Gender differences in mathematics: from the international literature to the Italian context

Differenze di genere in matematica: dagli studi internazionali alla situazione italiana

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Abstract / National and international surveys highlight a strong disparity in male and female results in mathematics: boys outperform girls in almost every country at all scholastic levels. In the international context, Italy appears to be one of the countries where the results related to gender differences in mathematics are more alarming and INVALSI test data confirm a very marked gender gap in favour of males at all scholastic levels. In this paper we present the international situation regarding gender differences in mathematics, starting from large-scale assessment and paying particular attention to the Italian context. We then present a detailed overview of the causes underlying the gender gap in mathematics, analysing the main studies on this issue and attempting to provide a complete, though complex, interpretation of this phenomenon.

Keywords: gender gap; large scale assessment; INVALSI; STEM.

Sunto / Dalle principali rilevazioni nazionali e internazionali emerge una forte disparità nei risultati di maschi e femmine nelle prove di matematica: gli studenti ottengono risultati migliori delle studentesse nella maggior parte delle nazioni e a tutti i livelli scolastici. Nel panorama internazionale, l'Italia risulta essere uno dei Paesi in cui i risultati relativi alle differenze di genere in matematica sono più allarmanti e i dati delle prove INVALSI confermano un gender gap molto marcato a favore dei maschi, presente a tutti i livelli scolastici. Questo articolo presenta la situazione internazionale relativa alle differenze di genere in matematica a partire dalle prove standardizzate, prestando particolare attenzione alla situazione italiana; quindi viene presentato un excursus dettagliato sulle cause alla base del gender gap in matematica, analizzando i principali studi sull'argomento e cercando di fornire una chiave di lettura completa, seppur complessa, di questo fenomeno.

Parole Chiave: differenze di genere; prove standardizzate; INVALSI; STEM.

1 Introduction

The number of women involved in STEM subjects (acronym of: Science, Technology, Engineering and Mathematics) has increased over the last few years; nevertheless, a strong imbalance in favor of males persists if we consider the number of enrolments at university for scientific courses and in the workplace related to STEM (Hill, Corbett & Rose, 2010; OECD, 2015).

Some factors that have led to this inequality in the number of men and women engaged in scientific subjects can be sought, first of all, in the history of customs and society (MacKinnon, 1990; Leder & Forgasz, 2008). Indeed, access to scientific culture, in particular to the study of mathematics, was historically reserved almost exclusively to men and very few women's names are remembered in the history of mathematics before last century (MacKinnon, 1990; Leder & Forgasz, 2008).

Since the beginning of the 1900s, great strides have been made in allowing women

equal access rights to education and the labour market, and in fighting gender-related stereotypes. Specific educational policies to encourage girls to study science and mathematics, guaranteeing them the same possibilities as men in the workplace, have been introduced in many countries since the '70s (Leder & Forgasz, 2008) but, despite this, gender differences in STEM subjects still exist today.
In the field of STEM subjects, mathematics plays a fundamental role for the development and learning of other disciplines (Hill et al., 2010) and, for this reason, many studies have focused on gender differences in mathematics.
In recent years, the issue of gender differences has been the subject of many studies from different points of view. Indeed, there are several theories which do not belong to educational research but rather belong to other fields such as sociology and psychology (Leder, 1992; Byrnes, 2005; Pajares, 2005). Psychology, in recent years, has developed a large research field concerning the difficulties of girls in learning mathematics, linking their weaker performances to affective and psychological factors such as anxiety and self-confidence (e.g. Primi, Busdraghi, Tomasetto, Morsanyi & Chiesi, 2014; Lindberg, Hyde, Petersen & Linn, 2010).
The introduction of international standardized assessments aimed at monitoring the learning of mathematics and other disciplines, allows the study of different performances by males and females, also comparing countries with different cultures and education systems. In the last few years, the results of the OECD PISA and IEA TIMMS tests have put great emphases on gender differences and offer the possibility to study this issue through a comparison of different geographical areas, also taking into consideration socio-economic and cultural status indices.
This paper sets out to provide an overview of research on gender differences in mathematics: in the first part we will analyse the main results of standardized tests on this issue, while the following sections will investigate the causes of the highlighted differences. We will take into account, above all, research findings from the mathematics education sector, flanked by major studies on the topic from other sectors.

2 Methodology

In this paper, we compare the main research studies in mathematics education on the issue of gender differences, integrating these with studies from other sectors in order to provide a comprehensive overview of this phenomenon.
We thus consider the principal papers on the issue of gender differences in mathematics published in grade A journals of mathematics education, following the classification (Törner & Arzarello, 2013) jointly produced by the members of ERME (Executive Committee of the European Society for Research in Mathematics Education) and EMS (Education Committee of the European Mathematical Society).
Many of these studies directly refer to the results of international large-scale surveys IEA TIMSS and OECD PISA and, for this reason, we decided to propose firstly the results of these surveys with regard to gender differences in mathematics and then, at a later stage, to discuss said results on the basis of the aforementioned studies. This first analysis allows us to identify the main features of this phenomenon and, wherever possible on the basis of international survey results, to explain these features in relation with different national situations.

We start by considering papers belonging to the mathematics education field, before extending the literature review by exploring the research cited in these articles more in depth, and through independent research by the author, also analysing studies from other sectors and journals in order to better understand some of the evidence which emerges. The characteristics of gender differences in mathematics highlighted in this way can be used to offer a complete overview of research on the topic and provide important information for comparing the relevant literature.

3 Study of gender differences through large-scale assessments

In 2008, Leder and Forgasz provided an overview of gender differences studies in the field of mathematics education and stressed the importance of using standardized tests in this direction:

> «The results of large-scale international testing, including the Programme for International Student Assessment (PISA), have attracted widespread attention from the general mathematics education research community as well as from those with a particular interest in gender differences in mathematics learning».
> (Leder & Forgasz, 2008, p. 516)

3.1 International surveys: OECD PISA and IEA TIMSS

The main international surveys aimed at measuring the learning of mathematics and other disciplines are the PISA tests, promoted by the *Organisation for Economic Co-operation and Development* (OECD), and TIMSS tests, promoted by the *International Association for Evaluation of Educational Achievement* (IEA).
The fundamental characteristics and differences of the two surveys are reported in the table below (the year 2015 is particularly interesting as the last year, up to now, in which both surveys were conducted):

Survey	OECD PISA	IEA TIMSS
First edition and cadence	2000; every 3 years	1995; every 4 years
Subjects investigated	Reading, Mathematics, Science and Financial literacy (each edition focuses on a specific subject)	Science and Mathematics
Sample	Fifteen year old students (sample surveys)	Students attending grades 4 and 8, corresponding to the fourth grade of elementary school and the third grade of middle school (sample surveys)[1] 1

1. In Italy the elementary school is called primary school; the middle school, secondary school of first grade; and the upper-middle school is called secondary school of second grade.

Purpose	Evaluate the acquisition of key competences for full participation in modern society[2]	Evaluate the acquisition of curriculum content and skills by students[3]
Participants in 2015	72 Countries, totalling approximately 540,000 students involved	57 Countries (not all included in those participating in OECD PISA)

Table 1
Main features of OECD PISA and IEA TIMSS surveys.

3.2 Gender differences in international survey results

The use of standardized tests for research in mathematics education has increased in recent years, even though the potential of such tests is not yet fully exploited (Maffia & Giberti, 2016; Sfard, 2005). The results reported in the next sections pertain mainly to the TIMSS and PISA reports, referring to the 2015 surveys which (as stated earlier) was a particularly interesting year as both surveys were carried out concurrently.

3.2.1 Results of the PISA 2015 survey

In 2015, 35 countries participated in the PISA mathematics surveys and the average score obtained in the test was 490 points (for further details on how the scores are given in the tests, on the bases of test equating, please refer to the technical report: OECD, 2016d). The following plot (**Figure 1**) reports, in the second column highlighted in light blue, the average scores obtained in the math test for each participating country and, alongside this, the difference between the average score achieved by boys and that achieved by girls. Hence, the histogram shows a gap in favour of males when the bar is to the right of the vertical line and a gap in favour of the females when the bar develops to the left. The symbols, also reported in the legend, indicate gender differences considering only the lowest-achieving students (i.e, those ranking below the 10th percentile) and the highest-achieving students (i.e. those positioned above the 90th percentile). In the figure, the darker colours indicate a statistically significant difference, both for the bars of the histogram and for the symbols related to the percentiles.

2. We refer to *mathematical literacy* according to the definition given by OECD (2016c, p. 66): Mathematical literacy is an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens.
3. The tests given to the students are related to the common parts of the curricula across different countries.

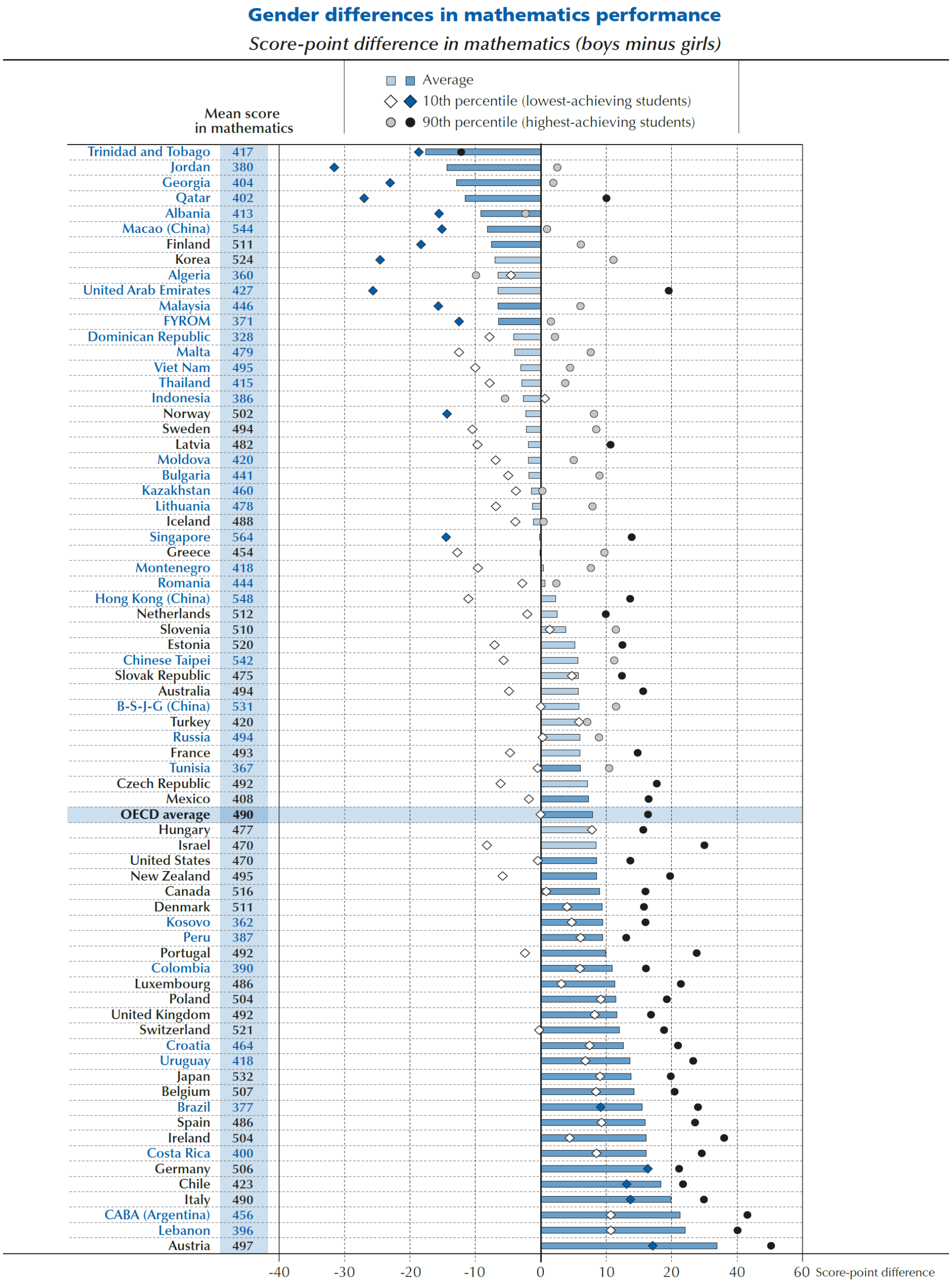


Figure 1
Gender differences in mathematics in PISA 2015 tests scores (OECD, 2016a). Source: PISA 2015 Results, excellence and equity in education (Vol. I).

If we consider the results as a whole, the males achieve an average of 8 points more than females (OECD, 2016a), but the differences vary considerably from country to country.

Gender differences in the math test do not occur uniformly across all the countries involved in the survey: about half of the countries show a statistically significant gap in favour of males but in almost the same number of countries the gap is not statistically significant and in some cases the girls' results even outperform those of boys. The lack of homogeneity of the phenomenon is also one of the reasons why some studies do not find a significant gap: according to the countries involved in the surveys, in fact, there may be greater or lesser gender differences.

Moreover, these differences do not seem to be strictly linked to the overall score obtained in the test: among countries showing a very marked gender gap, it is possible to identify scores above the OECD average (e.g. in Japan) and nations that achieve

results far below the OECD average (e.g. Brazil), and the same is true for countries where the gender gap is not significant or is even in favour of girls.
The PISA tests involve 15-year-old school children and, as also specified in the PISA reports (OECD, 2016c), the sample might be affected in some countries by the fact that they are not administered to all 15-year-olds but only those who are schooled and that in some countries there are difficulties in reaching some regions to carry out the tests. For this reason, in interpreting the above graphs we must also take into account the fact that in some countries population coverage may not be sufficient and that the sample of students involved could be representative of the fifteen year-old school population but not the entire population of 15-year-olds (for this country-specific information, see table 11.11 of the 2015 PISA technical report: OECD, 2016d). In some countries, where only a minority of females have access to education and the possibility to continue their studies up to 15 years, these factors can significantly influence the estimate of gender gap in mathematics.
Moreover, as already highlighted by previous OECD surveys, the gap between males and females is more marked if we consider only the highest-achieving students. In this case, the average gap in the countries included in the survey is 16 points and, for all countries where the gap is significant and in favour of males, the difference in performance (indicated with the white circle) among students who exceed the threshold of the ninetieth percentile is always significant (black circle) and higher than the gap relative to the entire nation (OECD, 2016a).
Looking at the Italian context, although the students obtain an overall average score equal to the OECD average (Figure 1), we observe a significant gap, equal to 20 points, between the performances of boys and those of girls (OECD, 2016b). Thus, Italy is one of the OECD countries where girls are the most disadvantaged in mathematics and from 2012 to 2015 the gap is unchanged (or possibly slightly increased) while in most countries the gap for that same period is unchanged or slightly decreased (OECD, 2015).

3.2.2 Results of the TIMSS 2015 survey

The earlier remarks on PISA surveys are largely confirmed also by the results of the TIMSS 2015 tests which investigate the school levels 4 and 8, corresponding to the fourth grade of elementary school and to the third grade of middle school in the Italian school system.
In the TIMSS tests, the score scale is centred on 500 which then corresponds to the average test score considering all the countries participating in the survey; the units of the scale are chosen so that 100 points correspond to the standard deviation of the distribution of scores (Mullis, Martin, Foy & Hooper, 2016).
The following graphs show the results of the 2015 TIMSS tests administered for grade 4 (Figure 2) and grade 8 (Figure 3). For each country involved in the survey, the average score obtained by males and females is reported, together with the percentage of males and females present in the sample. The difference between the male and female average scores is reported both in numerical terms and through the histogram in the last column.
Also in these graphs, statistically significant differences are indicated in blue, while an insignificant gap is indicated by a grey bar on the histogram. At the bottom of the graphs, there is an explanation of the symbols inserted alongside the individual nations, indicating peculiarities linked to the representativeness of the sample and

the guidelines used by TIMSS for the creation of the national sample. The information concerning the gender gap that can be extrapolated from the graphs must be read, also in this case, taking into consideration the representativeness of the sample with respect to the entire population.

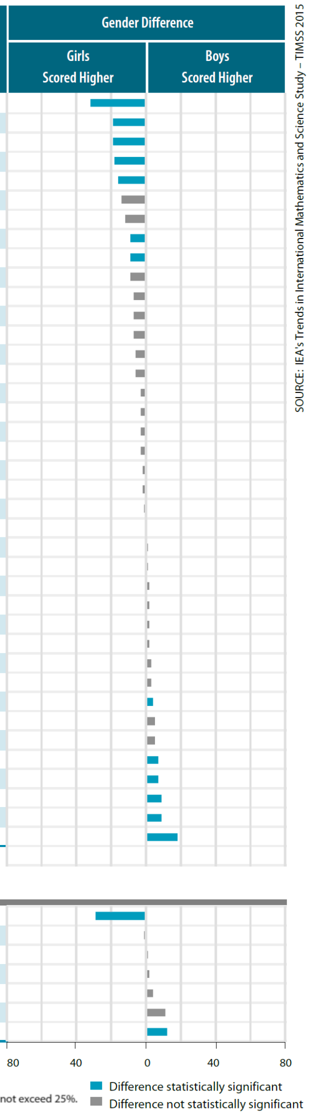
Country	Girls		Boys		Difference (Absolute Value)
	Percent of Students	Average Scale Score	Percent of Students	Average Scale Score	
ψ Saudi Arabia	49 (1.0)	405 (4.4)	51 (1.0)	363 (6.5)	43 (7.7)
Oman	50 (0.7)	436 (3.0)	50 (0.7)	415 (2.8)	22 (2.9)
Jordan	46 (2.4)	399 (3.3)	54 (2.4)	379 (4.9)	20 (5.8)
South Africa (5)	48 (0.8)	384 (3.8)	52 (0.8)	368 (4.4)	15 (4.2)
[2] Bahrain	50 (0.7)	459 (1.7)	50 (0.7)	443 (2.3)	15 (2.5)
ψ Kuwait	51 (2.0)	359 (5.4)	49 (2.0)	347 (5.6)	12 (6.2)
Iran, Islamic Rep. of	50 (0.9)	437 (4.5)	50 (0.9)	426 (4.5)	10 (6.3)
Indonesia	48 (0.6)	403 (4.0)	52 (0.6)	393 (3.9)	10 (2.7)
Finland	48 (0.8)	540 (2.3)	52 (0.8)	531 (2.6)	9 (2.9)
Bulgaria	49 (0.8)	527 (5.7)	51 (0.8)	522 (5.1)	5 (2.9)
Norway (5)	49 (0.9)	551 (2.6)	51 (0.9)	547 (3.1)	4 (2.9)
[2] Singapore	48 (0.5)	620 (3.9)	52 (0.5)	616 (4.3)	4 (3.0)
United Arab Emirates	48 (2.2)	453 (3.9)	52 (2.2)	450 (3.4)	3 (5.4)
[1] Georgia	49 (0.9)	465 (3.9)	51 (0.9)	461 (4.4)	3 (4.0)
[3] Serbia	48 (0.8)	520 (3.7)	52 (0.8)	517 (4.7)	3 (4.7)
Qatar	51 (2.5)	440 (4.1)	49 (2.5)	438 (4.9)	3 (5.9)
[2] Lithuania	50 (0.9)	537 (2.8)	50 (0.9)	534 (3.1)	2 (3.3)
Kazakhstan	49 (0.8)	546 (4.6)	51 (0.8)	543 (4.8)	2 (2.8)
Morocco	48 (0.7)	378 (3.5)	52 (0.7)	377 (3.9)	1 (2.8)
[2] Sweden	49 (1.0)	519 (3.2)	51 (1.0)	518 (3.2)	1 (3.0)
Russian Federation	49 (0.9)	564 (3.7)	51 (0.9)	564 (3.7)	1 (2.8)
Japan	50 (0.5)	593 (2.0)	50 (0.5)	593 (2.5)	0 (2.3)
Chile	49 (1.7)	458 (2.8)	51 (1.7)	459 (3.0)	1 (3.2)
Poland	50 (0.8)	534 (2.3)	50 (0.8)	536 (2.7)	1 (2.5)
Turkey	49 (0.6)	482 (3.2)	51 (0.6)	484 (3.5)	2 (2.7)
‡ Northern Ireland	50 (1.1)	569 (3.8)	50 (1.1)	571 (3.1)	2 (3.8)
New Zealand	49 (0.7)	489 (2.8)	51 (0.7)	492 (2.6)	2 (2.8)
Germany	48 (0.7)	520 (2.4)	52 (0.7)	523 (2.3)	3 (2.3)
Ireland	47 (1.5)	545 (2.6)	53 (1.5)	549 (2.9)	4 (3.4)
Slovenia	49 (0.8)	518 (2.1)	51 (0.8)	522 (2.4)	4 (2.6)
Chinese Taipei	49 (0.6)	594 (2.2)	51 (0.6)	599 (2.3)	6 (2.5)
† Belgium (Flemish)	50 (0.9)	543 (2.4)	50 (0.9)	549 (2.4)	6 (2.4)
Hungary	49 (0.9)	526 (3.4)	51 (0.9)	532 (3.8)	6 (3.4)
France	49 (0.7)	485 (3.2)	51 (0.7)	491 (3.2)	6 (2.8)
[2] † Denmark	49 (0.8)	536 (3.1)	51 (0.8)	542 (3.0)	6 (2.8)
England	51 (0.7)	543 (3.0)	49 (0.7)	549 (3.3)	6 (2.9)
Cyprus	49 (0.7)	520 (2.9)	51 (0.7)	526 (3.1)	6 (2.7)
[2] † United States	51 (0.6)	536 (2.3)	49 (0.6)	543 (2.6)	7 (1.9)
Czech Republic	49 (0.9)	525 (3.0)	51 (0.9)	532 (2.5)	7 (3.2)
Korea, Rep. of	48 (0.5)	604 (2.3)	52 (0.5)	612 (2.5)	7 (1.9)
† Netherlands	50 (0.9)	526 (1.8)	50 (0.9)	534 (2.2)	8 (2.2)
Australia	49 (1.0)	513 (3.1)	51 (1.0)	522 (3.9)	9 (3.5)
[1] [2] † Canada	49 (0.5)	506 (2.5)	51 (0.5)	515 (2.6)	9 (2.1)
† Hong Kong SAR	46 (1.5)	609 (3.8)	54 (1.5)	619 (2.8)	10 (3.3)
[2] Portugal	49 (0.8)	536 (2.4)	51 (0.8)	547 (2.5)	11 (2.2)
Slovak Republic	48 (0.9)	493 (3.0)	52 (0.9)	504 (2.6)	11 (2.6)
[2] Spain	49 (0.9)	499 (2.7)	51 (0.9)	511 (2.7)	12 (2.4)
Croatia	49 (0.8)	496 (2.1)	51 (0.8)	508 (2.3)	12 (2.7)
[2] Italy	49 (0.7)	497 (2.7)	51 (0.7)	517 (3.0)	20 (2.7)
International Avg.	49 (0.2)	505 (0.5)	51 (0.2)	505 (0.5)	
Benchmarking Participants					
[2] ψ Abu Dhabi, UAE	47 (3.7)	422 (8.0)	53 (3.7)	417 (6.6)	4 (11.2)
[1] Florida, US	49 (1.1)	548 (4.9)	51 (1.1)	544 (5.5)	4 (4.5)
Dubai, UAE	48 (3.3)	510 (3.1)	52 (3.3)	512 (2.7)	2 (5.0)
Norway (4)	49 (0.9)	492 (2.9)	51 (0.9)	494 (3.0)	3 (3.6)
Buenos Aires, Argentina	50 (1.0)	430 (3.5)	50 (1.0)	435 (2.9)	5 (2.8)
Ontario, Canada	49 (0.8)	509 (2.6)	51 (0.8)	516 (2.8)	7 (2.9)
‡ Quebec, Canada	50 (1.0)	531 (3.9)	50 (1.0)	541 (4.8)	11 (3.8)

SOURCE: IEA's Trends in International Mathematics and Science Study – TIMSS 2015

Ж Reservations about reliability because the percentage of students with achievement too low for estimation exceeds 25%.
ψ Reservations about reliability because the percentage of students with achievement too low for estimation exceeds 15% but does not exceed 25%.
1 National Target Population does not include all of the International Target Population.
2 National Defined Population covers 90% to 95% of the National Target Population.
3 National Defined Population covers less than 90% of the National Target population (but at least 77%).
TIMSS guidelines for sampling participation: The minimum acceptable participation rates were 85 percent of both schools and students, or a combined rate (the product of school and student participation) of 75 percent. Participants not meeting these guidelines were annotated as follows:
† Met guidelines for sample participation rates only after replacement schools were included.
‡ Nearly satisfied guidelines for sample participation rates after replacement schools were included.
‡ Did not satisfy guidelines for sample participation rates.

Figure 2
Gender differences in mathematics in TIMSS 2015 test score – grade 4. Source: TIMSS 2015 International Results in Mathematics (Mullis et al., 2016).

Country	Girls		Boys		Difference (Absolute Value)
	Percent of Students	Average Scale Score	Percent of Students	Average Scale Score	
ψ Oman	48 (1.7)	420 (2.9)	52 (1.7)	388 (3.5)	32 (4.6)
ψ Botswana (9)	51 (0.6)	400 (2.5)	49 (0.6)	381 (2.5)	19 (2.9)
ж Jordan	50 (2.6)	395 (4.0)	50 (2.6)	376 (5.4)	19 (7.0)
Thailand	54 (1.5)	440 (5.2)	46 (1.5)	422 (5.7)	18 (5.5)
Bahrain	48 (0.9)	462 (2.4)	52 (0.9)	446 (2.2)	16 (3.6)
ж Saudi Arabia	51 (1.6)	375 (5.1)	49 (1.6)	360 (7.1)	14 (8.2)
United Arab Emirates	50 (2.5)	471 (3.5)	50 (2.5)	459 (4.0)	12 (6.4)
Malaysia	50 (1.8)	470 (3.8)	50 (1.8)	461 (3.8)	9 (2.8)
2 Singapore	49 (0.6)	626 (3.4)	51 (0.6)	616 (3.8)	9 (3.5)
ψ Egypt	53 (2.3)	397 (5.5)	47 (2.3)	387 (5.1)	9 (6.7)
ж South Africa (9)	51 (1.1)	376 (5.3)	49 (1.1)	369 (4.6)	7 (4.1)
ψ Kuwait	50 (2.5)	396 (4.6)	50 (2.5)	389 (7.1)	7 (7.5)
ψ Qatar	50 (3.0)	440 (3.2)	50 (3.0)	434 (4.5)	7 (4.9)
Turkey	48 (0.8)	461 (4.8)	52 (0.8)	455 (5.3)	6 (3.6)
Kazakhstan	49 (0.9)	531 (5.8)	51 (0.9)	525 (5.3)	6 (3.7)
ψ Iran, Islamic Rep. of	48 (0.9)	438 (5.0)	52 (0.9)	435 (7.5)	3 (8.9)
England	51 (1.6)	520 (5.2)	49 (1.6)	517 (4.8)	3 (5.6)
Malta	49 (0.3)	495 (1.8)	51 (0.3)	492 (1.6)	3 (2.8)
† New Zealand	51 (2.0)	494 (3.2)	49 (2.0)	491 (4.6)	3 (4.2)
Japan	51 (1.0)	588 (3.1)	49 (1.0)	585 (3.0)	2 (4.2)
ж Morocco	46 (0.7)	385 (2.3)	54 (0.7)	384 (2.6)	2 (2.0)
1 2 Georgia	47 (0.9)	454 (3.9)	53 (0.9)	453 (4.0)	1 (4.0)
Chinese Taipei	49 (0.8)	599 (2.6)	51 (0.8)	599 (3.0)	0 (2.8)
Korea, Rep. of	47 (0.5)	605 (2.6)	53 (0.5)	606 (3.1)	1 (2.7)
Norway (9)	50 (0.7)	511 (2.5)	50 (0.7)	512 (2.7)	1 (2.6)
† United States	50 (0.6)	517 (3.3)	50 (0.6)	519 (3.2)	2 (2.0)
Australia	51 (1.6)	504 (3.8)	49 (1.6)	506 (3.5)	2 (4.0)
3 Israel	49 (1.2)	510 (4.3)	51 (1.2)	512 (4.8)	2 (3.9)
Slovenia	48 (0.7)	515 (2.4)	52 (0.7)	518 (2.5)	2 (2.4)
Lebanon	53 (1.6)	441 (3.7)	47 (1.6)	444 (4.5)	3 (3.9)
2 Lithuania	50 (0.8)	510 (3.4)	50 (0.8)	513 (3.1)	3 (3.4)
1 † Canada	51 (1.0)	525 (2.0)	49 (1.0)	530 (2.7)	4 (2.0)
Ireland	50 (1.1)	521 (2.6)	50 (1.1)	526 (4.0)	5 (3.9)
Hong Kong SAR	47 (2.1)	591 (4.7)	53 (2.1)	597 (6.0)	5 (5.7)
2 Italy	49 (0.8)	491 (3.0)	51 (0.8)	498 (2.8)	7 (2.8)
Sweden	48 (1.0)	497 (3.3)	52 (1.0)	504 (3.1)	7 (3.2)
Hungary	50 (0.9)	510 (4.3)	50 (0.9)	519 (4.0)	9 (3.4)
Russian Federation	49 (0.9)	533 (5.1)	51 (0.9)	543 (4.6)	9 (2.9)
ψ Chile	48 (1.8)	418 (3.7)	52 (1.8)	436 (4.2)	18 (4.9)
International Avg.	50 (0.2)	483 (0.6)	50 (0.2)	480 (0.7)	
Benchmarking Participants					
Abu Dhabi, UAE	49 (4.4)	457 (6.0)	51 (4.4)	427 (7.7)	29 (10.7)
1 Florida, US	48 (1.3)	494 (7.2)	52 (1.3)	493 (6.5)	1 (4.7)
Norway (8)	50 (0.7)	486 (2.4)	50 (0.7)	487 (2.3)	1 (2.5)
Ontario, Canada	50 (1.2)	521 (2.9)	50 (1.2)	523 (3.3)	2 (2.6)
Dubai, UAE	52 (3.7)	510 (3.7)	48 (3.7)	514 (4.3)	4 (6.9)
† ж Buenos Aires, Argentina	51 (1.7)	391 (4.8)	49 (1.7)	401 (5.4)	11 (5.8)
‡ Quebec, Canada	53 (1.9)	538 (3.8)	47 (1.9)	550 (5.1)	12 (4.6)



SOURCE: IEA's Trends in International Mathematics and Science Study – TIMSS 2015

ж Reservations about reliability because the percentage of students with achievement too low for estimation exceeds 25%.
ψ Reservations about reliability because the percentage of students with achievement too low for estimation exceeds 15% but does not exceed 25%.
1 National Target Population does not include all of the International Target Population.
2 National Defined Population covers 90% to 95% of the National Target Population.
3 National Defined Population covers less than 90% of the National Target population (but at least 77%).
TIMSS guidelines for sampling participation: The minimum acceptable participation rates were 85 percent of both schools and students, or a combined rate (the product of school and student participation) of 75 percent. Participants not meeting these guidelines were annotated as follows:
† Met guidelines for sample participation rates only after replacement schools were included.
‡ Nearly satisfied guidelines for sample participation rates after replacement schools were included.
‡ Did not satisfy guidelines for sample participation rates.

Figure 3
Gender differences in mathematics in TIMSS 2015 test score – grade 8. Source: TIMSS 2015 International Results in Mathematics (Mullis et al., 2016).

In both grades, also in this case, the gender gap is not uniformly distributed across the different countries.
There were 49 participating nations in 2015 at grade 4, and 18 of these reveal a difference between the scores of males and females that is statistically significant and, on average, 9 points in favour of males. In 23 countries there is no significant difference and in only 8 countries do females achieve better results.
Considering the grade 8 test, however, gender differences are generally less pronounced and in 26 out of 39 countries there is no statistically significant difference.
The results of the TIMSS 2015 tests also confirm that, in terms of gender differences in mathematics, the situation in Italy is well defined and critical. The overall average results of the Italian students are, in the tests of both levels, close to the overall average of all the countries involved, but it can be noted that at grade 8, and even more at grade 4, Italy shows a strong gender gap and this is clearly in evidence from the first years in which the surveys were carried out (Figure 4).

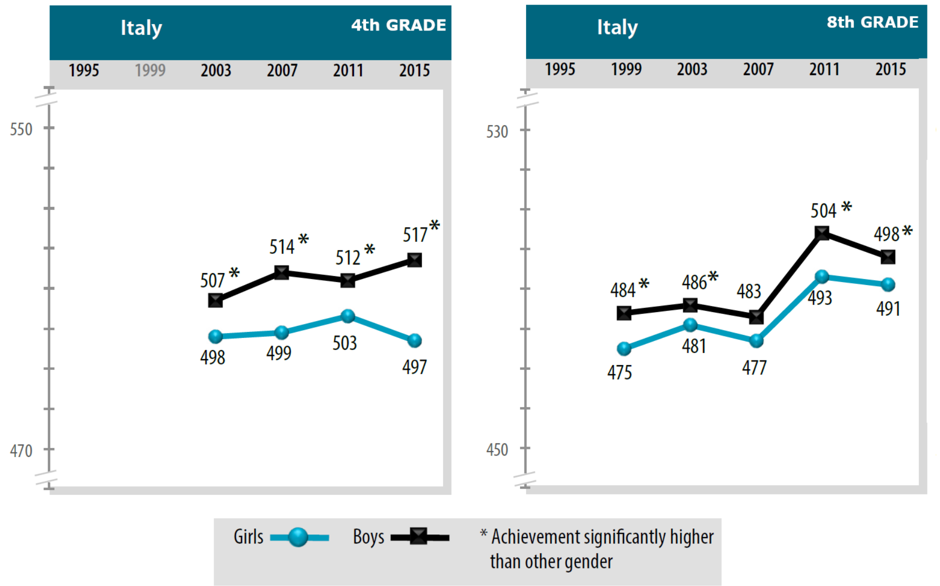


Figure 4
Evolution of gender gap in mathematics in TIMSS tests scores from 2003 to 2015 in Italy. Source: TIMSS 2015 International Results in Mathematics (Mullis et al., 2016).

3.3 Gender differences in Italy: from international surveys to INVALSI tests

As we have seen in the previous sections, the data reveal the Italian situation to be one of the most alarming in the international scenario: Italy is one of those countries in which the gender gap is most pronounced and gender differences in mathematics are also confirmed by the INVALSI tests carried out at national level (INVALSI, 2016; Contini, Di Tommaso & Mendolia, 2017).

In Italy, since the 2007/2008 school year, the National Evaluation Service (SNV), which is part of the INVALSI Institute, has administered standardised tests of mathematics and Italian (grammar and text comprehension) at different school levels. The main objective of the INVALSI tests is to evaluate the effectiveness of the national education system, through the collection of information on students' learning in mathematics and Italian (since 2018, surveys in secondary schools also involve English).

The INVALSI tests have thus been administered in Italian schools for almost a decade and offer an enormous quantity of data on Italian and mathematics learning of students from primary to secondary school. Nevertheless, the use of these tests in the field of research in mathematics education is still limited (Maffia & Giberti, 2016) and, considering the issue of gender differences in mathematics, these data are used almost exclusively from a statistical point of view: there is a lack of didactic interpretation of this phenomenon at national level. In the INVALSI National Reports, the gender gap is usually presented in terms of the difference between the average scores obtained by males and females within the test.

The latest INVALSI findings show marked differences between the performance of males and females in mathematics and confirm the evidence from the international surveys PISA and TIMSS.

The following graph (Figure 5) shows the results of INVALSI mathematics tests administered in 2017 at different scholastic levels. For each school level, the average score achieved by girls (in pink) and the average score achieved by boys (in blue) is reported, with their confidence intervals. The results, in accordance with those of the previous INVALSI surveys, show a gender gap statistically significant at all school levels involved: second and fifth grade of elementary school, third year of middle school (grade 8) and second year secondary school (grade 10).[4]

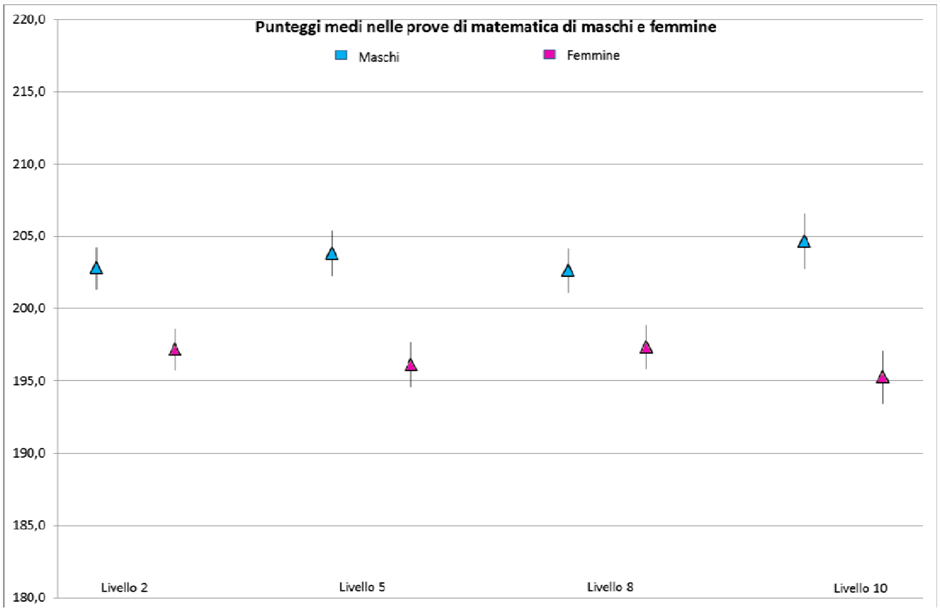


Figure 5
Results of males and females in the INVALSI math tests of 2017 in the different scholastic levels. Source: Rilevazione Nazionale degli apprendimenti 2016-17 – Rapporto Risultati (INVALSI, 2017).

4

With regard to the results of grade 10, moreover, it can be seen that the gap between males and females is present in all types of school but is more marked in professional, then technical and finally high schools (INVALSI, 2017).

4 Gender differences in mathematics: the current situation

Gender differences in mathematics has been widely debated in recent decades and there are numerous studies that have investigated the characteristics and causes of the gender gap in mathematics in favour of males (Leder & Forgasz, 2008; Forgasz, Becker, Lee & Steinthorsdottir, 2010; Forgasz & Rivera, 2012; Contini et al., 2017).
In the following sections, still bearing in mind the specific Italian context, we will attempt to provide an overview of the characteristics of gender gap in mathematics and an interpretation of its causes as revealed by the main research studies on the phenomenon.

4.1 Evolution of gender gap during school years

According to various research studies, gender differences in mathematics are not yet present at pre-school age but emerge during the first years of school.
At the end of elementary school, the gap in performances by males and females is evident and this continues to increase in middle and high school (Fryer & Levitt, 2010; Hyde & Mertz, 2009; Hyde, Fennema & Lamon, 1990; Spelke, 2005).

4. In Italy there are three years of middle school and five years of secondary school.

Fryer and Levitt (2010) have analysed mathematical performances of males and females from kindergarten to the end of elementary school (grade 5). They highlight that the gap begins in the early years of school and increases as the years go by.
To date, several years on from their introduction, the INVALSI tests administered in Italy can be used for studies similar to that of Fryer and Levitt, which was developed in the U.S. In a recent study based on INVALSI data, Contini et al. (2017) observe the evolution of the gender gap in mathematics also in the Italian context, and note an overall widening of the gap in favour of males from grade 2 to grade 10; however, the increase in the gap is concentrated in elementary school years and in the transition from grade 8 to grade 10, remaining almost stable during the middle school years.

4.2 Distribution of the gender gap with reference to students' levels of ability

Standardised testing and the use of statistical models for data analysis also make it easy to highlight whether a gap is particularly marked for certain skill levels of students.
From the study by Fryer and Levitt (2010), it emerges also that the gap between males and females, in favour of the first ones, is greater if we compare the results of students with high ability levels in mathematics. While girls in kindergarten occupy 45% of the 5 highest percentiles, after five years of school only 28% of the 5 highest percentiles is made up of females.
Again from the analysis of PISA 2009 data, it emerges that in most of the participating countries there is a significant gender gap in mathematics in favour of males, which is more marked among students with high levels of ability (González de San Román & De La Rica, 2012). This is also confirmed by the results of the 2012 and 2015 PISA tests: although there is considerable variability among the countries involved in the survey, girls are underrepresented among the *highest-achieving* students (OECD, 2016a; OECD, 2012). As previously noted, in 2015 the average gap between male and female performance in OECD countries is 8 points but this gap doubles when considering only the 10% of males with best performances and the 10% of females with best performances (OECD, 2016a).
According to PISA surveys, Italy is one of the countries in which this phenomenon is most evident and in 2015 only 8% of girls reached the highest level in the PISA scale as compared with 13% of boys (OECD, 2016a). Contini et al. (2017) confirm these results by analysing the INVALSI data and, through a longitudinal study of the tests from grade 2 to grade 10, note that at grade 2 the gender gap does not exist for lower ability levels and it is only slightly marked also for medium and high ability levels; over the years this gap appears even for the lowest ability levels of the distribution but the growing disparity between male and female results is much more marked in high ability levels.
The research on the issue of gender gap is very controversial and the literature supplies also several studies that do not show a statistically significant gap. As already pointed out, the reasons for this may be related to geographical non-homogeneity of the phenomenon and therefore of the countries involved in the surveys, but a second cause could also be the non-uniformity of the gap with respect to the math ability level of the students.
One article that has caused considerable discussion in this sense was that published by Hyde, Lindberg, Linn, Ellis, and Williams in 2008 in Science Magazine. In ana-

lysing the data of standardized tests of the United States, Hyde and his colleagues conclude that «*In contrast to earlier findings, these very current data provide no evidence of a gender difference favouring males emerging in the high school years*» (Hyde et al., 2008, p. 494). In the same year, Leder and Forgasz (2008) highlight the possible causes that led Hyde to produce results that conflict with most research findings in the field. Among the reasons given, the main explanation is related to the fact that gender differences are more visible for high ability levels. Leder and Forgasz explain that Hyde and colleagues' use of tests consisting mainly, in items of medium and low cognitive level, may be the reason for the lack of a gender gap in their study. Therefore, an in-depth knowledge of the peculiarities of this phenomenon also allows a deep reflection on what constitutes a suitable tool for best detecting gender differences: test construction should always take these factors into account.

4.3 Interpretation of factors determining the gender gap

With regard to the identification of factors underlying the gender gap, the literature is very broad and debated: we found interpretations of biological, social, cultural and psychological nature and these must be considered together to fully understand this phenomenon. In particular, it is possible to distinguish between so-called *internal factors* (i.e. factors dependent on the individual) and *external factors* (factors dependent on the socio-cultural and environmental context).

Internal factors

Some studies also consider biological and physiological differences (Baron-Cohen & Wheelwright, 2004; Gallagher & Kaufman, 2004) as some of the internal factors that may allow males to better develop some skills related to learning mathematics. On the other hand, the variability of the phenomenon between one country and another (as shown by international surveys) seems to show the limits of this interpretation as a single explanation. (Contini et al., 2017; OECD, 2016a; Hill et al., 2010). The differences in the main cognitive abilities do not seem to be so great as to explain the gender gap in mathematics. Many studies, in fact, claim that there are no significant differences in general cognitive abilities (Ruffing, Wach, Spinath, Brünken & Karbach, 2015; Halpern, Beninger & Straight, 2011). Only in the case of visual-spatial abilities has some research shown better results for male students (Lawton & Hatcher, 2005). On the other hand, such skills can be easily developed through targeted and short-term training: the gap in this sector could therefore be easily filled (Hill et al., 2010).

Among the factors closely related to the individual that have been studied in relation to the gender gap, there also figure psycho-social factors related to motivation, student beliefs and their confidence in their own abilities (Winkelmann, van den Heuvel-Panhuizen & Robitzsch, 2008). Already in elementary school, studies observe a lower confidence in math skills on the part of females and, even when the results between the two genders are similar, it seems that female students tend to underestimate their self-abilities in relation to their male peers (OECD, 2015; Fredericks & Eccles, 2002; Herbert & Stipek, 2005).

In this direction, the OECD mainly analyses three constructs related to mathematics: *math self-concept, math self-efficacy and math anxiety*. The first two constructs fall within self-beliefs and are strictly interconnected while reflecting different aspects relating to the sphere of beliefs, motivations and emotions of students doing math-

ematics. In fact, *self-efficacy* concerns the feelings and beliefs of the students when they have to solve a specific problem (e.g. solve an equation), while in the case of *math self-concept* the questions addressed to the students are more general and related to the overall discipline, not to a specific task (Pajares & Miller, 1994).
The roles of *self-efficacy* and *self-concept* are fundamental in the learning of any discipline but particularly in the case of mathematics (OECD, 2015; Marsh & O'Mara, 2008): a student with scarce confidence in his/her own abilities will in fact be less confident when faced with a task and, when in difficulty, he/she will be less inclined to persevere in order to achieve the objective.
The results reported on these factors are taken from the PISA 2012 survey - since mathematics was the focus of that year' survey, the context questionnaires were also aimed at investigating aspects related to the learning of mathematics. From these questionnaires, it is therefore possible to obtain information on aspects related to the psychological and metacognitive sphere of mathematics learning. In particular, in the OECD PISA 2012 report it emerges that, even in middle and secondary school, there is still a considerable difference between boys and girls both in terms of *self-efficacy* and *self-concept* in mathematics.

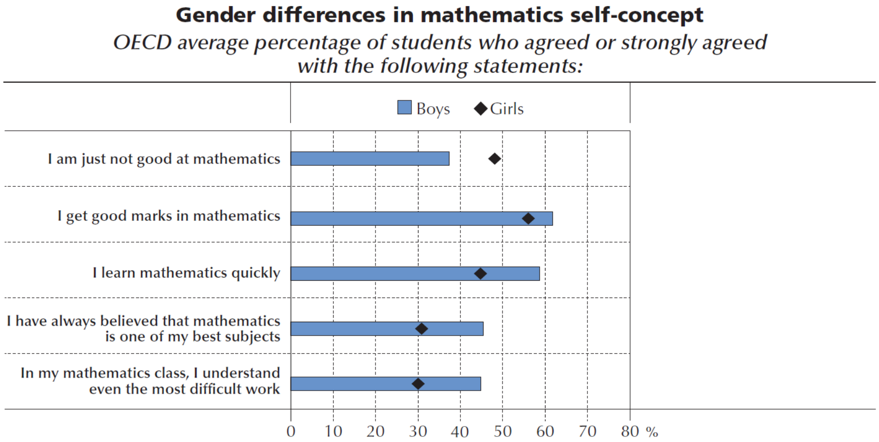


Figure 6
Math self-concept in relation to gender, data from the OECD PISA 2012 survey. Statistically significant differences are highlighted with darker colours (in this case, they are all significant). Source: *The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence.* (OECD, 2015).

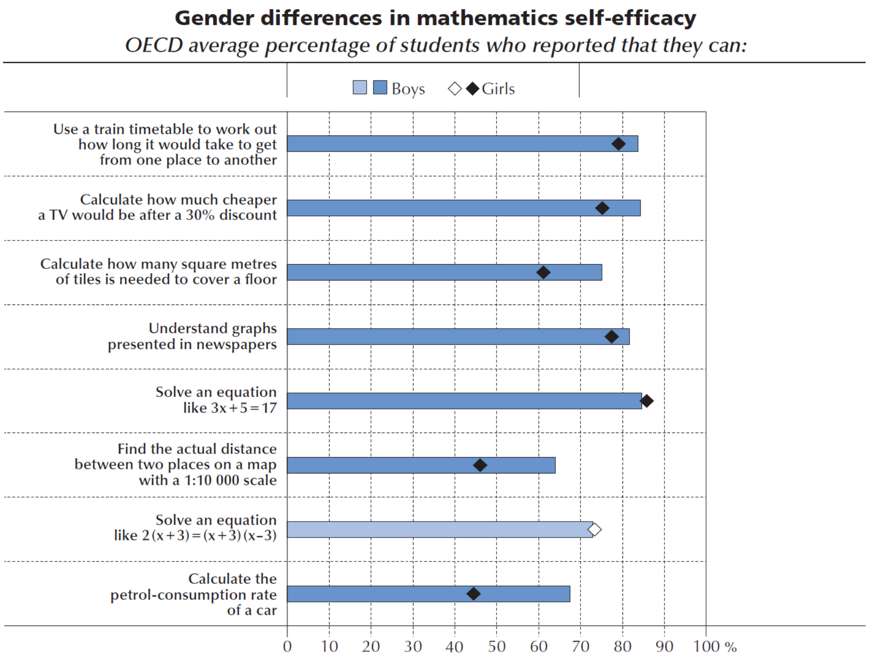


Figure 7
Math self-efficacy in relation to gender, data from the OECD PISA 2012 survey. Statistically significant differences are highlighted with darker colours. Source: *The ABC of Gender Equality in Education: Attitude, Behaviour, Confidence.* (OECD, 2015).

As can be seen from the above plots (**Figure 6** and **Figure 7**) concerning the 2012 PISA survey, girls in general show less confidence in their own abilities in mathematics. Females consider themselves less skilled at math than males, affirming that they are not fast in learning the subject and that they are often in difficulty, especially when dealing with more complex tasks (**Figure 6**).
From the same plots, relating to the *math self-concept*, we can see that the answers of males and females are quantitatively closer only if they have to answer on the basis of an external reference, such as school grades. From the OECD surveys, we also observe that the difference between males and females regarding *math self-concept* are present even when considering students with the same math ability or the same test results, and these findings are in accordance with previous relevant literature on self-beliefs and gender gap in mathematics (OECD, 2015; Jacobs, Lanza, Osgood, Eccles & Wigfield, 2002; Hill et al., 2010).
As for *math self-efficacy*, it is interesting to note (**Figure 7**) that the only two tasks in which the difference is not in favour of males are those in which it is necessary to solve an equation: in this case we are dealing with exercises solvable through the application of routine procedures, and already performed in the classroom - this apparently allows girls to have greater confidence in their problem-solving ability.
Another very important construct used to analyse the different mathematical results of males and females is *mathematical anxiety*, defined as an emotional reaction against mathematics or the prospect of mathematics (Hembree, 1990).
Numerous studies have shown that being anxious, frightened and tense in dealing with a mathematics task leads students to achieve results inferior to their abilities (Hembree, 1990; Ma, 1999; Dowker, Sarkar & Looi, 2016; Primi et al., 2014; OECD, 2015).
The OECD results for the 2012 PISA test show a clear difference in *anxiety* levels between boys and girls (**Figure 8**), also confirmed by numerous other studies both internationally (Dowker et al., 2016; Hembree, 1990; Devine, Fawcett, Szűcs & Dowker, 2012), and at the national level (Primi et al., 2014; Cargnelutti, Tomasetto & Passolunghi, 2016).

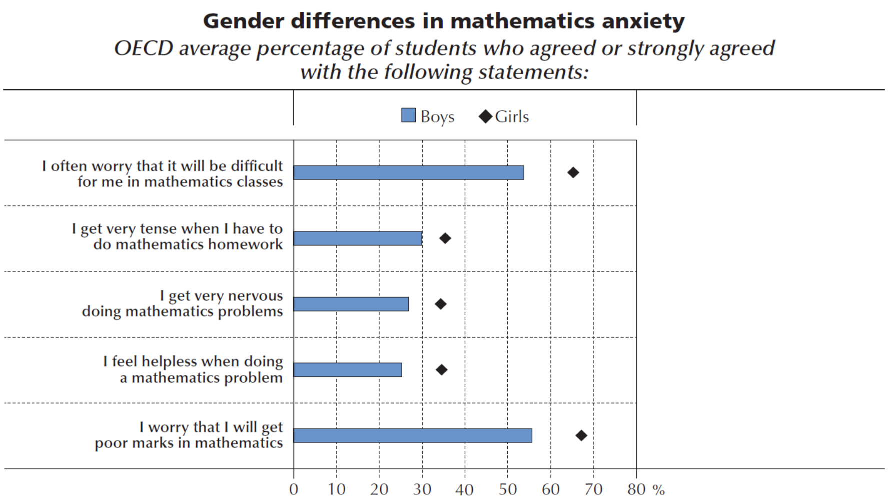


Figure 8
Math anxiety in relation to gender, data from the OECD PISA 2012 survey. Statistically significant differences are highlighted with darker colours (in this case they are all significant). Source: *The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence.* (OECD, 2015).

It is interesting to note that, if we consider males and females with equal levels of *math anxiety* and math *self-beliefs*, the gap in the results of math tests disappears (OECD, 2015).

Moreover, the analysis of the results in mathematics in relation to the self-regulation model, defined as the ability to control, direct and plan one's thoughts, emotions and behaviours (Schunk & Zimmerman, 1997) deserves a separate discussion. From the point of view of discipline, respect for rules, participation and self-control, girls generally perform better than boys (OECD, 2015; Matthews, Ponitz & Morrison, 2009; Calkins, 2007; McClelland & Cameron, 2011) and this also favours them in their academic performance in various disciplines, including mathematics. In a recent study in Germany, Weis, Heikamp and Trommsdorff (2013) highlighted that, even if there is no significant gender difference when considering only the performance in mathematics, this result can also be due to better *self-regulation* on the part of the girls.

External Factors

To explain gender differences in mathematics, internal factors (of biological or psychological nature) must be accompanied by other factors, external to the individual and linked to the social and cultural context in which the student lives. In this perspective, there are several research studies that have linked the gender gap in mathematics with the main gender equity indices used in the economic and social fields. This research has shown that in societies where there is a greater general equality, the gap tends to disappear (Guiso, Monte, Sapienza & Zingales, 2008; OECD, 2015; Cascella, 2017).

One particularly significant study in this sense is that of Guiso et al. (2008) based on the analysis of the 2003 OECD PISA survey. The authors relate the gender gap in mathematics and in Italian (graph above in **Figure 9**) with one of the main indices used to highlight the gender gap in society: *GGI - World Economic Forum's Gender Gap Index* (graph below in **Figure 9**). This index reflects gender equality for each country, based on economic, political, educational and health conditions.

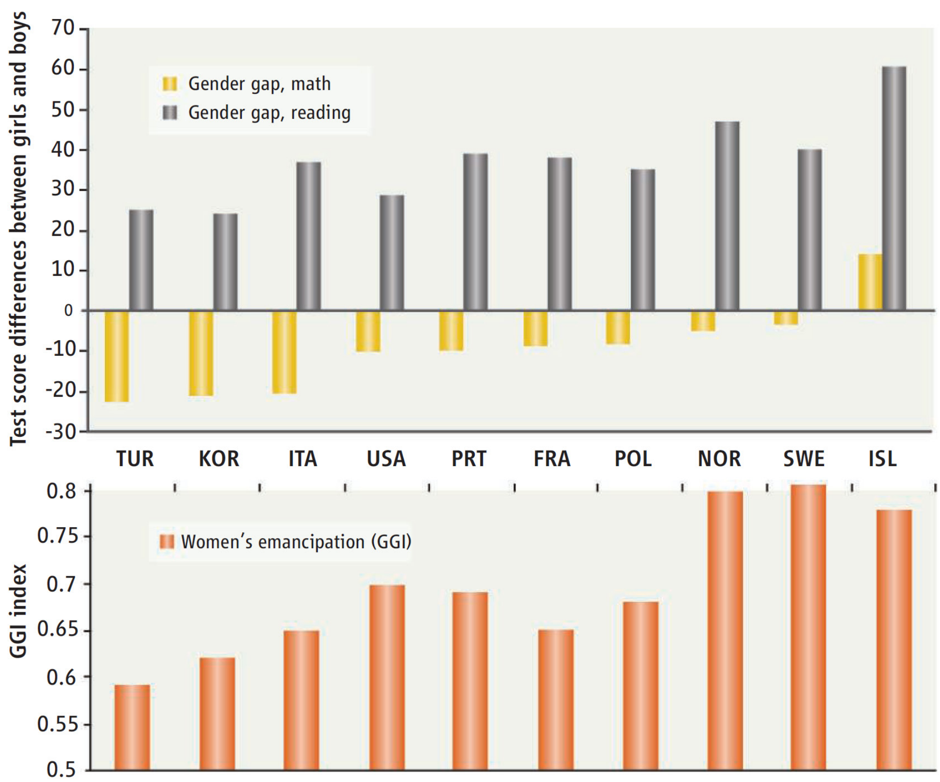


Figure 9
Analysis of the results of PISA 2003 tests of reading comprehension and mathematics in relation to the Gender-gap Index of each country. Source: *Guiso et al., 2008.*

In the above graphs, for each of the countries examined, the value of the Gender Gap Index (GGI) can be compared with the results of the PISA 2003 test in terms of gender gap in the math and reading test. Guiso et al. (2008) note that, in countries where the role of women in society has reached high levels of emancipation (GGI major), the gender gap in mathematics tends to close and the gap in favour of girls in the reading comprehension increases. These results are confirmed, in the same article, using other statistical indices based also on cultural factors.
From 2006 to 2017, the Global Gender Gap Report shows that Italy was in a rather critical situation in terms of gender equality: in 2017 Italy was 82nd out of 144 countries, a result much worse than most European countries. The analyses of Guiso and colleagues were also replicated by Fryer and Levitt (2010) and the results of the OECD PISA survey were confirmed. The same analyses, however, were also repeated using the results of the IEA TIMSS 2003 survey and, in this case, there was not the same correlation between the reduction of the gender gap in mathematics and gender equality in society. Fryer and Levitt explain that these differences are related to the fact that there are several countries participating in the two surveys: by narrowing the TIMSS results to the nations participating in PISA survey, the correlation between GGI and the decrease in the mathematical gap emerges again. The nations that participate exclusively in TIMSS surveys are mainly Middle Eastern countries, where the role of women is very disadvantaged in society but, unexpectedly, the results in mathematics do not seem to be affected (Fryer & Levitt, 2010), this could be due to problems of representativeness of the sample, as already explained in the previous sections.
These studies show how fundamental the role of culture and society is in students' education and to what extent the achievement of real social gender parity can positively influence the possibilities of future generations. Research has focused on the economic and social consequences caused by gender disparities in education and, for example, have found less economic growth in countries where inequalities are greater (Klasen, 2002). Furthermore, educational policies aimed at achieving gender equality opportunities in the field of education benefit future generations as it has been seen that, if women and mothers achieve more emancipatory roles in society, this has a positive influence on education and children's health (Schultz, 2002; Doepke, Tertilt & Voena, 2011; Farré & Vella, 2013).
There are many studies that emphasize the importance that the mother assumes within the family and society, and how this affects the mathematical performance of children and, in particular, of daughters (Fryer & Levitt, 2010; Jacobs & Eccles, 1992; González de San Román & De La Rica, 2012).
The learning of mathematics and the disparity in the results in this discipline are influenced by the context, the socio-economic and cultural features of each country and the role of women in society. There are also studies based on more recent investigations that have confirmed these hypotheses and investigated in depth the relationship between women's emancipation and gender gap in mathematics. For example, the research of González de San Román and De La Rica (2012), through an analysis of the PISA 2009 results, confirms the strong influence of social and cultural norms of a country on gender differences.
In determining the observed gender differences, factors that are more closely related to the convictions and psycho-social sphere of the individual are considered relevant. In fact, the beliefs of teachers and parents play a fundamental role as regards the different abilities of males and females in mathematics, and the stereotypes that see

boys as more predisposed towards scientific subjects while girls tend towards literary subjects.

All this has been found to have a significant influence on students' perceptions of their own capacities (beliefs about themselves) and therefore affect their real performance (Jacobs & Bleeker, 2004; Riegle-Crumb, 2005; Fryer & Levitt, 2010).

The stereotypes linked to gender that are rooted in the culture of our country and many others, continue to promote the idea that males are naturally more inclined towards scientific subjects and also influence the way in which parents act towards their children from the first years of life (Jacobs & Bleeker, 2004; Tomasetto, 2013; Tomasetto, Mirisola, Galdi & Cadinu, 2015). Parents have different behaviours and expectations towards a son or a daughter, and a different perception about their abilities and successes in mathematics (Tiedemann, 2000; Tomasetto, 2013). All this is reflected in the perception that the student has of his/her own abilities, thus acting to the disadvantage of girls in scientific subjects and, in particular, in mathematics (Jacobs & Eccles, 1992; Spinath & Spinath, 2005; Tomasetto, 2013).

It is also very interesting that there are different motivations that parents put forward to justify a success or failure in mathematics; these motivations depends on the sex of the child: the success of sons is often associated with a natural predisposition for the discipline while for females success is considered more often the result of commitment and constancy; as regards failure, parents tend rather to explain them as a lack of commitment by their sons and a poor ability of their daughters (Eccles, Jacobs & Harold, 1990; Yee & Eccles, 1988; Tomasetto, 2013).

However, stereotypes do not affect only parents; teachers also show that they are influenced by the same beliefs and tend to credit boys with greater mathematical skills than girls (Helwig, Anderson & Tindal, 2001; Li, 1999).

The impact that teachers' and parents' convictions have on students' abilities is significant and the fact that female students are deemed to be less gifted in mathematics than their male peers means that they themselves have less confidence in their abilities and therefore obtain lower results (Lindberg et al., 2010).

Finally, factors that are closely linked to the school context and teaching practices can also provide a possible key to understanding gender differences in mathematics. In a 1992 paper, Leder highlights possible causes of gender differences in mathematics as including variables related to the specific curricula of the discipline: the topics covered, the type of questions, the evaluation and teaching methods all play a fundamental role in the emergence of gender differences in mathematics. More recent studies have confirmed this hypothesis and have shown that, in addition to variables related to the curricula, also the teaching and assessment methods, didactic practices and socio-mathematical norms that are established in class have a significant influence on the gender gap in mathematics (Leder & Forgasz, 2008; OECD, 2016; Giberti, Zivelonghi & Bolondi, 2016; Bolondi, Cascella & Giberti, 2017; Bolondi, Branchetti & Giberti, 2018; Ferretti, Giberti & Lemmo, 2018).

Learning abilities e learning strategies

As mentioned previously, the factors that influence the gender gap in mathematics include variables related to the specific contents of mathematics. It is therefore necessary to analyse the gender gap not only from the point of view of the entire discipline, but also presenting the mathematical ability in its many components and considering the different cognitive processes that students must activate in solving a mathematical task.

Females show greater difficulty than males in problem-solving activities, while they show equivalent or slightly higher skills in tasks that require primarily computational skills (Hyde et al., 1990; Byrnes & Takahira, 1993). Other studies have shown that males and females have a different way of tackling problem-solving activities and therefore adopt different strategies: girls tend to repeat routine procedures, already used and known algorithms, and conventional strategies, while boys, who are less fearful of making mistakes, tend to apply new unconventional methods and approaches (Bell & Norwood, 2007; Gallagher, De Lisi, Holst, McGillicuddy-De Lisi, Morely & Cahalan, 2000; Gould, 1996; Fennema, Carpenter, Jacobs, Franke & Levi, 1998).
This evidence, now confirmed by recent studies also in the psychological field, had already been presented in 1998 by Fennema and Carpenter in a longitudinal study concerning the first years of elementary school. The researchers did not find particular gender differences except in the case of a specific type of problem (extension problems) and exclusively in degree 3, but at the same time

> «significant differences in problem-solving strategies were found in all grades. Girls tended to use concrete solution strategies like modelling and counting, and boys tended to use more abstract solution strategies that reflected conceptual understanding».
>
> (Fennema & Carpenter, 1998, p. 4)

Again in this case, the different problem-solving strategies do not seem to be strictly linked to different biological characteristics between males and females, but rather to socio-cultural factors linked to the sphere of convictions. Among these, we surely find girls' lower confidence in their abilities, widely diffused stereotypes (for example, *good girls follow the rules*) (Langer, 1997), and factors related to teaching, the school system and classroom practices (Boaler, 1997).
From this perspective, the comparison with other research studies related to learning strategies applied by students when tackling different subjects is particularly interesting. There are no differences in cognitive skills (Halpern et al., 2011), but there are significant gender differences in learning strategies (Kesici, Sahin & Akturk, 2009; Marrs & Sigler, 2012; Virtanen & Nevgi, 2010).
The literature shows how strong an influence cognitive skills and learning strategies have on student performances; this is true even in predicting academic success (Rohde & Thompson, 2007; Richardson, Abraham & Bond, 2012). A recent article by Ruffing et al. (2015) address gender differences and learning strategies on the basis of their impact on academic performance. From this paper it emerges that there are no particular differences in terms of cognitive abilities, but that males and females show a different approach to the learning strategies taken into consideration. In particular, the following learning strategies are considered:
- *Effort*
- *Attention*
- *Organization*
- *Relationship*
- *Rehearsal*
- *Critical evaluation*
- *Time management*
- *Learning environment*
- *Learning with fellow students*

– *Literature*
– *Meta-cognition*

Among these we find only two strategies that are more popular with males than females: *Relationship* and *Critical Evaluation*. Girls, on the other hand, show a greater use of many of the remaining strategies: *Effort, Organization, Rehearsal, Time Management* and *Meta-Cognition* (Ruffing et al., 2015).
Differences in learning strategies can clearly be the underlying cause of the very different characteristics of learning for males and females. These results could be a possible explanation of some phenomena observed in the learning of mathematics: the girls' focus mainly on the commitment, on organization of study and on the repetition of concepts, could be more related to the procedures already seen in class or when studying at home, leaving them less ready to respond to new stimuli which require learning based on a deep understanding of concepts in order to rework them.

5 Conclusions

The results of standardized tests are an exceptional tool for the study of the gender gap in mathematics and allow researchers to highlight the main characteristics of this phenomenon. In particular, from an analysis of the PISA and TIMSS tests it is clear that not all nations display a statistically significant gender gap in favour of males, and this leads to the exclusion of biological differences among the main causes of gender differences; the hypothesis is that the nature of this gap is due rather to social and cultural factors.
Research studies show that it is not possible to identify a single cause of the gender gap in mathematics, but rather that there are many different factors to consider.
Social and cultural aspects are particularly important; for example, the level of emancipation of women in society. Stereotypes, linked to the history and culture of society and of the family itself, are another important factor because they have an impact on the approach to mathematics and on psychological and metacognitive factors. These factors can lead to a different approach to the subject and also influence the way of dealing with a specific mathematical delivery.
The psychological differences between males and females, such as greater *math anxiety* and less confidence in their abilities for girls, but accompanied by greater control and discipline, can have a significant influence on the attitude of students in the classroom and on the relationship that is established with the teacher and towards mathematics.
There are also significant differences in terms of learning strategies for males and females, a greater difficulty on the part of female students in tackling problem-solving activities due to a greater fear of making mistakes, and a greater reticence in adopting new strategies to solve known algorithms and routine procedures. This evidence is particularly important for research in mathematics education and for teachers themselves who can adapt their teaching methods by taking into account these differences in order to fill this gap.
In fact, it is essential to tackle this phenomenon by considering not only the effects of social and cultural nature in general, but also micro-social factors, related to the

habits of the classroom context, the relationship with the teacher and teaching practices.

The incidence of micro-social factors, related to teaching and classroom practices, is also supported by the fact that, as noted in the previous paragraphs, gender differences in mathematics emerge during the first years of school and increase as the years go by, and it is at this level that the action of the individual teacher can have maximum effectiveness.

The PISA and TIMSS tests show that in Italy the gap between the performances of males and females in mathematics is one of the most marked. The INVALSI national tests confirm this gap at all school levels. In Italy, this phenomenon is accompanied by an even more general decline of the *Gender Gap Index*, linked to gender equality, taking into consideration the gap between men and women in four areas: work, education, health and political representation.

It is therefore necessary to consider the issue on two different levels: the first, political, to understand why Italy is still in a situation so critical in terms of gender equality, and the second, didactic, to investigate more in depth how these disparities affect students' performance in mathematics.

Awareness of this phenomenon, which is particularly marked in Italy, can lead teachers and educators in general to reflect on their convictions and on their approach to the discipline. Collaboration between teachers and the research world in education can help identify the difficulties that hinder girls in mathematics and ascertain whether these are linked to particular contents or transversal skills. In this way it will be possible to elaborate didactics aimed at closing the gap in mathematics between males and females.

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