Chapter #1

MATHEMATICS EDUCATION AND PERFORMANCE, THROUGH THE PRISM OF PISA, IN GREECE AND PORTUGAL

Eleni Nolka[1], & Chryssa Sofianopoulou[2]
Harokopio University of Athens, Greece
[1]PhD Candidate
[2]Associate Professor

ABSTRACT
Greece and Portugal are two Southern European countries, with nearly the same population as well as a centralized educational system, which were both deeply affected by the economic crisis during the last decade. Despite being severely hit by the economic crisis, Portugal has advanced to the OECD average level in its students' mathematical performance in the Programme for International Student Assessment (PISA 2018), while Greece has performed below the OECD average. PISA, as one of the most influential international educational surveys, aims to evaluate educational systems and provides a valuable platform for comparisons. In the first PISA 2000, Portuguese students outperformed their Greek counterparts by only 7 points and went on to widen the difference by 41 points in PISA 2018. What national strategies have been set up and implemented in Portugal so as to foster student's mathematical literacy competencies? The main aim of this study is, through a recording of the Greek and Portuguese students' mathematics achievements in PISA and at the same time of the mathematics education in both countries, through available policy documents and research reports, to comment on the current outcomes of the two educational systems and their students' performance in Mathematics.

Keywords: mathematics education, mathematical literacy, PISA, Greece, Portugal.

1. INTRODUCTION

One of the key competences necessary for personal fulfillment, active citizenship, social inclusion and employability in the knowledge society of the 21st century, is the mathematical competence (European Commission, 2011). Therefore, an understanding of mathematics is recognized by OECD as pivotal to a young person's preparedness for life in modern society and through the Programme for International Assessment (PISA), it measures the achievement of 15-year-old students on 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 plays in the world and to make the well-founded judgments and decisions needed by constructive engaged and reflective citizens" (OECD, 2019a, p.75).

The intertemporal importance of PISA can also be located to the point that it has changed the philosophy of world educational policies, by giving feedback to policy-makers to reevaluate their educational system. That's exactly what happened in Portugal, starting from 2001 when the results of first PISA 2000 were published and were disappointing for

Portuguese students. It was then that policymakers started to set the stage for the endorsement of a series of ongoing education measures by placing great importance on mathematical education (Marôco, 2021). Furthermore, in Greece, according to Breakspear's survey, "PISA has provided policy-makers with useful information and tools to improve the quality and efficiency of the existing education system in Greece" (Breakspear, 2012, p. 19). Nevertheless, the Mathematics performance of Greek 15-year-olds students in PISA in all the cycles of PISA remains stable and below the respective OECD average, in contrast with Portugal, that has taken a quantum leap (Crato, 2020). More specifically, 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 subject's, reading, science and of course mathematics, which is our subject of interest, throughout its participation in PISA (OECD, 2019b).

According to international surveys, mathematics education is influenced by the quality of teaching and certain structural and organizational features of education systems such as the curriculum, assessment arrangements, teacher education and support structures (European Commission, 2011). PISA's assessment is used as a very useful tool to measure the impact of educational policies on student performance and a lot of OECD publications, which are derived from PISA surveys include many analyses trying to identify which good practices distinguish good performing countries from the rest (OECD, 2016; OECD, 2019b; OECD, 2019d). Below we will develop the major educational policies regarding mathematics education, of both Greece and Portugal, with focus to the above structural and organizational characteristics which have taken place in the last 2 decades and which are explicitly justified or supported by PISA outcomes in both countries.

The data for this study comes first from the PISA's international assessment database for all PISA years between 2000 and 2018 and specifically of the mathematical literacy achievements and performance recorded for the two countries, Greece and Portugal. This data is available as online material provided by OECD. Second, more data for the present work comes also from available online policy documents for both countries, research reports, OECD and EU statistical data and reports.

2. KEY FEATURES OF GREEK AND PORTUGUESE EDUCATION SYSTEM

The Greek education system is highly centralized as it is overseen by the Ministry of Education and Religious Affairs (MofERA). Likewise, its Portuguese counterpart, Ministry of Education (ME), is responsible for the education stages from pre-school until upper secondary. Compulsory education in Greece lasts 11 years from the age of 4[1] to 15, or from pre-primary school to the end of lower secondary school, Grade 9, whereas in Portugal it lasts 12 years, between the age of 6 and 18 or from the beginning of primary school until the conclusion of upper secondary education, Grade 12. The stages of the Greek education system are comprised of Primary education which includes pre-primary schools and primary schools and spans six years and of secondary education which includes two cycles of study, the compulsory lower secondary which is called Gymnasio and lasts 3 years and the optional general or vocational upper secondary which is called Lykeio and lasts also 3 years (EC/EACEA/Eurydice, 2021a). The duration of the compulsory pre-primary education in Greece, until 2018, was one school year and since 2018/19 school year a

[1]In 2018, the Greek Government extended compulsory schooling and pre-primary education to 4-year-olds, instead of 5-year-olds.

gradual implementation approach extended the duration into two school years. According to PISA's 2012 analyses, students who had attended pre-primary education for more than one year, outperformed the rest in many countries by more than one school year, even when taking into account the student's socioeconomic background (OECD, 2013). This is highly pertinent to Greek students, who were characterized as low performers in mathematics in PISA 2012, and who were far more likely not to have attended pre-primary school (OECD, 2018b). So, it could be said that the extension of compulsory pre-primary education into two school years seems a very promising measure for improving Greek mathematics education or mathematics' performance in PISA.

The Portuguese education system is divided in non-compulsory pre-school education (from the age of 3 until the start of basic education), in compulsory basic education which lasts nine years and in upper secondary education which lasts three years and has become compulsory since 2009. The basic education is also divided into three sequential cycles: a) the first cycle that corresponds the Grades one to four, b) the second cycle which corresponds Grades 5 and 6 and c) the third cycle which lasts three years and corresponds to lower secondary education, Grades 7 to 9 (EC/EACEA/Eurydice, 2021b).

3. PISA AND MATHEMATICS PERFORMANCE

Greece's mean performance in Mathematics has been consistently below the OECD average ever since it participated in PISA and can be described as hump-shaped, mainly due to a spike in performance in PISA 2009 while the performance in all other years was stable (OECD, 2019b). On the other hand, Portuguese students' mean performance in Mathematics has improved since 2000, 2003 and 2006 while their mean performance in 2018[2] was close to the level observed over the period 2009-2015 and is placed above the OECD average. The average 3-year trend in mathematics mean performance in Greece is only +0.1 points while in Portugal it is +6 points. In the latest PISA 2018, Greek students' mean performance in Mathematics (451) was statistically significantly below the OECD average (489) and between the lowest among OECD countries and simultaneously statistically significantly different from Portuguese's students mean performance (492), who had no statistical significantly difference from the OECD average. This difference of 41 points between the two countries' mean scores in Mathematics, corresponds to one whole school year, since the OECD has calculated that the 38 points correspond to one school year.

Results from PISA 2018 also showed that the share of Greek low achievers in Mathematics, those who scored below Level 2, remains among the highest in the European Union with a shrinkage of 3.1 percentage points since 2003. "The global indicators for the United Nations Sustainable Development Goals identify Level 2 proficiency as the "minimum level of proficiency" that all children should acquire by the end of secondary education. While students who score below this minimum level can be considered particularly at risk, Level 2 proficiency is by no means a "sufficient" level of mathematics proficiency for making well-founded judgements and decisions across a range of personal or professional situations in which mathematical literacy is required" (OECD, 2019b,

[2]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).

p. 105). On the other hand, as top performers are characterized the students who are capable of advanced mathematical thinking and have performed at or above PISA's proficiency Level 5. The share of Greek top performers students has also decreased by 0.3 percentage points since 2003. However, in contrast to Portugal, both low and high achieving students have significantly improved their scores and the corresponding share of students who scored below Level 2 in mathematics has shrunk by 6.8 percentage points since 2003 while the share of students performing at or above proficiency Level 5 has increased by 6.2 percentage points. More specifically in 2018, more than one-third of Greek 15-year-olds participating in PISA were low achievers in Mathematics (35.8% compared to an OECD average of 22.2%) while in Portugal they were less than one-fourth (23.3%). The highest Levels 5 and 6, were reached only by the 3.7% of Greek students as compared to the OECD average of 11.4% and to the Portuguese corresponding average of 11.6%.

Another remarkable element is the girls' and boy's performance. In PISA 2003 while boys in Greece outperformed girls in mathematics by 19 points, by 2012 this difference had shrunk to 8 score points and in the latest PISA 2018 there was no difference in mathematics score points between genders. This, however, is due to the reduction of boys' performance and not to the improvement of girls (OECD, 2019d). At the same time the boys from Portugal in PISA 2003 outperformed girls in by an also notable amount of 12 score points, but in 2012 this gender gap narrowed by only 1 score point (11 score points). In PISA 2018 the corresponding gender gap has remained a notable amount of 9 score points which was greater than the OECD average (5 score points) (OECD, 2004; OECD, 2014c; OECD, 2019c). Moreover, between 2003 and 2012 and between 2012 and 2018, a reduction was showed in the share of girls in both countries Greece and Portugal, who performed below Level 2 and an increase in the share of girls who performed at Level 5 and 6 (OECD, 2014c; OECD, 2015; OECD, 2019c). On the other side the share of boys who performed below proficiency Level 2 shrunk between 2003 and 2012 in both countries, too, while between 2012 and 2018 in Portugal this share narrowed but in Greece increased. As far as the share of boys who were characterized as top performers in the two periods 2003-2012 and 2012-2018 is concerned, it decreased in Greece but in Portugal there was increase in both periods (OECD, 2015).

One of the most disturbingly facts resulting from Greek students' reports in PISA 2018, is that more than one in two students, which is one of the biggest percentages between OECD countries, agreed with the fixed mindset statement "*Your intelligence is something about you that you can't change very much*" (OECD, 2019c). Only in three OECD countries, Greece, Mexico and Poland, did the majority of their students appear to agree with this statement. Those students according to OECD are unlikely to make the investments in themselves that are necessary to succeed in school and in life (OECD, 2019c). On the other hand, the majority of Portuguese's students disagreed or strongly disagreed with this statement. A growth mindset could be described as "the belief that one's skills and qualities can be cultivated through effort, good strategies, and support from others, as opposed to a fixed mindset that supposes them to be determined at birth" (OECD, 2021, p. 14). Students with a growth mindset "is more likely to embrace challenges and learn from setbacks to reach greater levels of achievement than a person with a fixed mindset who avoids challenges and mostly seeks approval" (OECD, 2021, p. 14).

4. MATHEMATICS CURRICULUM

In both countries, curriculum is defined centrally. The latest revision and update of the mathematics curriculum for primary and lower secondary education in Greece took place in 2003 with the single cross thematic curriculum framework (DEPPS) and the detailed curricula (APS). In comparison, to Portugal's curriculum that was introduced on 2008, both countries' mathematics curricula are similarly more focused on cross-curricular links and on the interaction of mathematics with philosophy, science and technology (European Commission, 2011). A revision of the Portuguese curriculum for Mathematics of the second cycle of primary and lower secondary education took place in 2012/13 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, 2014b). A more flexible curriculum in Portugal has also sprung from a pilot programme in 2017/18 and has been in effect since 2018 (EC/EACEA/Eurydice, 2021b).

The poor alignment of Greek Mathematics curriculum in lower secondary school with the PISA's assessment Mathematics framework and the strong content focus (Breakspear, 2012; OECD, 2018b) are highlighted through an IEP's survey which showed that in Greek curriculum, Mathematics applications appear as consequences and not as fields within which Mathematics emerge, as stated in PISA (IEP, 2019). The problem solving in Greek 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).

An important proxy that helps to explain the relative importance of Mathematics as a school subject, compared to others in the curriculum is the recommended taught time which means the curriculum time allocated for teaching mathematics (European Commission, 2011). According to last decades' annual European reports, the weight of mathematics in the curriculum of primary education in Portugal was placed in the highest rank among the European countries whereas in Greece it was in the lowest. Moreover, in Greece a student who completes primary school has been taught less than half the number of hours of mathematics in total than his Portuguese counterpart (European Commission/EACEA/Eurydice, 2018). In lower secondary education, Greece is between the European countries with the fewest number of hours but with not so wide gap with Portugal (European Commission/EACEA/Eurydice, 2018; European Commission, 2011). According to students' responses in PISA 2018, the learning time per week in regular mathematics lessons were estimated at 3.4 hours for Greece and 4.5 hours in Portugal (OECD average hours 3.7) (OECD, 2019d). Moreover, in Portugal, it was reported that in 2012 students spent one-and-a-half hours more per week in mathematics lessons than students in 2003 did while in 2012 they spent around one hour less in after-school study than students in 2003 did (OECD, 2013, p. 104).

The textbooks, being a central tool for the implementation of the mathematics curriculum, in Portugal are chosen from the teachers among all available textbooks previously approved by the Ministry of Education, while in Greece schools are limited to one specific authorized mathematics textbook that has been approved by the Institute of Educational Policy (IEP) and is the same for all students attending the same grade (EC/EACEA/Eurydice, 2021a). The Greek Mathematics textbooks in lower secondary school, according to an IEP's (2019) survey, contain low percentage of real-life math problems whilst the majority of them could be described as "standard" word problems, which can be solved with any combination of arithmetic operations, rather than "problematic" ones which can be compared to the PISA mathematical literacy problems, according to Verchaffel, Greer and De Corte classification.

5. ASSESSMENT IN MATHEMATICS

Student assessment in mathematics is a crucial element of the teaching and learning process and national tests in mathematics are widely implemented and used to inform or guide policymakers to support equity and quality of student learning (European Commission, 2011; OECD, 2018a). After Portugal was affected by the poor PISA results, the low-stakes were promoted in 2003 and the corresponding high-stakes exams for Mathematics at the end of Grade 9 were used in 2005 (Marôco, 2021). The application was also expanded (2012) to grades 4 and 6 (OECD, 2014b) but was terminated in 2016 (Santiago, Donaldson, Looney, & Nusche, 2012). Today, student assessment includes both internal and external national assessment in Portugal. 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 in 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 (Liebowitz, González, Hooge, & Lima, 2018; OECD, 2020a; EC/EACEA/Eurydice, 2021b).

In contrast to Portugal, the Greek educational system has no national assessments in mathematics 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 which takes place in Greek educational system is the Panhellenic university admissions examination which is administered only at the end of upper secondary education. In lower and upper secondary school, written progression and school leaving examinations are administered on a number of subjects, as is the case with exams in Mathematics, which are performed by each school and their respective Mathematics' teachers (EC/EACEA/Eurydice, 2021a). It was only as far back as in 2013 that efforts were made to create a more national approach to student assessment in selected school subjects, including mathematics, in upper secondary school (in Grades 10 and 11) with national tests banks including question items at different levels of difficulty. The use of these test banks was abandoned in 2015/16, given concerns about equity and early school leaving (OECD, 2018b).

In Portugal the research work of Marôco and Lourenço, has shown the concurrent and content validity of PISA with the national high-stake exams for mathematics (Marôco, 2021 Crato, 2020). In Greece, due to the absence of national student assessment it is difficult to conduct such surveys. IEP (2019), through some data from the promotion and school-leaving mathematics examinations in 9th grade which were delivered from individual schools and teachers of mathematics during the last decade, it was estimated that from 232 such tests only on 5 (2%) included at least one item of real-life problem, that could be compared to PISA mathematical literacy problems. So due to the absence of national standardized assessments in Mathematics to provide regular information about students learning outcomes (OECD, 2020b) 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, 2018b).

6. IMPROVING STUDENT'S MOTIVATION IN MATHEMATICS

"Motivation and engagement can be regarded as the driving forces behind learning. Given the importance of mathematics for students' future lives, school systems need to ensure that students have not only the knowledge that is necessary to continue learning mathematics beyond formal schooling, but also the interest and motivation that will make them want to do so" (OECD, 2014a, p.1). As it is also referred on "PISA in Focus" (OECD, 2014a, p. 1), "students who are highly motivated to learn mathematics because they believe it will help them later on score better in mathematics – by the equivalent of half a year of schooling – than students who are not highly motivated" or it can be one of the most important determinants of students' achievements in school (European Commission, 2011).

In order to improve student motivation and encourage positive attitudes towards mathematics learning and education, Portugal implemented the "Action Plan for Mathematics", which was launched in 2005. The six components of the plan were: a)implementing a mathematics plan in each school, b)training teachers in basic and secondary schools, c)reinforcing mathematics in initial teacher training, d)readjusting the mathematics curriculum throughout the compulsory education system, e)creating a resource bank or database specifically devoted to mathematics and f)evaluating textbooks on mathematics (OECD, 2013). The Action Plan is referred that "allows students to dedicate more time to the study of mathematics and focus on exploration, investigation and problem-solving" (European Commission, 2011).

In Greece there are no such national strategies or initiatives (European Commission, 2011).

7. EDUCATION AND PROFESSIONAL DEVELOPMENT OF MATHEMATICS TEACHERS

In Greece both primary teachers and secondary education teachers who teach mathematics hold at least a first cycle degree (UNESCO, 2015; OECD, 2018b) and no additional degrees or pedagogical training certificates are required. In Portugal, with the implementation of the Bologna process (finalized in 2009/2010) the minimum requirement for teaching is a second cycle degree, a master's degree, and the preparation of secondary education mathematics teachers which includes components concerning mathematics, general education, didactics of mathematics and a period of teaching practice (Ponte, Santos, Oliveira, & Henriques, 2017). In all six grades of primary school in Greece and in the first four grades of basic education in Portugal, mathematics is being taught from teachers who teach the majority of the subjects but in Grades 5 to 6 in Portugal, mathematics is being taught by teachers who are qualified in mathematics and may be in other subjects as well. In secondary education, lower and upper, in both countries, mathematics is being taught by a single teacher with a qualification to this subject only.

The focus on mathematics teachers training could be regarded also as a measure responsible for the improvement of Portuguese 15-year-old students in mathematics (European Commission, 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 (European Commission, 2011).

8. FUTURE RESEARCH DIRECTIONS

The experience and the conclusions from this study could provide a platform or a guide for future discussions and researches. In the present paper took place a recording of students' mathematics achievements in PISA and at the same time analysed the mathematics education between the two Southern European countries, Greece and Portugal respectively. This research study could be a beneficial preparation for a possible enlarged study for mathematics education and performance, through the prism of PISA among more European countries or more specifically among Southern European countries.

9. CONCLUSION/ DISCUSSION

We believe that this paper has managed to show or to highlight some positively related factors to the performance of Portuguese students in PISA mathematics which have eventually fostered student's mathematical literacy competencies and which are the following: the frequent reevaluation or revision of mathematics curriculum in compulsory education, the improvement of the level of students' motivation in mathematics classrooms, as well as the focus on mathematic teachers' training that has laid emphasis on their collaboration. Last but not least, another factor is the implementation of national tests in mathematics in compulsory education with the scope to inform the policy makers for the curriculum development as well as the improvement in teachers training. Furthermore, we can also attribute their improved performance to the shift towards more outcome-oriented accountability, which could change the ways mathematics teachers and schools perceive external assessments like PISA. On the other hand, the stable and low position of Greece in PISA mathematics since 2000 till today could be justified to some extend by the poor alignment of Greek mathematics curriculum and mathematics textbooks in lower secondary school with the PISA's assessment mathematics framework and their strong content focus. Moreover in comparison to Portugal, by outlining the respective Greek reality in mathematics education during the past 20 years which runs parallel to the PISA survey, we can focus briefly on the infrequent reevaluation or revision of mathematics curriculum in compulsory education, the lack of the focus on mathematics teachers training for the purpose of their professional development, the lack of national assessments in mathematics and last but not least on the lack of organizing programs at a national level in order to improve Greek students' motivation in mathematics.

A positive conclusion that can be drawn, as demonstrated by the experience of Portuguese Education system and could prove useful to Greek education as well, is that top performers can be nurtured while simultaneously assisting struggling students, thus strengthening the OECD view that "*Countries do not have to choose between nurturing excellence in Education and reducing underperformance*" (OECD, 2016, p. 266).

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AUTHORS' INFORMATION

Full name: Eleni Nolka
Institutional affiliation: Harokopio University of Athens, Greece
Institutional address: 9, Omirou Str. 17778, Tavros, Athens, Greece
Short biographical sketch: Eleni Nolka is a PhD candidate at Department of Informatics and Telematics in Harokopio University of Athens. She has graduated from the Department of Mathematics – University of Crete and she holds a master's degree in Didactic of Mathematics and New Technology from the Department of Primary Education – University of Western Macedonia. She is a teacher of Mathematics in Secondary education and the last years she is teaching Mathematics in the Music school of Piraeus.

Full name: Chryssa Sofianopoulou
Institutional affiliation: Harokopio University of Athens, Greece
Institutional address: 9, Omirou Str. 17778, Tavros, Athens, Greece
Short biographical sketch: Chryssa Sofianopoulou is Associate Professor at Harokopio University of Athens. She holds a bachelor's degree in Mathematics and a PhD in Education Sciences from the University of Athens. Her area of expertise is "Analysis of Educational Performance and Computer Training". Her research focuses on socio-economic factors and geographical characteristics related to educational performance, social inequality in the educational system, and the use of ICT to improve the quality of learning. She is National Project Manager and Member of Governing Board of the OECD PISA Program and also National Expert of EU. She participates in international, European and national projects dealing with the analysis of the educational process.