Mathematics in Southern Europe: Mathematics Education and Performance, Through the Prism of PISA, in Greece, Italy, Portugal and Spain

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Abstract
A mathematically literate student, according to PISA and OECD, recognizes the role that mathematics plays in the world in order to make well-founded judgments and decisions needed by constructive, engaged and reflective citizens. Among European countries who have participated in PISA since 2000 till today, the top performing countries in mathematical literacy are concentrated more in East and North Europe and as a consequence, researchers are showing more interest in these European regions. The analysis and research pertinent to the Southern European countries' mathematical literacy competences of their 15-year-old students and their mathematics education systems is relatively scarce. The four Southern European countries that we will focus on this research are Greece, Italy, Portugal and Spain. More specific, Italy, Portugal and Spain scored at a similar level in mathematics over the period 2009-2018. On the other hand, Portugal and Italy have both showed a significant improvement in mathematics performance of their students throughout their participation to PISA. In contrast, Greece appears to have a stable mean performance and has a difference of more than 30 points ranking below the other three countries over the period 2012-2018. This paper aims to record Greek, Italian, Portuguese and Spanish students' mathematics achievements in PISA as they are formed over time. At the same time, it attempts to identify the similarities and differences of their educational systems with regard to their mathematics education and some reasons or factors that have led Southern European countries to these positions in PISA's ranking.

Keywords: Mathematical Literacy, Mathematics Education, PISA, Southern Europe

1 INTRODUCTION

The modern societies and economies of 21st century "*reward individuals not for what they know, but for what they can do with what they know*" (OECD, 2019).OECD, has been promoting this fact through the Programme for International Assessment (PISA), which is held every three years, and assesses how well students can extrapolate from what they have learned and can apply that knowledge in unfamiliar settings, both in and outside their school context/environment. One of the three basic subjects that are being assessed by PISA is Mathematics. It seems very important for PISA to understand the degree to which 15-year-old students, who they are approaching the end of compulsory education, are adequately prepared to apply mathematics in order to understand important issues and to solve meaningful problems that arise from daily life (OECD, 2019). In order to encapsulate this broader concept of mathematics knowledge and skills, PISA constructs and assesses the concept of mathematical literacy which is defined as "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 recognize the role that mathematics play in the world and to make the well-founded judgements and decisions needed by constructive, engaged and reflective citizens" (OECD, 2019).

PISA, except for measuring students' achievements in mathematical literacy, it is also regarded as one of the most prominent comparative and influential educational international assessment programs and has had a large impact on educational practices and reforms in many countries through the world. Its value also lies in providing international benchmarks, by comparing students' performance between different countries directly or over time (Breakspear, 2012). One of the ET2020 benchmarks which is included in the strategic cooperation framework "Education and Training 2020" reports: the rate of underachievers[1] in reading, mathematics or science among 15 year-olds in the EU should be less than 15% by 2020.

The biggest attention for researchers is usually devoted to the countries where the highest PISA scores are recorded, in order to identify and incorporate the factors producing the "good" results. Among European countries the countries with the highest scores in PISA 2018 in mathematics, were Estonia, Finland, Poland, Denmark which are the countries who have met the 15% ET2020 benchmark and are followed by Ireland, the Netherlands and Slovenia. Between the above countries, Finland used to be for years the most commonly listed influential European country, like for Greece and Spain (Breakspear, 2012), while in more recent years, Estonia is in the spotlight (Tire, 2021). Most of these countries are located in Northern and Eastern Europe. "Always the gaze seems to be to the North" (Prokou, 2018). Southern European countries, despite their common features, have so far not been in the spotlight for researchers, analysis and comparative educational studies (Novoa, 2018), even if Portugal the last PISA years appears to have taken a quantum leap (Crato, 2020) and is referred as "Europe's biggest success story at PISA" (Maroco, 2021).

The Southern European countries which are included in the present paper are Greece, Italy Spain and Portugal. Except for the same climate, the same landscapes, the same way of life

[1] As underachievers in PISA are defined those students who fail to reach the minimum proficiency level necessary to participate successfully in society (European Commission, 2019).

that they are all four sharing (Guimaraes et al., 2018) they are also having common characteristics such as their similar socio-political and contemporary economic situations. Moreover they have had cultural affinities and long-lasting historical and cultural interactions between each other. According to some recently research regarding their education, a common feature seems to be the lack of decentralization in educational decision making (Argyropoulou, 2015). Moreover in these countries the provision of education is mainly done by the state with private education accounting a small percentage, teachers are referred to, as civil servants after being appointed and paid also by the state (Argyropoulou, 2015). Their different positions in world dynamics influences the comparative education section (Palomba & Capa, 2018). The Southern-European countries are seen as eternally attempting to bridge the various types of gaps that divide them from the Western-European countries which are considered more 'advanced' (Palomba & Cappa, 2018).

The present study addresses the following questions: How students' performance on PISA's mathematical literacy of the four southern European countries has been shaped over time? What are their basic characteristics and reforms of mathematics education the last 20 years, which may have emerged on the occasion of PISA's results or may have affected the PISA's mathematics results? What are their basic similarities or differences of the four educational systems with regard to their mathematics education or reforms?

2 METHODOLOGY

This study is primarily based on the data of the mathematical literacy achievements and performance of the 15-year-old students recorded in the four selected Southern European and OECD countries participating in PISA. More specific this data comes from the online available PISA database for the years between 2000 and 2018. Moreover, more data for the present paper comes from available online policy documents for all four countries and research reports. The method of this study is the collection and review of the available literature.

3 RESULTS

3.1 PISA and Mathematics performance

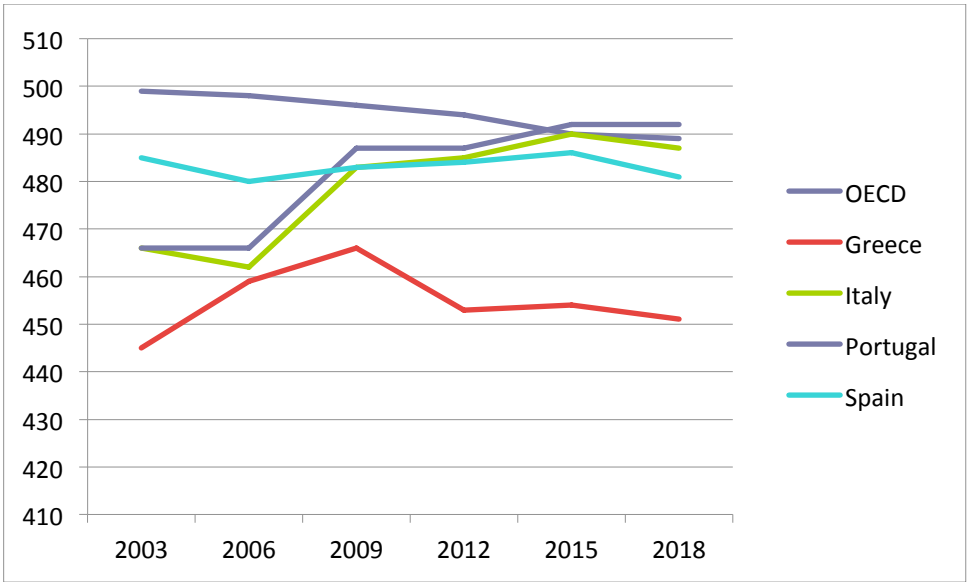

Figure 1. Average mathematics performance in PISA over time

Greece's mean performance in Mathematics has been consistently below the OECD average ever since it participated in PISA with an average difference from it, around 40 score points. It is described by OECD as hump-shaped, mainly due to a spike in performance in PISA 2009 while the performance in all other years was stable (OECD, 2019b). Stable has remained also Spain's[2] mean mathematics performance, around a flat trend line and below the OECD average, with an average difference around 11 score points, throughout the country's participation in PISA, and above Greek's mean scores with an average gap of 30 scope points. In Italy, mean performance in mathematical literacy has improved since 2003 and 2006, by an average of 20 score points, and then remained stable after 2009, with scores in 2015 and 2018 around the OECD average. According to the OECD country's note of PISA 2012, Italy was one of the countries with the largest improvement in mathematics performance since 2003. Similarly to Italy, Portuguese students' mean performance in Mathematics has improved since 2003 and 2006 while their mean performance in 2018[3] was close to the level observed over the period 2009-2015 and is placed above the OECD average. According to PISA's 2018 reports, Portugal is the only member of OECD that has experienced a significant improvement in its students' performance in all PISA's subjects, throughout its participation in PISA (OECD, 2019b). Both in Italy and Portugal the average 3-year trend in mathematics mean performance is statistically significant. Greek students' mean performance in mathematics appears with a difference of more than 30 points ranking below the other three countries over the period 2012-2018. Specifically, this difference between Greece and Portugal in 2018 reaches the 41 mean score points in Mathematics, which corresponds to one whole school year. Italy, Portugal and Spain scored at a similar level in mathematics over the period 2009-2018.

Furthermore, large regional differences in mathematics performance can be observed within Italy and Spain. In Italy the North-center regions perform generally better than the southern ones (Furno, 2021) and in PISA 2018, Trento and Bolzano scored close to the top performing European countries. The biggest regional gap reaches the 54 score points, a difference which is equivalent to more than one year of schooling. In Spain the picture is more diverse than in Italy, between 17 regions. The gap among Spanish regions is 92 score points in PISA 2018, the equivalent of more than two years of schooling.

The students who scored below PISA's level 2 are characterized as low performers[4]. The global indicators for the United Nations Sustainable Development Goals identify Level 2 as the "minimum level of proficiency" that all children should acquire by the end of secondary education (OECD, 2019b). According to PISA 2018 the share of Greek low achievers in Mathematics remains among the highest in the European Union with shrinkage of 3.1 percentage points, since 2003. Italy and Portugal reduced both their share of low achievers by

[2] In PISA 2018 OECD has decided to defer the publication of Spain's reading results due to the implausible student-response behaviour. The mathematics results, however, appear less affected by this anomalous response behaviour and they were published (OECD, 2018b).

[3] In PISA 2018 it was required that at least 80% of the students chosen within participating schools participated themselves and this percentage was not met by Portugal, where only 76% of students who were sampled actually participated. But, through a non-response analysis based on data from a national mathematics assessment in the country it was shown that the upward bias of Portugal's overall results was likely small enough to preserve comparability over time and with other countries. As a result, the data from Portugal were therefore reported along with data from the countries/economies that met this 80% student-participation threshold (OECD, 2019b).

[4] Low performers are characterized the students who cannot compute approximate price of an object in a different currency or compare the total distance across two alternative routes.

8.1 and 6.8 percentage points respectively, between 2003 and 2015, with almost similar percentage as the OECD average. Spain on the other hand increased this share by 1.7 percentage points, but its percentage of low achievers has been close to OECD average and close to Italy's and Portugal's in PISA 2012 and 2018.

On the other hand, the students who performed at or above PISA's proficiency Level 5 are characterized as top performers[5]. The share of Greek top performers and the Spanish ones has had no significant changes through the PISA years. According to Gomendio's research (2021), the low levels of Spanish students' mathematics performance and the stagnation over time seem to be explained mainly by the low proportion of Spanish top performers. However, in contrast to Portugal high achieving students have significantly improved their scores and exceeded the corresponding OECD share. In Italy the corresponding share also improved in 2018 since 2003, but without reaching the OECD average.

In PISA 2003 boys in Greece outperformed girls in mathematics by the notable amount of 19 points, but in PISA 2018 there was no difference between genders. This, however, is due to the reduction of boys' performance and not to the improvement of girls (OECD, 2019c). At the same time the boys from Portugal in PISA 2003 outperformed girls by an also notable amount of 12 score points, but in 2018 this gender gap was narrowed by 3 score points (OECD, 2004; 2014; 2019d). One of the largest gaps in favour of boys among PISA participating countries and economies through all PISA years is noted in Italy and has remained stable in all years, by an average of more than 16 points. In Spain the gap between boys and girls increased, in favour of boys, from the amount of 9 points in 2003 to the more notable amount of 16 points in 2012 and then in 2018 this gap was reduced to 6 score points close enough to the OECD average gap. Greece is the only country among the four, whose difference between boys' and girls' performance is lower than OECD's average difference in PISA 2012 and 2018. Portugal also in PISA 2012 reduced the gender gap in a lower amount than the OECD average but still, it came short the difference manifested in Greece.

In Greece, Portugal and Italy, the share of girls who did not reach the baseline level of proficiency was reduced between 2003 and 2018. In Italy and Portugal a reduction of low performing boys also took place between 2003 and 2018. Greece and Spain reduced the share of low performer boys between 2003 and 2012 but in 2018 this share increased, without big difference from the OECD average but higher than it. A notable increase in the share of both boys and girls, who performed at Level 5 and 6 between 2003 and 2018, was shown in Italy and Portugal, with Portugal surpassed the OECD average for boys in 2018. Spanish and Greek boys and girls top performers narrowed their share, but nevertheless, failed to reach such a notable amount, between 2003 and 2008.

3.2 Education policies and reforms in mathematics education the last two decades

3.2.1 Greece

In Greece, according to Breakspear's (2012) survey, "PISA has provided policy-makers with useful information and tools to improve the quality and efficiency of the existing education system in Greece". Nevertheless, the Mathematics performance of Greek students in all the cycles of PISA remains stable and below the respective OECD average (Nolka & Sofianopoulou, 2021). This stable and low position could be justified to some extend by the poor alignment of Greek mathematics curriculum and mathematics textbooks in lower

[5] Top performers are characterized the students who are capable of advanced mathematical thinking.

secondary school with PISA's mathematics framework and their strong content focus (Nolka & Sofianopoulou, 2021; OECD, 2018a; IEP, 2019). The latest revision and update of the mathematics curriculum for primary and lower secondary education dates back to 2003. According to a survey of the Greek Institution of Educational Policy (IEP, 2019), it was showed that in curriculum, mathematics applications appear as consequences and not as fields within which Mathematics emerge, as stated in PISA. The problem solving in curriculum appears as an application of a specific theory and not as a real-life problem which has an invisible or a subtle connection with the "theory", as encountered in PISA's mathematical literacy problems (IEP, 2019). Concerning the Mathematics textbooks which are a central tool for implementation of the mathematics curriculum, in lower secondary school, contain low percentage of real-life math problems (IEP, 2019). Moreover, in Greece, no national assessments in mathematics are performed in order to track student performance comparatively across schools, at a regional or national level, either in primary or lower secondary education. The only high-stake national assessment is the Panhellenic university admissions examination which is administered at the end of upper secondary education. In lower and upper secondary school, written progression and school leaving examinations are administered in Mathematics, which are performed by each school and their respective Mathematics' teachers (EC/EACEA/Eurydice, 2021a). In 2013 some efforts were made to create a more national approach to student assessment in selected school subjects, including mathematics, in grades 10 and 11, with national tests banks including question items at different levels of difficulty. In school year 2015/16 the use of these test banks was abandoned, given concerns about equity and early school leaving (OECD, 2018). So due to the absence of national standardized assessments in Mathematics to provide regular information about students learning outcomes (OECD, 2020), PISA results in Mathematics and data could be provide some evidence to this direction or an international overview of student's performance in relation to other OECD and European countries in order to develop a higher-quality and more equitable mathematics education (OECD, 2018).

3.2.2 Italy

Confronted with lower-than-expected results in student performance in PISA 2003 and 2006, the Italian Ministry of Education (MIUR) launched the program "Plan for information and awareness about the OECD-PISA study and other international researches" in 2008 (Arzarello et al., 2015). The program first involved Mathematics and Science teachers from 9th and 10th Grades and since 2009 the project has been enlarged for primary and lower secondary teachers, with main goals: i) the information of teachers about the OECD-PISA study in a clear and correct way, ii) the analysis of the PISA framework for Mathematics, particularly the structure of the test and the public items, iii) the comparison of them with the most diffuse didactical practices in Italian classrooms, iv) the analysis of Italian students' results in PISA study, v) the comparison of PISA mathematics framework with the one used by the Italian National Assessment System (SNV), which began to be applied in 2008. The National Institute for the Evaluation of the Education System (INVALSI) develops standardized national tests to assess students' mathematical competence, reading comprehension and grammatical knowledge and administers them to students of 2nd, 5th, 6th, 8th and 10th grade. Moreover, since 2008 in Italy, all students in grade 8 have had to face a final standardized SNV test on mathematical and reading competencies which is part of the national final examination and is carried out at the end of middle school (Arzarello et al, 2015; Garuti et al., 2017; Garuti & Martignine, 2015). The SNV tests differ from PISA in its frequency (annual vs. triennial), on the type of tested population (census vs. sample), on the target population (grade based vs. age-based students) and for its goals. The SNV tests

results aim to provide a national benchmark for the assessment of students at different grades taking into account the national curriculum (Garuti et al, 2017; Garuti & Martignine, 2015). Although the SNV framework is very strongly coherent with PISA framework, the items which are used in the Italian national assessments are asking for more arguments and proofs, which seem to reflect with a typical Italian tradition in mathematics teaching (Arzarello et al, 2015). Additional in 2008, the Italian Ministry of Education organized a teachers' education program, "the m@t.abel project" which means basic mathematics with e-learning, with the participation of teachers from grades 6th to 10th. The main aim of the project was to provide examples of best practices in mathematics classrooms, which are often drawn in coherence with PISA mathematics framework (Arzarello et al, 2015).

3.2.3 Portugal

The disappointing results of PISA 2000 for Portugal set the stage for the much-needed education reforms that took place in the following years (Maroco, 2021). Setting off in 2001, policymakers started to set the stage for the endorsement of a series of ongoing education measures by placing great importance on mathematical education (Maroco, 2021; Nolka & Sofianopoulou, 2021). In 2008 a new curriculum was introduced and in 2012/13 a revision of it for mathematics of the second cycle of primary and lower secondary education took place with the aim of setting learning standards of basic skills to be reached by all students and to give more flexibility over curriculum management (OECD, 2014). In 2017/18 a more flexible curriculum sprang from a pilot programme and has been in effect since 2018 (EC/EACEA/Eurydice, 2021b).

Concerning student's assessment, in 2003 the low-stakes were promoted and the corresponding high-stakes exams for Mathematics at the end of grade 9 were used in 2005 (Maroco, 2021). The application was also expanded (2012) to grades 4 and 6 (OECD, 2020b) but was terminated in 2016 (Santiago et al., 2012). Today, student's assessment includes both internal and external national assessment. The internal student summative assessment is organized by the schools while the external one is carried out by the Educational Evaluation Institute (IAVE) and involves national final exams at the end of basic education cycle, grade 9, in the subjects of Mathematics and Portuguese, whereas in grades 2, 5 and 8 standardized tests are administered. There are also national examinations in the end of general secondary education (EC/EACEA/Eurydice, 2021b; Liebowitz et al., 2018; OECD, 2020b). According to Marôco's and Lourenço's research, exists a concurrent and content validity of PISA with the national high-stake exams for mathematics (Crato, 2020; Maroco, 2021).

The implementation of the "Action Plan for Mathematics", in 2005, aimed at the improvement of students' motivation and the encouragement of positive attitudes towards mathematics learning and education. It is referred that "allows students to dedicate more time to the study of mathematics and focus on exploration, investigation and problem-solving" (EACEA/Eurydice, 2011). The six components of the plan were: i) implementing a mathematics plan in each school, ii) training teachers in basic and secondary schools, iii) reinforcing mathematics in initial teacher training, iv) readjusting the mathematics curriculum throughout the compulsory education system, v) creating a resource bank or database specifically devoted to mathematics and vi) evaluating textbooks on mathematics (OECD, 2013).

Another measure was the focus on mathematics teachers training (EACEA/Eurydice, 2011). Through the "Action Plan of Mathematics", the training of teachers in both primary and

secondary education, collaboration between them and co-teaching in the classroom were developed. Also, in measures like "Teams for Success", schools received support teachers, specialists in mathematics teaching, to help them implement innovative three-year projects focused on the improvement of students' mathematics learning, the promotion of professional development programmes, the creation of database of educational mathematics resources, the reorganization of initial teacher training programmes and access to STEAM teaching (Kearney, 2011). In additional, at the end of the school year, every school carried out self-evaluation within the scope of the Mathematics Plan II which included an evaluation of the strategies implemented, student performance in mathematics, and the development and implementation of the mathematics programme (EACEA/Eurydice, 2011).

3.2.4 Spain

The disappointing results of Spanish students in PISA 2003 provoked debate and generated significant attention in the media for weeks and the main issue raised, was to understand the reasons for the decline (Gortazar, 2018). Spain's education system is blind, since no national evaluations exist and no information is available on how students perform according to homogeneous standards. As a consequence, PISA's results represent the only information available concerning how Spain performs in relation to other countries and over time, but it also informs on the divergence between Spanish regions (Gomendio, 2016). Unfortunately, despite the furore over PISA, this did not lead to education reforms for more than a decade. The Spanish education system from 1990 till 2013 has followed the comprehensive model LOGSE, which was based on the premise that all students should be treated equally. The most extreme forms of LOGSE regard evaluations as a discriminatory tool that unfairly segregates students who fail (Gomendio, 2021). In 2013 an education reform (LOMCE) was approved with its implementation in primary school in academic year 2014/15. Three of the main pillars are: i) the modernization of curricula and the definition of evaluation standards to promote the acquisition of both knowledge and competences instead of the prevalent model which is required almost exclusively the memorization of the contents, ii) the re-definition of areas of the curricula that would be defined by the state and the regions and iii) the establishment of national evaluations that would in turn, allow the detection of students lagging behind early on, so as to provide the support required to catch up, and would signal the knowledge and competences required to obtain the degrees at the end of each educational stage, so that students, teachers and families would be aware of the standards required. However, the national evaluations were never fully implemented due to the intensity of the political pressures against them. In 2014/2015 the new curricular contents as well as the national evaluations in primary, were implemented, while in the following academic year, the full implementation of the calendar designed for evaluations at the end of lower secondary and upper secondary was interrupted (Gomendio, 2021).

4 CONCLUSIONS

Among the four countries that we analyzed in the present paper, Portugal and Italy have both showed a significant improvement in their 15-year old students' mathematics performance throughout their participation in PISA. Spain and Greece have shown a more stable curve in their students' mathematics performance. However, Spain scored similarly to Portugal and Italy during 2009-2018 and has scored far above them in the preceding years. Greece appears to have a difference of more than 30 points ranking below all the others over the period 2012-2018 while Portugal is the only that has exceeded the OECD average in 2015 and 2018.

In Spain and Greece due to the absence of national standardized tests in mathematics, PISA's assessment represent the only available information concerning the performance of their students in relation to other countries and also internally in each country over time. Despite the furore over PISA in Spain and the information of the disappointing results of Greece, didn't lead to mathematics education reforms, in Spain for more a decade and in Greece for almost two decades. On the other hand, in Italy and Portugal, the starting point for the ongoing education measures was the very first years of the disappointing PISA results. The implementation of national tests in Mathematics in compulsory education and the focus on mathematics teachers' training are two common educational reforms that have taken place in both countries. Moreover, in Portugal some other educational reforms were the frequent reevaluation or revision of mathematics curriculum in compulsory education and the improvement of the level of students' motivation in mathematics classrooms. In addition, Italy has managed to organize a program focusing specifically on PISA namely, the "Plan for information and awareness about the OECD-PISA study and other international researches".

With the optimistic examples of Portugal and Italy to stand out for their remarkable improvement among the countries of Southern Europe and even the whole of Europe, maybe it's time to turn the gaze into South. As long as PISA 2022 has Mathematics again as a major domain to be assessed, provides the opportunity to expand the comparisons in Mathematics students' performance in Southern Europe.

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