' skills acquired through computer use, including through video games.[119] However, other studies have shown mixed results in computer-based tests, for example, in Canada, suggesting that performance may be context-specific.[214]

The content of assessments are also important, as evidenced by the differential findings in TIMSS as compared to PISA. Again, while results are not directly comparable even in countries participating in the same surveys due to different sampling parameters, time frames, and ages, the gender differences to boys' advantage are much larger in PISA where students are assessed on applied knowledge and skills. PISA 2012 found that girls do better when they work on mathematical or scientific problems that are similar to those typically encountered in school. However, when required to 'think like scientists', girls underperform considerably compared to boys.

Gender differences have also been observed in the way teachers mark boys and girls.[195] In one study of Israeli primary students, girls outscored boys in math exams when graded anonymously, but boys outscored girls when graded by teachers who knew their names. Researchers concluded that the teachers overestimated boys' abilities and underestimated girls', impacting girls' enrolments in advanced level math class in upper secondary, and ongoing studies.[215] Gendered assessment procedures, were also confirmed in other settings. For example in the European Union, female students tended to be marked down and male students marked up. This has led some countries to conceal the name and sex of the student during examination marking.[195]

Psychological factors and perceptions about ability

As mentioned earlier, gender stereotypes and girls' own perceptions about their abilities can affect performance. When confronted with gender stereotypes about their abilities, girls tend to underperform, as evidenced by a US study. Here, women with equally strong backgrounds and ability in mathematics as men scored lower when the stereotype 'women are bad at mathematics' was present, and scored equal to men when it was removed.[216] Girls with higher motivation to do well in tests seem to be more influenced by gender stereotyping about ability.[212]

Girls' and teachers' anxiety about mathematics and assessments can also have a negative impact on their performance. Girls reported stronger feelings of tension and anxiety related to performance in mathematics than boys in many studies,[119,140,218] and are more likely to suffer from test anxiety than boys.[218] The effect of mathematics anxiety has been associated with a decline in performance of 34 score points – equivalent to almost one year of school.[119] It can also drive students away from mathematics and, as a result, from STEM studies and career.[219] Teachers' own math anxiety has been found to affect students' achievement, with more math anxiety among teachers lowering girls' scores in one study (a similar pattern was not found for male students).[118]

Other studies have demonstrated that assessment performance can be improved if these psychological factors are addressed. For example, in a study among British secondary school children, girls showed higher levels of mathematics anxiety but performed equally well as boys.[220] Experiments in the US suggest that exposing adult women to female role models who are high achievers in mathematics or are perceived to be mathematics experts can improve women's performance in mathematics tests; however, this effect has not been tested in younger girls.[75]

Key messages

- Qualified teachers with specialisation in science and mathematics can positively influence girls' performance and engagement with STEM education and their interest in pursuing STEM careers. Female STEM teachers appear to have stronger benefits for girls, possibly by acting as role models and by helping to dispel stereotypes about sex-based STEM ability.
- Teachers' beliefs, attitudes, behaviours and interactions with students can enhance or undermine an equal learning environment for girls and boys in STEM subjects. Attention to gender dynamics in the classroom and school environment is therefore critical.
- Curricula and learning materials play an important role in promoting girls' interest and engagement in STEM subjects. Positive images and text about women and girls, topics that are of interest to both girls and boys, and opportunities for inquiry and practice are essential.
- Opportunities for real-life experiences with STEM, including hands-on practice, apprenticeships, career counselling and mentoring can expand girls' understanding of STEM studies and professions and maintain interest.
- Assessment processes and tools that are gender-biased or include gender stereotypes may negatively affect girls' performance in STEM. Girls' learning outcomes in STEM can also be compromised by psychological factors such as mathematics or test anxiety and stereotype threat about their ability in STEM.

2.4 Societal-level factors

Decisions about what fields of study or employment are considered possible or appropriate for men and women are deeply embedded in the socialization process. Societal and cultural norms, broader measures of gender equality, policies and legislation, and mass media are important influences.

Gender equality and wider societal and cultural norms

Girls' participation and achievement in STEM education have been found to be positively correlated to more gender-equal societies, where women and girls have access to education, decent work, and representation in political and economic decision-making processes. For example, studies have found that girls tend to have more positive attitudes towards, confidence about, and achievement in, mathematics in these settings, and the gender gap in achievement between boys and girls is smaller.[40,42] Analysis of PISA mathematics test scores found similar results for both mean level and high achievers, even when the analysis was controlled for economic development.[221] Positive correlation has also been found between girls' endorsement of gender equality and their motivation in science and math, perhaps due to girls' stronger resistance to gender stereotypes in these settings.[64] This does not mean, however, that higher learning achievement in STEM for girls cannot be observed in countries with lower gender equality index.

Conversely, gender inequalities in wider society as well as gender-based violence in and on the way to school,[217] can prevent girls from accessing education, including in STEM fields. A recent study in Pakistan found that patriarchal values affected girls' perceptions about their own ability and aspirations in math and science.[223] The threat of sexual harassment in public spaces also prevented girls from going to the market to buy materials for school STEM projects.

Policies and legislation

Policies and legislation can bring about sustainable change, prioritize and institutionalise girls' and women's participation in STEM education and careers. These can be specific policy measures focusing on STEM education, such as building the capacities of teachers, or aiming to motivate girls to select STEM subjects. Policies and legislation promoting gender equality and equal treatment, gender mainstreaming and specific measures for the advancement of women are also important as they can help change social norms and practices, which consequently affect girls' study and career choices. For example, Malaysia has enacted many STEM-related policies and legislation, reflecting the high priority attached to the issue.[224]

Mass and social media

Mass media play an important role in the socialisation process, influencing opinions, interests and behaviours. Gender stereotypes portrayed in the media are internalised by children and adults and affect the way they see themselves and others.[225-227]

Gender stereotypes in mass media can influence girls' perceptions of their abilities in STEM and their career aspirations for STEM fields.[102, 228-230] Media images of STEM professionals may be particularly salient for girls during adolescence as they actively consider future professional identities and options.[230] For example, some studies have found that when women are shown television advertisements that allege sex-based abilities in math, they report being less interested in majoring in or pursuing careers involving technical or quantitative skills.[231] Other studies have found that gendered stereotypes in the media of certain academic fields, such computer science, can negatively influence women's interest in pursuing these fields.[106]

Gender stereotypes on social media platforms can also have a harmful effect. For instance, a recent study of Latin American social media users found that gender stereotypes and negative messages about STEM were prevalent and often transmitted by girls and young women themselves.[232] Female social media users were more likely than male users to post or support posts promoting negative views about STEM subjects, especially mathematics. In this study, 75% of all self-mocking mathematics messages were posted by girls. One-third of students' social media shares about women and girls in STEM were sexist.

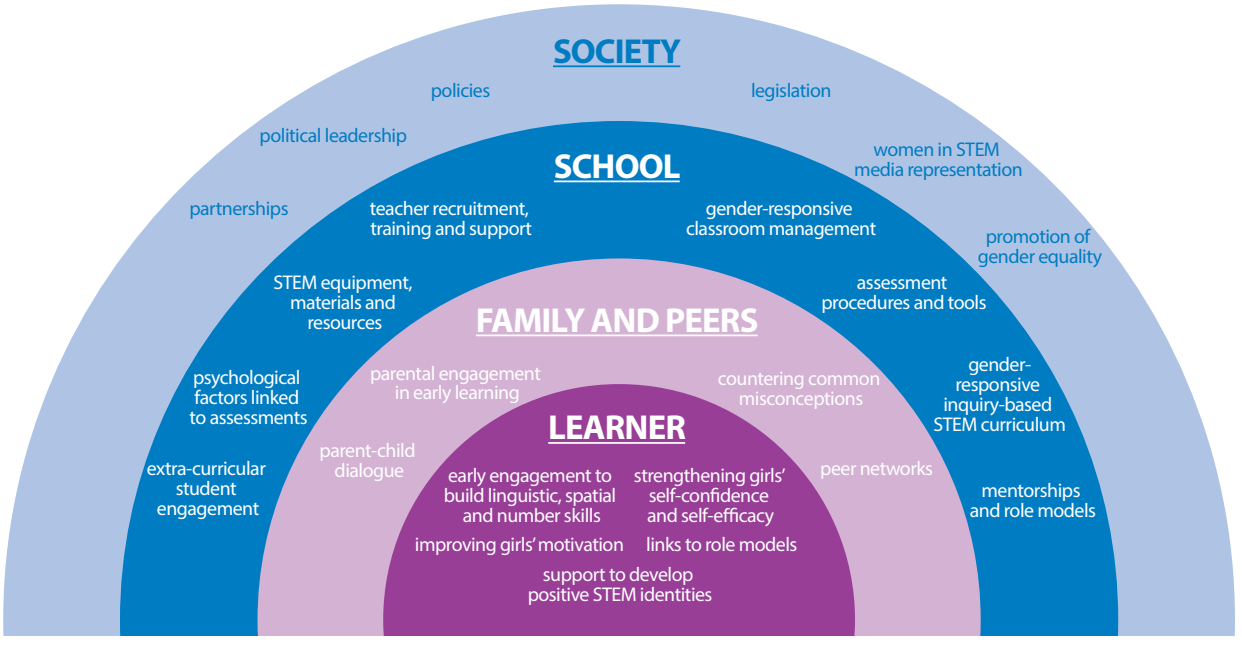
Decisions about what fields of study or employment are considered possible or appropriate for men and women are deeply embedded in the socialization process.

Key messages

- Cultural and social norms influence girls' perceptions about their abilities, role in society and career and life aspirations.
- The degree of gender equality in wider society influences girls' participation and performance in STEM. In countries with greater gender equality, girls tend to have more positive attitudes and confidence about mathematics and the gender gap in achievement in the subject is smaller.
- Targeted measures to promote gender equality, such as gender mainstreaming legislation or policies such as quotas, financial incentives or other, can increase girls' and women's participation in STEM education and careers.
- Gender stereotypes portrayed in the media are internalised by children and adults and affect the way they see themselves and others. Media can perpetuate or challenge gender stereotypes about STEM abilities and careers.

3. Interventions that help increase girls' and women's interest in, and engagement with, STEM education

3. Interventions that help increase girls' and women's interest in, and engagement with, STEM education



The ecological framework presented in the previous section demonstrates that there is no single factor that alone can influence girls' and women's participation, achievement and progression in STEM education. Positive outcomes are the result of interactions among factors at the individual, family, school and societal levels, and demand engagement from stakeholders at each of these levels.

Recognising that broader efforts are needed to combat gender discrimination and advance gender equality in society, this section focuses on what the education sector can do to make an impact. It provides examples of interventions from around the world, presented by the four levels of the ecological model:

- **Individual level:** interventions to build children's spatial skills, self-efficacy, interest and motivation among girls to pursue STEM studies and careers;
- **Family and peer level:** interventions to engage parents and families to address misconceptions about sex-based, innate abilities, to expand understanding of STEM educational opportunities and careers, and to connect families to educational advisers to build STEM pathways, as well as peer support;
- **School level:** interventions to address teachers' perceptions and capacity, to develop and deliver gender-responsive curricula, to implement gender-neutral assessments;
- **Societal level:** interventions to social and cultural norms related to gender equality, gender stereotypes in the media, and policies and legislation.

3.1 Individual-level interventions

Building linguistic, spatial and number skills from an early age

Linguistic, spatial and number skills strongly predict later achievement in STEM.[233] As with other cognitive abilities, these skills are flexible and highly influenced by instruction and practice and can be significantly improved through early experiences.[76,79] For instance, a study in India found that spatial skills interact with culture and that providing equal education and changing the way girls are treated at home has a positive influence on their spatial skills.[78] Parents and ECCE development centres can help with early interventions by providing opportunities for practice, for example, through playful learning, such as block play.[234] Parental engagement and activities to extend school learning into the home and other settings can also be promoted.

Developing positive STEM identities

Girls need support to develop positive math and science identities, belief in their abilities and a sense of belonging in STEM studies and careers.[66,235] This can be done by increasing girls' exposure to STEM experiences[155, 236] such as the one featured in Box 2. Even brief interactions have been found to shape student beliefs about their potential for success in STEM. For example, in Israel, a programme called Mind the Gap! organized school visits to Google, annual tech conferences and provided access to female engineers to discuss careers in computer science and technology.[237] The programme was found to impact on girls' choice of computer science as a high school major.[238]

Establishing links to role models

The presence of female role models in STEM subjects can mitigate negative stereotypes about sex-based ability and offer girls an authentic understanding of STEM careers.[91,240] Role models can also enhance girls' and women's self-perceptions and attitudes toward STEM, as well as their motivation to pursue STEM careers.[64] This contact can begin as early as primary education, and continue through secondary and tertiary levels and into career entry. In Nigeria, role models were found to assist in retaining girls in STEM at all levels of education.[241] Role models can be older students, professionals in STEM academic, business and research environments.

Box 2: Discover! United Kingdom

Discover! is an informal learning intervention designed to stimulate the imagination and interest of girls in Year 8 (age 12) and Year 9 (age 13) in secondary schools. It offers participants an opportunity to 'try-on' a variety of occupational roles in single-sex interactive workshops led by same-sex tutors. Girls are encouraged to play and act as scientists. With Discover! girls have the opportunity to explore new career opportunities. The Discover! Saturday Club received national recognition twice at the WISE Partnership Awards. An evaluation of the programme found that informal and experiential learning spaces can strengthen learners' interest in STEM and their ability to visualise their future as STEM professionals.

For more information: http://www.careerswales.com/prof/server.php?show=nav.7497

The expansion of 'STEM clinics' and camps, such as the ones featured in Box 3, can encourage girls' engagement through access to role models. For STEM role models to be effective, girls should be able to identify with them.[173] If girls believe that the success of role models is beyond their reach, they may feel threatened rather than motivated. This may distance girls from the role models' field. A US study found that the presence of same-sex role models has a far bigger impact on women than on men.[64]

Building self-confidence and self-efficacy

Girls with stronger self-confidence and belief in their capacities in STEM perform better at school and have better chances to pursue STEM careers.[125] For example, a study showed that when girls were told that their cognitive ability can increase with learning and practice, they performed better in mathematics tests and were more likely to be interested in future mathematics studies.[91] Opportunities for practice in areas like engineering, in particular, can also increase girls' self-efficacy and interest.[129] Box 4 presents examples of programmes aiming to build girls' ICT skills to become innovators in computer technology.

Box 3: Science, Technology and Mathematics Education (STME) Clinics, Ghana

The first Science, Technology and Mathematics Education (STME) Clinic was established by the Ghana Education Service in 1987 to help improve girls' enrolment and achievement in related subjects in secondary and higher education institutions. STME Clinics now exist in different locations, bringing together girls from secondary educational institutions for short-term intensive intervention programmes with female scientists. These scientists act as role models, providing an opportunity to change any negative perceptions girls might have about women scientists. This initiatives is helping to bridge the gender gap in the field of science and technology and maximize the potential of Ghanaian women in these fields.
For more information:
http://on.unesco.org/2sGbkZd

Box 4: Developing girls' coding skills

Girls Can Code | Afghanistan
This intensive programme, approved by the Ministry of Education and integrated in the public school curriculum, aims to empower and encourage girls to follow careers in computer science. In addition to coding, the programme also offers networking opportunities, connecting girls with mentors and internship opportunities, as well as further educational opportunities in computer science, including in higher education programmes. **For more information:** http://womanity.org/programs/afghanistan/

@IndianGirlsCode |India
This is a social initiative that provides free coding and robotics programmes for young underprivileged girls in India. It inspires girls to be innovators in the field of computer science and technology and helps them learn to code and innovate by creating real-world applications for real-world problems.
For more information: http://www.robotixedu.com/indiangirlscode.aspx?AspxAutoDetectCookieSupport=1

Girls Who Code | US
This is a non-profit organization that aims to educate, empower and equip adolescent girls with skills and resources to pursue opportunities in technology and engineering. Training is delivered through free after-school clubs or intensive summer programmes. More than 10,000 girls have participated in the programme, of which many are now studying for computer science degrees at top US universities.
For more information: https://girlswhocode.com/

Increasing girls' motivation

Improving girls' motivation is critical for increasing their participation in STEM. A systematic review of studies targeting students' motivation showed that certain interventions had positive effects on both motivation and academic outcomes.[137] It was also suggested that women may benefit more from such interventions as they are more affected by gender stereotypes about their ability in this field. On the other hand, women who have firmly internalized such stereotypes might be less receptive to motivation interventions. An example of an initiative to improve girls' motivation is featured in Box 5.

Box 5: Motivating and empowering girls through STEM Camps, Kenya

UNESCO together with the Government of Kenya, the National Commission for Science, Technology and Innovation (NACOSTI) and the University of Nairobi organize annual Scientific Camps of Excellence for Mentoring Girls in STEM. The aim of the camps is to demystify science, to inspire girls to embrace the sciences, and to nurture them as future STEM professionals and leaders.

During these one-week camps, girls share experiences with STEM university students, carry out science experiments and industry visits, build life skills, and discuss career choices. The camps are also linked to gender-responsive teacher training, and build partnerships with ministries and institutions, the private sector, and science-focused industries. To monitor performance and assess impact, an online tracking system has been developed which follows girls up to university level.

The Ministry of Education sees the programme as an important tool for inspiring girls to embrace science subjects, and has incorporated the camps into its workplan. It has also identified model STEM schools in each county. The United Nations Country Team in Kenya also identified the programme as a "best practice" and produced a documentary about it. Success is attributed to effective partnerships between key stakeholders in the education and STEM fields, a focus on learners and the STEM learning and working environments.
For more information: http://on.unesco.org/2uTmfPF
Video: Unlocking the Potential of Girls - STEM (UNESCO): https://goo.gl/7WEMA1

3.2 Family- and peer-level interventions

Laying the foundations for early learning and interest

Engaging parents, as the primary caretakers of children, and the wider family is critical to opening doors to STEM studies and careers for girls. Family engagement in the mathematics education of young children (aged 3-8) has been found to have a positive effect on learning, and can be facilitated through parental involvement in school activities, school outreach, and other channels.[243] Research has found that when parents play an active role in their children's learning, children achieve greater academic success, regardless of socioeconomic status, ethnicity, or the parents' own level of education.[244,245]

Countering common misconceptions

From early childhood into adulthood, many girls and women receive overt or subtle messages, particularly from parents, that STEM studies and careers are not for them. Schools and universities can provide parents with information about STEM educational opportunities and careers, and connect them to educational advisors who can counter common misconceptions about careers in STEM. In Zimbabwe, awareness-raising campaigns have been organized to address parents' perceptions, along with broader quality improvements to STEM education.[246]

Promoting parent-child dialogue

Parents can support their children's preparation and motivation[146] and can play an active role in motivating girls to engage in STEM, if given the proper support.[247] An experiment in the US provided parents with materials, through brochures and a website, which focused on the usefulness of STEM courses.[248] The intervention, which was designed to increase communication between parents and their adolescent children about the value of mathematics and science, improved mothers' perceptions of the value of STEM studies and stimulated parent-child conversations. This relatively simple intervention resulted in students taking, on average, nearly one semester more of science and mathematics in the last two years of high school, compared with the group that did not receive the intervention. The intervention was found to be most effective in increasing STEM course-taking for high-achieving daughters and low-achieving sons; however, it did not help low-achieving daughters.

3.3 School-level interventions

Improving system-level challenges

Education-system level improvements in recent decades have positively impacted on the quality of STEM education delivered in school classrooms, benefiting both boys and girls (Box 6). The education sector can take other steps at the policy-level and within schools to build girls' interest, confidence, engagement and career aspirations in STEM.

Recruiting male and female teachers

Sector planners need to address shortages in qualified teachers for science and mathematics, and their deployment to rural and remote areas. As there is evidence in some settings that female teachers can have a differential impact on female students' pursuit of STEM studies, and careers, some countries (Austria, Belgium, Lithuania, Switzerland, Israel, the Netherlands, Sweden, and the United Kingdom) have prioritised or identified as important the recruitment of more female STEM teachers.[249]

Box 6: Education-system level improvements

IEA found that the overall improvement in educational achievement in science and mathematics observed over a twenty-year period (1995-2015) in TIMSS was accompanied by a number of education system-level improvements. These include:

- improved school environments (e.g. safer schools)
- better educated teachers and more efforts to support teachers' professional development
- improved teacher attitudes towards their capacity to deliver mathematics and science
- higher teacher satisfaction with their careers
- more positive student attitudes about mathematics and science
- more engaging instructions by teachers (as reported by students)
- smaller mathematics and science classes
- better curriculum coverage

For more information: Mullis V.S, I., O. Martin, M., and Loveless, T. 2016. 20 Years of TIMSS: International Trends in Mathematics and Science Achievement, Curriculum, and Instruction. Boston, International Association for the Evaluation of Educational Achievement (IEA)[16]

Building teachers' capacities

Teachers need to understand the factors impacting on girls' interests to participate and continue in STEM education, and to have access to professional development that enhances gender-responsive STEM pedagogy. A range of initiatives are being implemented to strengthen STEM teachers' capacity to be more gender-responsive in their teaching practice and classroom management.[16,91,119,250] Examples of such initiatives are provided in Box 7.

Box 7: Building teacher capacity

The TeachHer Initiative

TeachHer is an innovative global public-private partnership, launched in June 2016 by UNESCO, the Costa Rican First Lady, Mercedes Peñas Domingo, and U.S. former Second Lady Dr Jill Biden. It aims to help close the gender gap in science, technology, engineering, arts and design, and mathematics (STEAM) curricula and careers for young women. Using UNESCO's network of training institutes, TeachHer is creating a Master Corps of champion educators capable of delivering state-of-the-art curricula in these subjects and building local support networks. During the 2016 pilot phase, 160 educators from six African and eight Central American and Caribbean countries participated in week-long regional training workshops organised by the US Mission to UNESCO with support from UNESCO Field Offices, Cluster Offices and the UNESCO International Institute for Capacity-Building in Africa (IICBA). During the workshops, government officials and national partners were exposed to practical methods for creating gender-responsive lesson plans and engaging and inspiring adolescent girls to pursue these subjects and related careers. Countries were encouraged to create national and local TeachHer action plans. TeachHer also emphasises the importance of after-school clubs and related activities for girls, and the creation of local networks to support dedicated champions – educators, administrators, and their students.

For more information: https://unesco.usmission.gov/teachher/

STEAM in a Box toolkit: https://1drv.ms/f/s!ArvnsTeqGHgehcx8_Sf33JhjJeNaEQ

The Mathematics and Science Education Improvement Centre, Ethiopia

The Mathematics and Science Education Improvement Centre in Ethiopia has been catalytic in improving girls' performance in science and mathematics. Recent studies confirm that there are no significant differences between females and males in mathematics achievement anymore. This has been achieved thanks to in-service teacher training which significantly improved teachers' capacities and teaching skills. The Centre was established by the Ministry of Education, as part of its Education Sector Development Strategy. It aims to develop science-based education as a way of promoting growth and the transformation of the country. The Government is also raising awareness among families about the importance of girls' education, especially in mathematics and science. The Centre is now focusing on other STEM topics and has developed a strategic science, technology and mathematics education policy.

For more information: http://www.moe.gov.et/en/directorate-6

Strengthening teaching practices

Effective teaching practices can help to promote girls' motivation and engagement in STEM.[40,251] Many female scientists report that experience with science in the early grades of schooling, such as through science projects and investigations, was important in developing a lasting interest and encouraging them to choose careers in science.[125] A meta-analysis identified five strategies that improve students' achievement, attitudes and interest in STEM subjects and careers: context-based; inquiry-based; ICT-enriched; collaborative learning and use of extra-curricular activities.[250] These strategies can be combined with more targeted ones which have been found to work best for girls, including: [91,125,135,194,252,253]

- Building a 'science identity' among girls by conveying messages that science is for everyone, using gender-neutral language, projecting examples of women in science and avoiding classroom hierarchies favouring boys.
- Involving girls in hands-on activities that are writing-intensive and inquiry-based, with adequate time to complete, revise and discuss.
- Providing diverse school experiences that match the different interests of students within science. This can include hands-on laboratory and design-based learning to increase girls' science and technological confidence and active classroom interactions that value students' points of view.
- Allowing more time and experience with computers for girls to help increase their technological confidence. One study showed that more girls than boys perceived computers as useful tools for conducting science investigation, graphing and organizing data.
- Providing girls with out-of-school academic activities and homework as well as exposure to role models, for example, through direct meetings, videos or success stories.

Such teaching strategies are more effective in an environment where students are encouraged to take risks[193] and are allowed to make mistakes, which forces the brain to grow by thinking about what went wrong.[254] Box 8 presents examples of initiatives.

Box 8: Teaching strategies to engage girls

Ark of Inquiry

Funded by the European Commission and led by UNESCO in collaboration with partners from 12 countries, this joint project aims to engage students from age 7 to 18 in science through "new science classrooms". These classrooms provide more challenging, authentic and higher-order learning experiences and more opportunities for pupils to participate in scientific practices and tasks. This is done through inquiry-based learning activities including reading scientific publications; formulating problems, inquiry questions or hypotheses; planning and conducting observations or experiments; analyzing collected data; and making conclusions or generalizations. The project is based on different pedagogical scenarios aiming to empower girls in the science classroom. A checklist for teachers has also been developed on how to engage and empower girls in science.
For more information: http://www.arkofinquiry.eu/

Encourage girls in mathematics and science subjects – A Practice Guide

The Practice Guide, produced by the US Department of Education's Institute of Education Studies provides five evidence-based recommendations for teachers to encourage girls to pursue mathematics and science studies and careers:

1. Teach girls that academic abilities are expandable and improvable to enhance their confidence in their abilities.
2. Provide girls with prescriptive feedback about their performance, focusing on the process of learning, the strategies used during learning and the effort made.
3. Expose girls to female role models to challenge negative stereotypes and promote positive beliefs about their abilities.
4. Create a classroom environment that sparks curiosity and fosters long-term interest through project-based learning, innovative tasks and technology.
5. Provide opportunities for girls to engage in spatial skills training.

For more information: Halpern, D., Aronson, J., Reimer, N., Simpkins, S., Star, J. and Wentzel, K. 2007. Encouraging Girls in Math and Science (NCER 2007-2003). Washington DC, National Center for Education Research, Institute of Education Sciences, US Department of Education[75]

Promoting a safe and inclusive learning environment

The learning environment can enhance or undermine STEM education for girls. Irrespective of their sex, students have higher levels of self-efficacy and self-motivation in supportive learning environments.[255,256] For example, a study found that schools which are supportive of girls in STEM have been shown to reduce the gender gap in STEM by 25% or more and with a sustainable impact.[200] Two school characteristics in particular have been found to play an important role: a strong science and mathematics curriculum and opportunities for concrete experiences and gender-integrated extra-curricular activities. These have been found to mitigate the effects of stereotyping about sex-based STEM ability. Also, a European Commission report found that students' informal interaction within the school environment was the most influential part of their socialisation as males or females, and argues that this aspect of the school culture needs to be challenged if things are to change.[195]

Cultivating learning beyond school walls

The learning environment also extends beyond the classroom. Workplaces, museums, exhibitions, urban settings and the natural world, all offer opportunities for learning[257] and for cultivating girls' interest in STEM. Informal science education, often provided by museums or science centres, can also provide opportunities to improve science skills, counter negative stereotypes, increase understanding and value of science, use science tools and equipment, and increase girls' feelings of success and achievement. For example, in the UK there has been considerable investment in science engagement and education activities in science centres, museums, science festivals, and other environments.[6] Camps and field trips can encourage girls' interest in STEM by providing them with real-world learning opportunities.[258] A recent study found that student attitudes towards, and interest in, science improved after a five-day camp held on a university campus where students engaged with STEM professionals in hands-on problem-based learning activities.[259] As found in one study, outreach summer programmes were successful in inspiring girls to pursue science and pre-engineering in lower and upper secondary education and to consider STEM careers.[260]

Strengthening STEM curricula

Research suggests that STEM curricula are more appealing to girls if they have a strong conceptual framework, are contextualised and relevant to real-world situations.[125,253,261,262] Curricula are also more likely to interest girls if they provide varied experience, which integrates social and scientific issues, provides opportunities for genuine inquiry, involves real-world experience, as well as opportunities for experimentation, practice, reflection and conceptualisation.[263] Box 9 below presents an initiative aiming to strengthen STEM curricula for girls.

Box 9: Strengthening STEM curricula for girls, Cambodia, Kenya, Nigeria and Viet Nam

UNESCO's IBE is partnering with the Malaysian Government on South-South cooperation to promote gender-responsive STEM education in Cambodia, Kenya, Nigeria and Viet Nam. Malaysia, where women attain 57% of science degrees and 50% of computer science degrees, brings expertise and successful experience in promoting the participation of girls and women in STEM. The initiative aims to mainstream gender in educational policies, plans, STEM curricula and teaching, through the development of country-contextualized gender-sensitive guidelines on curricula, pedagogy, assessment and teacher training. A Resource Pack for Gender Responsive STEM Education has been developed which provides practical guidance and can be used as a training tool.
For more information: http://unesdoc.unesco.org/images/0025/002505/250567e.pdf

Removing gender bias from learning materials

Curriculum designers can create content and resources suited to the learning styles and preferences of girls as well as boys, and remove gender bias from textbooks and other learning materials. Mexico, for example, has undertaken an analysis from a gender equality perspective of its primary education textbooks, developed a manual to incorporate gender equality in curriculum and teaching materials, and revised its materials to demonstrate similar capacities and equal opportunities in text and illustrations.[264] As curriculum revision can be a lengthy exercise, teachers also need the knowledge and ability to critically analyse and eliminate possible gender stereotypes present in existing teaching materials, and to avoid such stereotyping when interacting with students.

Facilitating access to gender-responsive career counselling

Gender-responsive counselling and guidance is critical to supporting non-stereotypical education and career pathways and retaining girls in STEM fields.[265-267] For example, WomEng, a non-profit organization in South Africa, has developed booklets with information on educational institutions offering engineering programmes, scholarship opportunities, and frequently asked questions about careers in engineering for secondary school girls.[268] Such materials, coupled with access to advisors who are familiar with STEM studies and careers, can engender interest and encourage girls to choose STEM careers. These should be attractive to girls and address common perceptions among girls about a mismatch between their abilities and interests and STEM career paths.[6,266,267] Examples of career counselling are featured in Box 10.

Box 10: Career and guidance counselling

How career counsellors can increase girls' STEM motivation and engagement

An Australian study made the following recommendations for career counsellors to help increase girls' motivation and engagement in STEM:

- Start STEM career development early, at primary school, before girls lose interest and disengage
- Collaborate with those that have a strong influence on girls' decisions to pursue or not to pursue STEM, such as parents, siblings, peers and teachers
- Provide diverse images of STEM professionals, for example, on career posters, in publications and online resources, to challenge the stereotype of the male scientist
- Use role models and mentors to develop in-school programmes so that girls are in contact with practising female STEM professionals
- Promote targeted work experience and out-of-school programmes, such as internships
- Engage with parents and families, providing them with information about STEM professions
- Target specific groups, including high-performing and disadvantaged girls
- Advocate for change in male-dominated workplaces, so that they can attract more women

For more information: Broadley, K. 2015. Entrenched gendered pathways in science, technology, engineering and mathematics: Engaging girls through collaborative career development. Australian Journal of Career Development, Vol. 24, No. 1, pp. 27-38. DOI: 10.1177/1038416214559548266

UNESCO training module on science career guidance and counselling

UNESCO has produced a training module on science career guidance and counselling for teacher trainers, education and career advisors, head teachers and teachers. The module covers training and supporting teachers, career guidance and career guidance activities, science and mathematics teacher training and teaching. It aims to assist countries to promote a positive image of women in science careers, provide girls with clear information about science careers and counter gender stereotypes, and ensure that teachers and career advisors have the tools required to meet the needs of female learners.

For more information: UNESCO. 2007. Girls into Science: A training Module. Paris, UNESCO.

Linking girls to mentorship opportunities

Mentorship programmes have been found to improve girls' and women's participation and confidence in STEM studies and careers. A US study found that, at lower secondary level, girls who were mentored by female role models during summer activities showed greater interest in science and mathematics when introduced to potential STEM career opportunities.[132] Another US study, which looked at an after-school mentoring programme, found a significant link between the quality of the mentoring relationship and girls' confidence in mathematics.[270] A study in Denmark, which looked at the reasons for choosing a career in engineering, found that men were more influenced by intrinsic and financial reasons but women were far more influenced by mentoring.[41]

Mentoring needs to take a broad perspective. Rather than focusing only on achievement and career choice, mentors can also help girls acquire knowledge to improve their learning and career options, including information about materials and strategies, goal-setting and opportunities for learning, networking and meeting others interested in STEM.[271] Mentors can also help girls learn how to improve their self-confidence, self-esteem and motivation, how to deal with bias, and how to overcome anxiety about assessments. They can also provide guidance about financial resources, such as scholarships, special programmes, networks and job opportunities and link girls with other girls and women who share a similar socio-economic or ethnic background and who have faced similar obstacles in their STEM careers.[113]

Expanding access to scholarships and fellowships

Scholarships and fellowships reserved for female students and researchers have been established in some countries in areas, such as engineering, where women are significantly under-represented. These can be provided by higher education institutions, the private sector, government, or other sources. In France a range of opportunities are available to women to enhance their engagement in STEM education and employment (Box 11).

Box 11: L'Oréal Foundation - For Girls and For Women in Science Programmes

L'Oréal Foundation has two programmes supporting girls' and women's engagement in science. The For Women in Science Programme is a partnership with UNESCO, which honours and rewards women scientists and showcases their work. The For Girls in Science programme aims to encourage girls to participate in science education and careers. It is a partnership between the L'Oréal Foundation, the French Ministry of National Education and the Ministry of Higher Education and Research. 100 'Science Ambassadors', of whom 40 are L'Oréal-UNESCO Prize winners, intervene in classes, serving as role models to deconstruct prejudices about women in science and to share their passion for their work. To-date, some 30,000 students have been reached. In 2015, 75% of the 2,000 participating students reported being 'more interested in scientific careers' after the intervention, compared to 46% at the outset. This private sector-government partnership is creating intergenerational links and building France's female scientific cadre.

For more information: http://www.forwomeninscience.com
Facebook: http://www.facebook.com/forwomeninscience/
Twitter: http://twitter.com/4womeninscience

3.4 Societal level interventions

Policies and legislation

Legislation, quotas, financial incentives and other policies can play a significant role in increasing girls' and women's participation in STEM education and careers. For example, in France, the Ministry of National Education, Higher Education and Research has enacted legislation to encourage the diversification of girls' professional choices.[6] This measure, combined with private sector engagement from L'Oréal and other partners (Box 11), is steering more women into STEM careers. In Germany, the Government developed a High-Tech Strategy and a National Pact for Women in STEM Careers, aiming to address gender disparities in STEM education and employment.[272] Other policy levers, including targets, quotas, and financial incentives can also be made available throughout secondary or tertiary education or to enhance entry into the STEM workforce. For example, in 2016, the Australian Prime Minster announced that 8 million Australian dollars would be invested in projects to inspire girls and women to study STEM.[273]

Promoting positive images of women in STEM through the media

Media engagement and efforts are needed to promote more gender-diverse representations of STEM occupations, and to challenge stereotypes about sex-based abilities.[227] Children should also have access to media literacy education programmes that enable them to critically assess media messages, to moderate harmful influences, and to engage with digital technologies.[274] Social media can also be used to dismantle stereotypes and initiate conversations about gender equality in STEM.

Building partnerships

Partnerships across sectors and advocacy can direct attention to gaps in engaging girls in STEM, and to labour market needs for STEM. This can include initiatives that involve partnerships between educational institutions (e.g., schools, teacher training institutions, universities, and technical and vocational education and training centres), research institutions, the private sector, (companies and professional associations), and other sectors. In the UK, the WISE campaign[275] has been working for more than 30 years to inspire girls and women to study and build careers in STEM. WISE works with various partners such as businesses, schools, young people and their parents to offer a range of activities such as a blog of inspiring women, a workshop and other learning materials which can be taken into schools and colleges, and discovery workshops for girls, parents and teachers.

4. Looking forward

4. Looking forward

iStock.com/ranplett

Despite unprecedented progress in expanding access to education, gender equality in education remains elusive. More girls are in school today than ever before but gender-based discrimination, social and cultural norms and other factors prevent them from equal opportunities to complete and benefit from an education of their choice.

Low female participation in STEM studies and consequently STEM careers has been a concern voiced by countries around the globe. STEM prevail over every aspect of our lives and are catalytic for the achievement of the 2030 Agenda for Sustainable Development, underpinning solutions to existing and emerging challenges. It is crucial for women and girls to have equal opportunities to contribute to, and benefit from, STEM.

Multiple and overlapping factors influence girls' and women's interest in, and engagement with, STEM, all of which interact in complex ways. Girls' disadvantage is not based on cognitive ability, but in the socialisation and learning processes within which girls are raised and which shape their identity, beliefs, behaviours and choices. 'Cracking the code' to decipher these factors is critical to creating more learning pathways for girls and women in STEM.

Getting more girls and women into STEM education and careers requires holistic and integrated responses that reach across sectors and that engage girls and women in identifying solutions to persistent challenges. This requires political will, strengthened capacity and investments to spark girls' interest and cultivate their aspirations to pursue further STEM studies, and ultimately STEM careers. Internationally comparable data are also needed on a larger scale to ensure evidence-informed planning and policymaking, as well as further documentation of the effectiveness and impact of interventions.

Recognizing that broader efforts are needed to combat gender discrimination and advance gender equality in society, this report focuses on the crucial role of the education sector. System-level changes are needed to improve the quality of STEM education to take account of the specific learning needs of girls. Engaging girls in STEM from an early age and ensuring that their overall education experience – the teaching and learning process, contents and environment – are gender-responsive and free from gender discrimination and stereotypes, are also important.

Looking forward, the education sector can take steps at all levels, defined in the ecological framework presented in this report, to create sustainable change. This includes the following priority actions:

Ecological framework levels	Individual level	Family level		School level		Societal level	
Stakeholders	Students	Parents	Peers	Policy-makers	Teachers	Private sector	Media
Ensure early care, play, and learning opportunities							
Cultivate girls' interest, confidence, and engagement in STEM from an early age	●	●			●	●	●
Avoid discrimination in care, play and recreational experiences	●	●	●		●		●
Build children's spatial skills and self-efficacy in science and math		●	●		●		
Provide good quality, inclusive and gender-responsive STEM education							
Mainstream gender equality in STEM education laws and policies				●			
Hire and train male and female STEM-specialized teachers in gender-responsive pedagogy and classroom management				●			
Remove stereotypes and biases in STEM textbooks and learning materials and expand opportunities for inquiry-based learning				●	●		
Create safe and inclusive STEM learning environments	●		●	●	●	●	
Provide authentic opportunities for STEM learning and practice inside and outside the classroom		●			●		
Expand access to mentoring, apprenticeship and career counselling to improve orientation on STEM studies and careers		●	●	●	●	●	●
Facilitate contact with female role models		●	●	●	●	●	●
Provide incentives (scholarships, fellowships) in areas where girls/women are significantly under-represented					●		
Address social and cultural norms and practices impeding on STEM participation, learning achievement and progression							
Mainstream gender equality in public policies and programmes across sectors, including education, social, labour				●			
Reach out to and engage parents to counter common misconceptions about STEM education and encourage dialogue		●		●	●	●	●
Challenge discriminatory social and cultural norms and practices	●	●	●	●	●	●	●
Raise awareness about the importance of STEM and women's achievements		●			●	●	●
Expand access to media literacy to promote critical thinking, help recognize gender stereotypes in the media, and promote positive representation of women in STEM	●	●	●	●	●	●	●
Promote and facilitate multi-sectoral collaboration and partnerships		●		●		●	●

Acronyms

CABA	Ciudad Autonoma de Buenos Aires (Buenos Aires, Argentina)
ECCE	Early childhood care and education
ECOSOC	United Nations Economic and Social Council
GEM	Global Education Monitoring Report
IBE	UNESCO International Bureau of Education
ICILS	International Computer and Information Literacy Study
ICT	Information and communication technology
IEA	International Association for the Evaluation of Educational Achievement
IICBA	UNESCO International Institute of Capacity-Building in Africa
MOE	Ministry of Education
MRI	Magnetic resonance imaging
NACOSTI	National Commission for Science, Technology and Innovation (Kenya)
NGO	Non-governmental organization
OECD	Organisation for Economic Co-operation and Development
PASEC	Programme d'Analyse des Systèmes Educatifs des Pays de la Conférences des Ministres de l'Education des Pays Francophones
PISA	Programme for International Student Assessment
SACMEQ	Southern and Eastern African Consortium for Monitoring Educational Quality
SAGA	STEM and Gender Advancement
SAR	Special administrative region
SDG	Sustainable Development Goal
STEAM	Science, Technology, Engineering, Arts/Design, and Mathematics
STEM	Science, Technology, Engineering and Mathematics
TERCE	Third Regional Comparative and Explanatory Study (Latin America)
TIMSS	Trends in International Mathematics and Science Study
TfYR	The former Yugloslav Republic (Macedonia)
TVET	Technical and Vocational Education and Training
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UIS	UNESCO Institute for Statistics
UK	United Kingdom
US	United States

Annex 1: Participation in standardized cross-national surveys

PARTICIPATION											
Studies	**TIMSS 2015**		**TIMSS ADVANCED 2015**	**TIMSS 2011**		**PISA 2015**	**PISA 2012**	**ICILS 2013**	**SACMEQ 2007**	**TERCE 2013**	**PASEC 2014**
Grade/Student age	4th grade	8th grade	12th grade	4th grade	8th grade	15-year-olds	15-year-olds	8th grade	6th grade	3rd & 6th grades	2nd & 6th grades
Arab States											
Algeria						+					
Bahrain	+	+		+	+						
Egypt		+									
Jordan	+	+			+	+	+				
Kuwait	+	+		+							
Lebanon		+	+		+	+					
Morocco	+	+		+	+						
Oman	+	+		+	+						
Palestine					+						
Qatar	+	+		+	+	+	+				
Saudi Arabia	+	+		+	+						
Syrian Arab Republic					+						
Tunisia				+	+	+	+				
United Arab Emirates	+	+		+	+	+	+				
Yemen				+							
Central and Eastern Europe											
Albania						+	+				
Bulgaria	+					+	+				
Croatia	+			+		+	+	+			
Czech Republic	+			+		+	+	+			
Estonia						+	+				
Hungary	+	+		+	+	+	+				
Latvia						+	+				
Lithuania	+	+		+	+	+	+	+			
Montenegro						+	+				
Poland	+			+		+	+	+			
Romania				+	+	+	+				
Republic of Moldova						+					
Russian Federation	+	+	+	+	+	+	+	+			
Serbia	+			+			+				
Slovakia	+			+		+	+	+			
Slovenia	+	+	+	+	+	+	+	+			
TfYR Macedonia					+	+					
Turkey	+	+		+	+	+	+	+			
Ukraine					+						
Central Asia											
Armenia				+	+						
Azerbaijan				+							
Georgia	+	+		+	+	+					
Kazakhstan	+	+		+	+	+	+				
East Asia and Pacific											
Australia	+	+		+	+	+	+	+			
China						+	+				
Taiwan Province of China	+	+		+	+	+	+				
Hong Kong, China	+	+		+	+	+	+	+***			
Indonesia	+				+	+	+				
Japan	+	+		+	+	+	+				
Macao, China						+	+				
Malaysia		+			+	+	+				
New Zealand	+	+		+	+	+	+				
Republic of Korea	+	+		+	+	+	+	+			
Singapore	+	+		+	+	+	+				
Thailand		+		+	+	+	+	+			
Viet Nam						+	+				
Latin America and the Caribbean											
Brazil						+	+			+	
Cuidad Autonoma de Buenos Aires (Argentina)						+	+	+***		+	
Chile	+	+		+	+	+	+	+		+	
Colombia						+	+			+	
Costa Rica						+	+			+	
Dominican Republic						+				+	
Ecuador										+	
Guatemala										+	
Honduras				+	+					+	
Mexico						+	+			+	
Nicaragua										+	
Panama										+	
Paraguay										+	
Peru						+	+			+	
Trinidad and Tobago						+					
Uruguay						+	+			+	

PARTICIPATION											
Studies	**TIMSS 2015**		**TIMSS ADVANCED 2015**	**TIMSS 2011**		**PISA 2015**	**PISA 2012**	**ICILS 2013**	**SACMEQ 2007**	**TERCE 2013**	**PASEC 2014**
Grade/Student age	4th grade	8th grade	12th grade	4th grade	8th grade	15-year-olds	15-year-olds	8th grade	6th grade	3rd & 6th grades	2nd & 6th grades
North America and Western Europe											
Austria				+		+	+				
Belgium						+	+				
Belgium	+			+							
Canada	+	+				+	+				
Cyprus	+					+	+				
Denmark	+			+		+	+	+***			
Finland	+			+	+	+	+				
France	+		+			+	+				
Germany	+			+		+	+	+			
Greece						+	+				
Iceland						+	+				
Ireland	+	+		+		+	+				
Israel		+			+	+	+				
Italy	+	+	+	+	+	+	+				
Kosovo*						+					
Liechtenstein							+				
Luxembourg						+	+				
Malta		+		+		+					
Netherlands	+			+		+	+	+***			
Northern Ireland (United Kingdom)	+			+							
Norway	+	+	+	+	+	+	+	+			
Portugal	+		+	+		+	+				
Spain	+			+		+	+				
Sweden	+	+	+	+	+	+	+				
Switzerland						+	+	+***			
United Kingdom	+	+		+	+	+	+				
United States	+	+	+	+	+	+	+				
South and West Asia											
Iran, Islamic Republic of	+	+		+	+						
Sub-Saharan Africa											
Angola									+*		
Benin											+
Botswana		+		+	+				+		
Burkina Faso											+
Burundi											+
Cameroon											+
Chad											+
Congo											+
Côte d'Ivoire											+
Ghana					+						
Kenya									+		
Lesotho									+		
Malawi									+		
Mauritius									+		
Mozambique									+		
Namibia									+		
Niger											+
Senegal											+
Seychelles									+		
South Africa	+	+			+				+		
Swaziland									+		
Togo											+
Uganda									+		
United Republic of Tanzania									+		
Zambia									+		
Zanzibar (United Republic of Tanzania)									+		
Zimbabwe									+		

*Angola participated in the SACMEQ IV project as an observer with a view to becoming a full member
**References to Kosovo shall be understood to be in the context of the UN Security Council resolution 1244 (1999)
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United Nations
Educational, Scientific and
Cultural Organization

Education
Sector

Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM)

Despite significant improvements made in recent decades, education is not universally available and gender inequalities are widespread, often at the expense of girls. Complex and inter-related socio-cultural and economic factors affect not only girls' opportunities to go to school but also the quality of education they will receive, the studies they will follow and ultimately their career and life paths. A major concern is girls' low participation and achievement in science, technology, engineering and mathematics (STEM) education.

STEM underpin the 2030 Agenda for Sustainable Development, and STEM education can provide learners with the knowledge, skills, attitudes and behaviours required for inclusive and sustainable societies. Leaving out girls and women from STEM education and professions not only deprives them the opportunity to contribute to and benefit from STEM but also perpetuates the gender gap and wider social and economic inequalities.

This report aims to 'crack the code' by deciphering the factors that hinder and facilitate girls' and women's participation, achievement and continuation in STEM education and, in particular, what the education sector can do to promote girls' and women's interest in and engagement with STEM education and ultimately STEM careers. It is intended as a resource for education stakeholders and others working to promote gender equality.

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4 QUALITY EDUCATION

Sustainable Development Goals