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Missing out on half of the world's potential: *Fewer female than male top achievers in mathematics and science want a career in these fields*

SUMMARY

Using IEA's Trends in International Mathematics and Science Study (TIMSS) 2019 data, this brief explores the relationship between students' gender, their confidence and achievement in mathematics and science, and their aspirations to pursue careers in these fields. We find that more boys than girls at grade 8 want to have a mathematics- or science-related job. Girls and boys who have high confidence in mathematics and science are significantly more likely to want to work in these fields than those with low confidence in mathematics. In addition, we find that boys want to pursue a job involving mathematics as adults significantly more than girls of the same achievement level. This increased likelihood for boys holds across both high- and low-achievement groups. In comparison, there are smaller or no gender differences in the likelihood of pursuing a science-related career depending on achievement levels. The brief concludes with a discussion on the potential implications.

IMPLICATIONS

- Students' self-assessment of their skills in mathematics and science differs between boys and girls, risking gender disparities in participation in mathematics and science fields.
- Fewer girls than boys who are top achievers in mathematics and science aspire to a career in the field. This means that precious talent is being lost in these fields.
- Low-performing boys who want a career in mathematics could fail in their tertiary studies as their study choice may be poorly aligned with their mathematics' capacities.

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INTRODUCTION

Science, technology, engineering and mathematics (STEM) fields are essential to addressing global challenges such as health technologies, climate change, and the scarcity of natural resources. Although a number of countries are investing a great deal of resources in the STEM fields, there are substantial gender disparities relating to both studies and employment in STEM fields. For example, in 2017 in OECD countries, only 30% of students starting bachelors programs in STEM were women (Encinas-Martin, 2020). Further, in 2017, globally, the percentage of females studying engineering, manufacturing and construction or information and communication technology (ICT) was below 25% in over two-thirds of countries (UNESCO, 2020b). This is despite recent international results from TIMSS 2019 showing that in grade 8, the science and mathematics achievement of boys and girls are similar in many countries with girls outperforming boys in mathematics and science in some countries (Mullis et al., 2020). Clearly, factors other than science and mathematics knowledge and skills are at play.

Drawing from IEA's Trends in International Mathematics and Science Study (TIMSS) 2019 data, in this brief we examine the relationship between students' gender, their confidence and achievement in mathematics and science, and their aspirations to pursue careers in STEM.

Specifically, this brief addresses the following questions:

- What is the relationship between gender and career aspirations in mathematics and science?
- What is the relationship between gender, confidence in mathematics and science and students' career aspirations in these fields?
- What is the relationship between gender, achievement in mathematics and science and students' career aspirations in these fields?
- What are the potential implications of these relationships?

DATA

TIMSS assesses students' achievement in mathematics and science in grade 4 and 8 every four years since 1995. For this brief we examined results from the grade 8 TIMSS 2019 assessment and student questionnaire. We used questions that asked students to indicate their level of agreement with liking a job that involves mathematics or science, combining the answer categories "agree a lot" and "agree a little" from the student questionnaire into "aspiration to pursue a job in the related subject" and "disagree a lot" and "disagree a little" into "no aspiration to pursue a job in the related subject" for the analysis. We also used students' reported answers about how confident they felt in mathematics and science, where we combined "very confident" and "somewhat confident" to "having confidence." The answer option "not confident" was used for the comparisons.

In TIMSS 2019 more than 250,000 students from 8,000 schools, and 30,000 teachers from 46 education systems¹ participated in the grade 8 assessment (Mullis et al., 2020). Not all participating education systems had data available for the purposes of our analyses. Consequently, we used data from 45 education systems².

¹ TIMSS participants include countries (39) and distinct educational systems within countries (7). In this brief, for ease of reading, we use the term "education systems" to describe both.

² 38 countries and 7 distinct educational systems within countries.

RESULTS

Gender differences in aspiration to pursue a job in mathematics or science

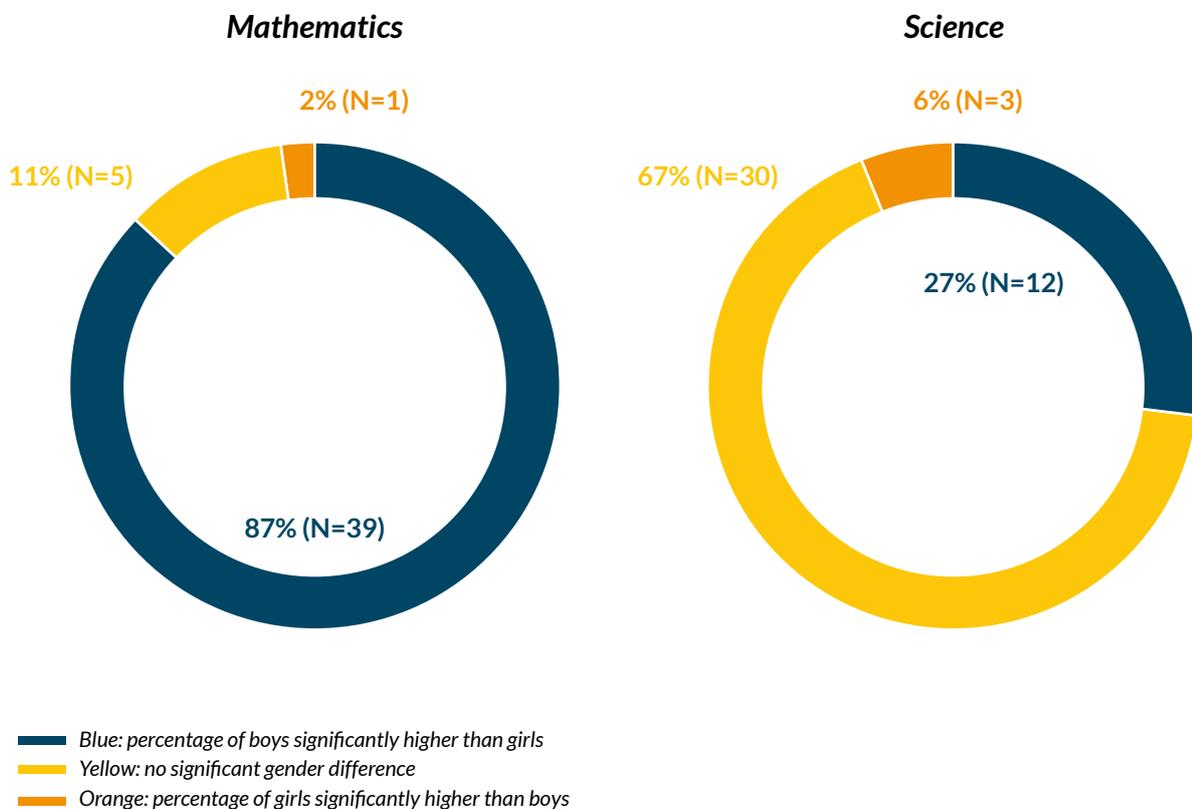
In almost all education systems (87%), boys responded significantly more often than girls that they would like to pursue a job that involves mathematics. The only exceptions were Malaysia, where the proportion of girls was higher, and Finland, Morocco, South Africa (overall as well as in the province of Gauteng) and Turkey, where there were no significant gender differences. For all other participants of TIMSS 2019, the percentage of boys wanting to pursue a job in mathematics was significantly higher than girls.

As shown in *Figure 1*, when considering career aspirations in science, the picture was different. In 12 out of 45

education systems (27%), the proportion of boys who indicated wanting to work in a job that involves science was statistically significantly larger than the proportion of girls. The only exceptions were in Chile, Ireland, and Lithuania, where the proportion of girls was higher. In two-thirds of education systems, the difference was not statistically significant.

Education systems where the percentage of boys with career aspirations for science were significantly higher than for girls were also among those with higher career aspirations for boys in mathematics. This could suggest, at the system level, that there are structural, cultural or other factors at play in shaping students' gendered beliefs or views about STEM careers.

Figure 1: Amount of education systems by gender differences in the percentage of students wanting to pursue a job in mathematics/science



Note: N: Number of education systems

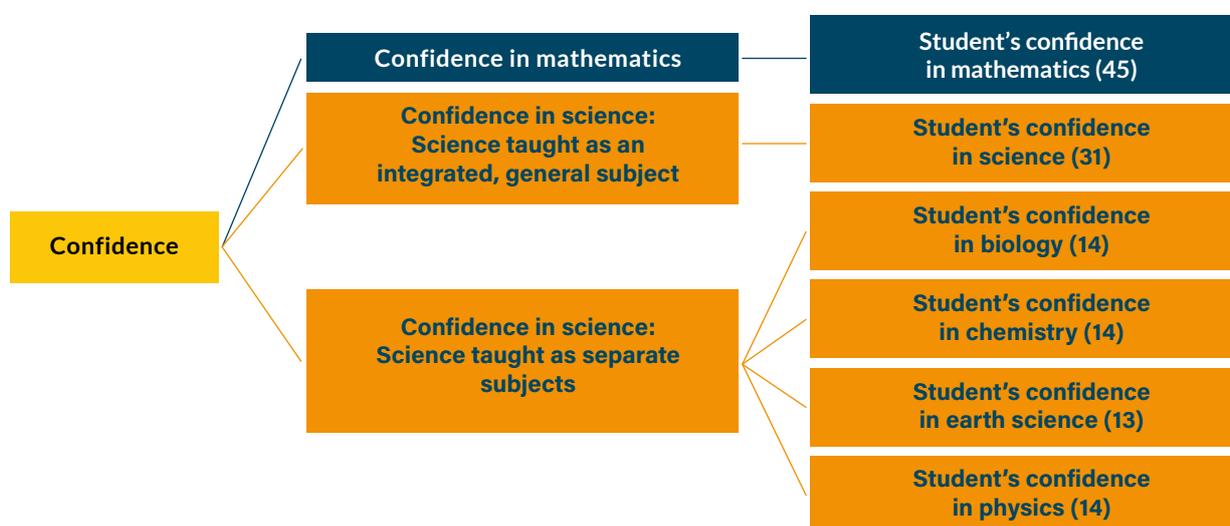
Gender differences in relation to confidence in mathematics and science

Previous research shows that confidence in mathematics and science is closely linked to career aspirations in STEM (Pajares, 2005; Sheldrake, 2016) and girls tend to have lower confidence in their mathematics and science abilities compared to boys (DeWitt et al., 2013; Liu, 2018).

In TIMSS 2019, the student questionnaire included questions on how confident students feel in mathematics

and in science. Since science is taught differently in participating education systems, the question was asked in its general form, namely if an education system teaches science as a general, integrated subject (this was the case in 31 out of 45 education systems). The question on confidence was asked related to biology, chemistry, earth science and physics separately and was not asked related to science in general, if science is taught as separate subjects (this is the case in the other 14 education systems). *Figure 2* illustrates this approach.

Figure 2: Questions related to confidence as they were provided to participating education systems in the student questionnaires



Note: Numbers in brackets indicate the number of education systems whose students received the corresponding questions related to confidence

Consistent with existing research, in TIMSS 2019, boys reported feeling significantly more confident than girls in mathematics. There were only two countries (Bahrain and Egypt) where girls were significantly more confident than boys.

A very different picture was observed for science. We first looked at education systems where science is taught as an integrated general subject (in total 31 out of the 45 education systems). Here, in 39% of the education systems, boys and girls were equally confident in their science abilities. However, there was a similar number of systems where significant gender differences existed: in nine education systems boys expressed higher confidence in science than girls and in 10 education systems girls expressed higher confidence in science than boys. All education systems where boys were significantly more

confident in science were also amongst those where boys showed higher confidence in mathematics. Additionally, the two countries in which girls showed higher confidence in mathematics were among those where girls showed higher confidence in science.

In the 14 systems that teach science as separate subjects at this grade level (biology, chemistry, earth science and physics), we looked at students' confidence in these specific studies separately. Different patterns were observed depending on the subject.

In biology, girls were significantly more confident than boys in more than half of the education systems (9 out of 14 education systems, or 64%). There was no education system where boys had higher confidence than girls.

In chemistry, this pattern changed slightly: in 5 out of 14 education systems (36%), girls were more confident than boys. In all except one (Cyprus), these education systems were also among those where girls had higher confidence than boys in biology. However, there were also three education systems (21%) where boys were more confident than girls in chemistry. In six education systems (43%) there was no statistically significant difference between boys' and girls' confidence in chemistry.

In earth science, there was no statistically significant gender difference in most education systems (11 out of 12, or 92%; two education systems do not teach earth science).

Gender differences in career aspirations and related achievements

We then investigated the relationship between student achievement in mathematics and science and career aspirations in these fields. For this analysis, we used the median achievement in each education system to divide the sample in each education system into low (below median) and high (above median) achievers.

Table 1 shows that within the group of low achieving mathematics students, boys reported more often than girls (by 9 percentage points) that they wanted to

Compared to the other science subjects analyzed, gender differences in confidence in physics appeared to be different. In physics, in 8 out of 14 education systems (57%), boys were significantly more confident than girls. There was no education system where girls were more confident than boys in physics and there were 6 education systems (43%) where there was no significant gender difference. All education systems where boys had a higher confidence in physics than girls also had boys with higher confidence than girls in mathematics. This finding suggests that policy interventions to address gendered views in STEM subjects could jointly consider mathematics and physics.

pursue a job involving mathematics. Within the group of high achieving mathematics students, this difference between boys and girls was 11 percentage points.

Looking at gender differences in science career aspirations within the groups of low and high achievers, there was only a very small average difference of roughly 3 percentage points (3.1% for low achievers and 2.9% for high achievers in science) across all education systems. However, when there were significant differences within education systems, these were, with very few exceptions, in favor of boys (in 29% of the education systems).

Table 1: Gender differences in percentage points of students with career aspirations in mathematics and science by achievement level

| Average of participating education systems | Gender difference amongst mathematics achievers | | Gender difference amongst high mathematics achievers | |
|--|---|--------------|--|--------------|
| | Percent | (s.e.) | Percent | (s.e.) |
| | 9.3 | (0.3) | 11.0 | (0.3) |
| Average of participating education systems | Gender difference amongst low science achievers | | Gender difference amongst high science achievers | |
| | Percent | (s.e.) | Percent | (s.e.) |
| | 3.1 | (0.3) | 2.9 | (0.3) |

- Blue-shaded cells indicate statistically significant differences favoring boys
- Yellow-shaded cells indicate differences are not statistically significant
- Orange-shaded cells indicate statistically significant differences favoring girls

Note: (s.e.) indicates the standard error of the estimates.
International averages in bold indicate the difference is statistically significant

Gender differences in career aspirations and confidence in the related subject

We next studied the interplay of gender, confidence in the subject, and career aspirations in this subject. **Table 2** shows that the aspiration for boys and girls to work in the field of mathematics is strongly associated with confidence in one's ability in the subject.

Within the group of students with low confidence in mathematics, the gender gap amounts to 10 percentagepoints in favor of boys, and it is significant in 39 out of 45 education systems (87%). The picture is similar among students with high confidence in mathematics, where the gap amounts to 7 percentage points, also in favor of boys, and is significant in 35 out of 45 systems (73%).

For education systems teaching science as a general subject, the gender difference in science career aspirations

for the group of students with low confidence in science was on average about half of the size compared to mathematics. Here there was a difference of 5 percentage points in favor of boys having higher aspirations to pursuing a job involving science. Significant differences tended to be in favor of boys (in 16 out of 31 education systems, 52%), although the magnitude of the difference varied across systems.

For the group of students with high confidence in science, the average gender difference amounted to only 2 percentage points in favor of boys, and in many education systems the difference was not statistically significant (18 out of 31 education systems, or 51%). However, there were significant gender differences amongst students with high confidence in science, favoring boys in 10 out of 31 education systems (32%), while in the remaining 4 education systems (13%), girls had higher aspirations to pursuing a job in science within the group of high confident students.

Table 2: Gender differences in percentage points of students with career aspirations by confidence in mathematics (45 education systems) and science (31 education systems)

| | Gender difference amongst students with low confidence in mathematics | | Gender difference amongst students with high confidence in mathematics | |
|--|---|--------------|--|--------------|
| | Percent | (s.e.) | Percent | (s.e.) |
| Average of participating education systems | 10.1 | (0.4) | 7.3 | (0.3) |
| | Gender difference amongst students with low confidence in science | | Gender difference amongst students with high confidence in science | |
| | Percent | (s.e.) | Percent | (s.e.) |
| Average of participating education systems | 5.4 | (0.5) | 2.3 | (0.3) |

Blue-shaded cells indicate statistically significant differences favoring boys

Yellow-shaded cells indicate differences are not statistically significant

Orange-shaded cells indicate statistically significant differences favoring girls

Note: (s.e.) indicates the standard error of the estimates.

International averages in bold indicate the difference is statistically significant

The results of students' confidence in the specific science domains are summarized in **Table 3** below. For the 14 education systems that teach science as separate subjects, the results showed that within the group of low confident students, boys reported more often wanting to pursue a job in the subject. This was the case especially in biology (6.1 percentage points more for boys than girls on average) and to a smaller extent in chemistry (2.9 percentage points) and physics (2.7 percentage points). There was no statistically significant difference within the low confident student group for earth science.

Interestingly, among students who reported having high confidence in biology, chemistry and earth science, there was no significant difference between boys' and girls' desire to pursue a job involving science. In physics, within the group of students having high confidence, girls reported more often that they want to pursue a job involving science (1.9 percentage points more often compared to boys).

Table 3: Gender differences in percentage points of students with career aspirations by confidence in separate science subjects (14 education systems)

| | Gender difference amongst students with low confidence in biology | | Gender difference amongst students with high confidence in biology | |
|--|---|--------------|--|--------|
| | Percent | (s.e.) | Percent | (s.e.) |
| Average of participating education systems | 6.1 | (0.8) | 0.3 | (0.6) |
| | Gender difference amongst students with low confidence in chemistry | | Gender difference amongst students with high confidence in chemistry | |
| | Percent | (s.e.) | Percent | (s.e.) |
| Average of participating education systems | 2.9 | (0.7) | -0.2 | (0.6) |
| | Gender difference amongst students with low confidence in earth science | | Gender difference amongst students with high confidence in earth science | |
| | Percent | (s.e.) | Percent | (s.e.) |
| Average of participating education systems | 1.8 | (1.0) | 0.3 | (0.6) |
| | Gender difference amongst students with low confidence in physics | | Gender difference amongst students with high confidence in physics | |
| | Percent | (s.e.) | Percent | (s.e.) |
| Average of participating education systems | 2.7 | (0.7) | -1.9 | (0.7) |

- Blue-shaded cells indicate statistically significant differences favoring boys
- Yellow-shaded cells indicate differences are not statistically significant
- Orange-shaded cells indicate statistically significant differences favoring girls

Note: (s.e.) indicates the standard error of the estimates.
International averages in bold indicate the difference is statistically significant

DISCUSSION AND CONCLUSION

Our analysis of the TIMSS 2019 data finds that more boys than girls at grade 8 want to pursue a mathematics- or science-related career. We examined these differences further based on differences in confidence and achievement levels.

For both girls and boys, high confidence in mathematics or science skills is associated with a higher likelihood to want to enter a job in mathematics or science. As our analysis shows, boys at grade 8 are more confident in mathematics than girls. This gender difference was less pronounced in science.

Our analysis found that more high performing boys than girls aspire to enter a career in mathematics, confirming earlier research from high- and middle-income countries (OECD, 2019). Research has shown that many young women who are high achievers in mathematics and sciences opt for biology, medicine, or psychology majors rather than physics, mathematics, and engineering (Bieri Buschor et al., 2014).

Our analysis also found that more low performing boys than girls aspire to enter a career in mathematics. Boys may be over-confident in their mathematics skills and girls under-confident in their mathematics skills. Gender disparities in aspirations to enter a science career were found to be less pronounced. This could lead to fewer well-performing girls entering STEM tertiary education fields. It could also lead to the failure of boys from the low achiever group in their tertiary studies whose study choice is poorly aligned with their capacities.

This suggests that addressing confidence of girls in science and mathematics should continue to be a concern for policy makers, even though the gender differences in performance in mathematics and science have been reduced over the past years.

Girls' confidence in mathematics and science can be negatively affected by peers, parents, teachers, and school counselors who hold or even promote gender stereotypes in STEM (Carlana, 2019; Kelley et al., 2020; UNESCO, 2020a, b; UNESCO, 2017; Trusz, 2020; Welsch and Windeln, 2019). Likewise, teaching and learning materials can perpetuate stereotypes in STEM. Only 6 percent of the characters in the Chilean grade 6 science textbook were female, for instance (Covacevich and Quintela-Dávila, 2014).

STEM education as well as school counseling needs to become gender transformative. This necessitates teachers who are trained on gender-transformative STEM education and teaching and learning materials free from bias. Gender-transformative STEM education not only addresses the different needs and aspirations of girls and boys but also challenges gender norms and wider inequalities. School counseling needs to encourage girls who perform well in mathematics and sciences to pursue further study in these fields and propose alternative career paths for boys who are underperforming. All girls and boys who perform well in mathematics and science should be provided with adequate information on STEM careers and be encouraged to pursue STEM at higher education levels. Informal opportunities such as after-school clubs and activities, and STEM camps targeting girls during secondary education have proven to be successful in building girls' interest and confidence in STEM (UNESCO, 2019). Moreover, interventions using female role models have shown to increase girls' confidence in STEM (Hughes et al., 2013; UNESCO, 2020a). Therefore, schools need to ensure access to role models and mentors, including successful women in these fields. Parents also need to be brought on board. Parental outreach programs can help to dismantle harmful gender stereotypes about women in STEM.

This brief raises several leads for further research. Our analysis focused on high- and upper-middle income countries. What is the relationship between gender, performance in mathematics and science and career aspirations in lower-middle and low-income countries? The relationship between overconfidence of low performing boys and their career choice as well as their success and failure in STEM subjects also needs to be further researched. Further, curricula, structural, educational, and labor market trends could be analyzed at the system level in a set of countries sharing similar characteristics to better understand the link between gendered beliefs and attitudes and educational and career pathways.

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ABOUT THIS BRIEF

This special issue of IEA Compass: Briefs in Education has been created in partnership with UNESCO. In this special issue we aim to translate TIMSS study findings into the education field, both for policymakers as well as teachers, and other practitioners in the education sector.

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