Review

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On the Performance of Greek Students on Pisa Fields Using Pisa Data: A Comprehensive Analysis

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Review

On the Performance of Greek Students on PISA Fields Using PISA Data: A Comprehensive Analysis

Eirini Golegou, Manolis Wallace and Kostas Peppas *

University of the Peloponnese, Department of Informatics and Telecommunications, Tripoli, Greece

* Correspondence: peppas@uop.gr

Abstract: 21st century skills are the most important skills for students to acquire at the end of their basic education. The PISA international student test is one of the accepted ways of measuring success in the acquisition of some of these skills. In this article, we first look at the performance of Greek students in mathematics and science. The first question is whether these results are encouraging. The second question is whether STEM education could contribute to their improvement. During the research process, data on the performance of Greek students by year were collected and compiled into tables, from which graphs were then created. This makes it easier to draw valid conclusions about the level of the students. Next, reference is made to the objectives of STEM education so that its full alignment with 21st century skills is evident. The results show that the performance of Greek students in both subjects is consistently low and therefore the acquisition of relevant skills is limited. It is highlighted that STEM education could contribute to the acquisition of the required skills and to better performance in PISA.

Keywords: STEM education; PISA results; performance of Greek students; 21 st century skills

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Introduction

In a constantly evolving world, artificial intelligence, digital transformation, green transition, globalisation and an ageing population (Mohamedou, Bell, Staats, & Raznikova, 2024), are creating new conditions that we cannot ignore. The acquisition of skills is becoming increasingly important on the agenda of education systems, as those who master them can use them throughout their lives, from work to everyday life (OECD, OECD Skills Strategy 2019: Skills to Shape a Better Future, 2019).

The rationale for conducting this research was the persistently low performance of Greek students on the PISA written tests; at the same time, the GhatGPT outperformed the average performance of students on the test questions (Mohamedou, Bell, Staats, & Raznikova, 2024), making it even more important to improve students' skills. Both the literature and the OECD reports link student performance to 21st century skills. In this report, we try to substantiate this link, as the tasks of the competition correspond to each of these skills. We emphasise that the PISA test is considered to have the necessary scientific basis to measure the level of mastery of the 21st century skills tested. The mastery of the goals of STEM education, i.e. the mastery of 21st century skills, cannot be assessed by traditional assessment systems such as standardised written examinations (El Nagdi & Roehrig, 2022), which are an important part of testing in the Greek education system. Therefore, it is argued that STEM education can strengthen these skills through its interdisciplinary approach (Mohamedou, Bell, Staats, & Raznikova, 2024; Khalil, Tairab, Qablan, Alarab, & Mansour, 2023). Students who have received a STEM education have been shown to have a greater ability to generate a large number of ideas, to think alternatively, to consider all the data and to come up with an original idea (Khalil, Tairab, Qablan, Alarab, & Mansour, 2023). Meanwhile, mechanical analogue design provides opportunities for students to engage in higher-level reasoning based on tangible evidence through mathematical and scientific principles (Lesseig, Slavit, & Simpson, 2023). Strengthening the skills system can support the economy and social cohesion of any country in the future (Mohamedou, Bell,

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Staats, & Raznikova, 2024). To this end, it is suggested that it should be included in the curriculum and not necessarily that the whole education system should be changed, as low performance in the competition does not measure the degree of success of the education system, but is clearly focused exclusively on skills. It is emphasised here that the acquisition of skills is associated with a number of benefits both for the individual and for society as a whole. Specifically, individuals who have mastered skills are more likely to find employment, earn higher wages, enjoy greater trust, participate in democratic and social processes, and have better health (Mohamedou, Bell, Staats, & Raznikova, 2024). It is STEM education that can contribute to the acquisition of 21st century skills and thus to the creation of a well-rounded global citizen (El Nagdi & Roehrig, 2022). This article does not propose STEM education as a solution to low performance in the PISA tests, but as a solution to acquiring the necessary skills, which in turn will lead to better performance in the test. It also suggests that students should be exposed to STEM education not only through the school environment but also through extracurricular activities.

21. st Century Skills

The 21st century skills defined by the response needs of Industrial Revolution 4.0 are those that can ensure inclusive and equitable education throughout life (Gonzalez-Perez & Ramirez-Montoya, 2022) and will be a driver of global economic growth (Howard, 2018). This shift in education has its roots in the 1980s in the United States, where educators, government and businesses began publishing reports on emerging trends (Howard, 2018)(Howard, 2018). Twenty-first century skills are defined as those that provide the necessary capabilities for students to enter the professional arena with skills that will be useful to them and also contribute to the development of the global economy (Gonzalez-Perez & Ramirez-Montoya, 2022; Howard, 2018). A development based on ethics, humanism and sustainability (Gonzalez-Perez & Ramirez-Montoya, 2022).

In the OECD report defining skills for 2030, a skill is defined as an individual's ability to use knowledge in a responsible way to achieve a goal. Skills are part of a broader framework that includes knowledge, attitudes and values. The 2030 competences are grouped along the following axes

- Cognitive and metacognitive
- Cognitive, perceptual and metacognitive
- Material and practical (OECD, SKILLS FOR 2030, 2019).

Cognitive skills refer to the whole process of thinking with language and numbers, as well as the reasoning the individual has arrived at (e.g. creative thinking). Metacognitive skills encompass an individual's knowledge, skills and values (OECD, SKILLS FOR 2030, 2019). They include higher-level thinking that checks lower-level thinking. For example, students see mistakes as an opportunity to improve rather than a failure (Gonzalez-Perez & Ramirez-Montoya, 2022). Social and emotional skills are related to an individual's ability to express each thought in consistent patterns (OECD, SKILLS FOR 2030, 2019); more specifically, they are related to flexibility, adaptability, the ability to take initiative, social and intercultural skills, responsibility and leadership (Partnership for 21st Century Skills. Framework for 21st Century Learning., 2019). . An individual's ability to communicate is related to the ability to express ideas using written and spoken language (Sen, Ay, & Kiray, 2018). While manual skills are related to the ability to use tools and are mainly associated with manual tasks (OECD, SKILLS FOR 2030, 2019).

Skills such as creativity, innovation, critical thinking, problem solving, communication and collaboration are the elements that can prepare students to enter the workforce (Partnership for 21st Century Skills. Framework for 21st Century Learning., 2019; Howard, 2018). Other 21st century skills are considered to be adaptability, entrepreneurship, literacy in each of the STEM fields, prediction and analysis, logical thinking, quantitative reasoning and reflection (Lin, και συν., 2023). Critical thinking is related to the analysis and evaluation of evidence, claims and beliefs. Collaboration is related to students' ability to work together in different educational environments with different people at the same time, a characteristic of any collaboration is mutual respect. Creativity and collaboration, on the other hand, are related to the ability to generate new ideas (Sen, Ay, & Kiray, 2018). Businesses are the ones most interested in ensuring that their future employees are equipped with 21st century skills to deal with ambiguity, think innovatively and have an entrepreneurial spirit (Howard, 2018).

High achievement at school level requires social and emotional skills in order for students to be able to perform. While engagement in the arts and physical skills can help improve cognitive skills (OECD, SKILLS FOR 2030, 2019).

Identifying the skills required for the 21st century also has a major impact on curricula, as they are required to be aligned with the needs of the labour market. Today's school environment has as its main objective the development of the personality of the 21st century citizen, so it must also provide him or her with the corresponding skills (McLennan, 2021). Knowledge can be made more engaging through the use of appropriate technology, real-world connections and personalised teaching (Partnership for 21st Century Skills. Framework for 21st Century Learning., 2019) so that it can be tailored to each student's interests.

Education is an investment that, by harnessing the technological potential of the 4.0. Industrial Revolution (McLennan, 2021). Literature references included in the article (Gonzalez-Perez & Ramirez-Montoya, 2022) clearly indicate the contribution of STEM education to the acquisition of all the skills mentioned. A prerequisite for the success of STEM education is adequate school infrastructure and the reduction of the digital divide.

Stem Skills and Stem Education

STEM education is an emerging trend whose main purpose is to expose students to the concept of interdisciplinarity, as in our evolving world many of the problems of everyday life are interdisciplinary in nature (De Loof, et al., 2023).

To date, STEM education has not been strictly defined. This ambiguity in the definition complicates the process of assessing the achievement of learning objectives (El Nagdi & Roehrig, 2022).

It is worth noting that the different definitions given can be divided into two main groups: those that refer to STEM education as the sum of the individual fields, and those that treat it based on the principle of interdisciplinarity, paying particular attention to the connection between the different fields (Gao, Li, Shen , & et al., 2020). The interdisciplinary approach is also adopted by integrated STEM education (De Loof, et al., 2023).

A key concept of STEM education is the coherence of knowledge in the disciplines of mathematics, science, technology and engineering. Because of their transversal application, they can be used in a unifying way. The combination of skills that these disciplines can produce when they coexist in the same individual leads to an active citizen who can contribute to the national and global economy (Tytler, Aderson , & Li, 2020).

A key approach to STEM education is interdisciplinarity, which can contribute to the development of key STEM skills such as critical thinking, innovation, collaboration and teamwork. Through this approach, the metacognitive skills that students acquire are more than the sum of the individual knowledge that they would acquire if they studied a particular problem from the perspective of a single discipline (Tytler, Aderson , & Li, 2020).

Another pedagogical approach is the holistic STEM approach, the principle of which is the integration of STEM content. The focus of the educational process then becomes the problem that students are asked to solve. The solution is expected to be found through exploratory methods, planning and collaboration. The proposal for this approach is based on the basic principle of STEM to relate learning to the real world. In the real world, solving a problem is not done by breaking it down into individual problems, but by tackling it holistically. Content integration refers to the learning objectives that come from different areas of knowledge. The basic principle is that the problem is one that is encountered in everyday life. Through exploration, the student can question, discover new concepts, develop new perceptions through experiential processes. Through design, students are able to deepen their understanding of the subject matter. The ultimate aim of using collaborative methods is for students to learn to communicate and collaborate (Thibaut, et al., 2018).

Stem Educations' Goals

The ultimate goal of STEM education is the acquisition of skills that will serve the students later in their professional life (Bybee, 27 Aug 2010) and the bridging of the gap between theory and practice (T. Martín-Páez, D. Aguilera, F. J. Perales-Palacios and J. M. Vílchez-González, 19 March 2019). This type of education is also an important way of supporting the global economy through the formation of a highly educated workforce (McDonald, 2016). The changes observed in modern society are not only related to the Fourth Industrial Revolution 4.0 which is underway ; they are also economic, social, and environmental changes that cannot be ignored. The goal of a modern educational system is to equip future active citizens with skills that will help them to successfully face all these challenges (K. Maass, V. Geiger, M. Ariza et al., 2019). It also needs to help young people to adjust their expectations to the new working standards in order to secure their future professional careers (R. Tytler, J. Aderson and Y. Li, Dec 2020). STEM education also functions as a guarantee for acquiring the necessary skills of the future and for ensuring sustainability (Bybee, 27 Aug 2010). Its contribution to the acquisition of skills related to working in groups, which are very likely to be needed for professional advancement, is undeniable (Widya, R. Rifandi and Y. L. Rahmi, 2019).

Furthermore, in a STEM education context, students are asked to solve real problems, such as those they will be faced with in their daily lives as adults, by applying knowledge acquired during their education (Widya, R. Rifandi and Y. L. Rahmi, 2019), thus making the connection between academic and real life possible (K. Maass, V. Geiger, M. Ariza et al., 2019). It is worth mentioning that Australia predicted, back in 2014, that in the future, 75% of professions will require some STEM skill. At the same time, it is estimated that the increase of individuals working in some STEM field will contribute to an increase in the GDP (R. Tytler, J. Aderson and Y. Li, Dec 2020).

Looking at higher education enrollment, one important conclusion to be drawn is that the market demand in engineers and technology-related professionals will likely not be met in the future (McDonald, 2016). At the same time a student's success in a STEM course can be assessed based on more objective criteria (Y. Xie, M. Fang and K. Schauman , Aug 2015). At the EU level, in 2021, the Council Resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021-2030), emphasizes the importance of modernizing STEM fields of study, the ultimate goal being the sustainability of educational systems and their contribution to the green economy and digital transition (Council Resolution on a strategic framework for European cooperation in education and training towards the European Education Area and beyond (2021-2030), 26.2.2021).

Interdisciplinarity being one of the main characteristics of STEM education, it is imperative that we identify the practical difficulties related to this holistic approach :

- Difficulty in applying STEM principles in everyday teaching
- Lack of specialized knowledge on the part of the teachers with regard to planning a STEM course
- Lack of trust on the part of the teachers in this type of education
- Even when STEM teaching is embraced, the inclusion of usually only two disciplines at the exclusion of others, which end up being severely under-represented (K. Maass, V. Geiger, M. Ariza et al., 2019).

On the other hand, as far as those who have received STEM education are concerned, some end up working in fields unrelated to their education. And as far as those who haven't are concerned, pursuing a career in these fields is even more difficult (Y. Xie, M. Fang and K. Schauman , Aug 2015). All in all, STEM education does not secure a career in one of the relevant fields, but lack thereof definitely makes it harder to pursue one.

The success of STEM education is based on the following main axes :

- Focus on secondary education in order to inspire interest in STEM fields in students ;

- Application of instructional practices which help maintain students' interest and will help them acquire 21st century skills and improve their performance in school ;
- Training teachers in these instructional practices so that they can positively influence students' attitudes towards these subjects (McDonald, 2016) ;
- Keeping parents well-informed ;
- Innovative planning of school units and of curricula ;
- Governmental support ;
- Social education resources (Quan, 2020)

Finally, it should be stressed that long-term engagement with the disciplines of STEM education is also an important factor. Engagement during secondary education years alone is insufficient. An earlier first contact, even from the years of kindergarten, is required (McDonald, 2016).

PISA Competition

The Programme for International Student Assessment (PISA) is an education survey that has been carried out every three years since 2000. The survey is organised by the OECD's International Education Division and the countries whose students take part (IEP, n.d.). In each of the competitions, students are asked to focus on an innovative area that is different each time (Sofianopoulou, Emvalotis, Pitsia, & Karakolidis, 2017).

The main objective of the programme is to track the skills and knowledge acquired by students from the participating countries at the end of their compulsory education (15 years). Their acquisition contributes to the equal and meaningful participation of young people in modern societies, whose demands are constantly changing. Student performance provides important information about the education systems of the participating countries. Most importantly, they provide feedback on the corrective steps to be taken in the curricula (IEP, n.d.). The main outcome of the analysis of the results is expected to be the establishment of common benchmarks and the evaluation of education systems in order to achieve the necessary changes (Pugliese & De Macedo Santos, 2022).

The results of the PISA studies allow firm conclusions to be drawn about the literacy levels of students in each country in each of the subjects in which they are tested. The concept of literacy refers to the set of desired knowledge, attitudes and skills in each of the subjects. More specifically, mathematical literacy is defined as a student's ability to recognise and understand the relevance of mathematics in everyday life. The use of mathematical thinking and knowledge to solve problems in everyday life is the ultimate goal. Similarly, in science, literacy refers to an individual's scientific knowledge and ability to use it both to acquire new knowledge and to explain phenomena encountered in everyday life. It also relates to the treatment of science as a form of knowledge and the recognition of its role in shaping material and immaterial culture. In both cases, it relates to any problem that needs to be solved as a thinking, active and creative citizen. It is worth noting that the issue of literacy is not limited to the knowledge that each student acquires at school, but extends to his or her everyday life (OECD, PISA 2006 VOLUME 2 DATA, 2007).

The skills that students acquire during STEM education are largely identical to the skills that students are expected to have by the end of compulsory education, as defined by the OECD and its targets set for 2030 (Tytler, Aderson , & Li, 2020). The results of the test are intended to provide a realistic picture of learning outcomes in each country. They also allow for a discussion of each country's curriculum goals for both general and STEM education (Schiepe-Tiska, Heinle, Duming, Reinhold, & Reiss, 2021). Therefore, a reference to the performance of Greek students in PISA seems appropriate, as this will allow us to identify the weaknesses of the Greek education system. On the other hand, based on international studies, it is possible to reach a safe conclusion on the extent to which STEM education can contribute to the improvement of the educational system.

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Greece's Performances in PISA Competitions

The next part of our analysis is dedicated to the performances of Greek students in mathematics and sciences in every competition since 2003 in order to assess their literacy in these subjects.

Taking into account all the results of the PISA competitions one can observe that Greece's overall scores in mathematics and science in every year of participation was lower than the average of the rest of the OECD countries.

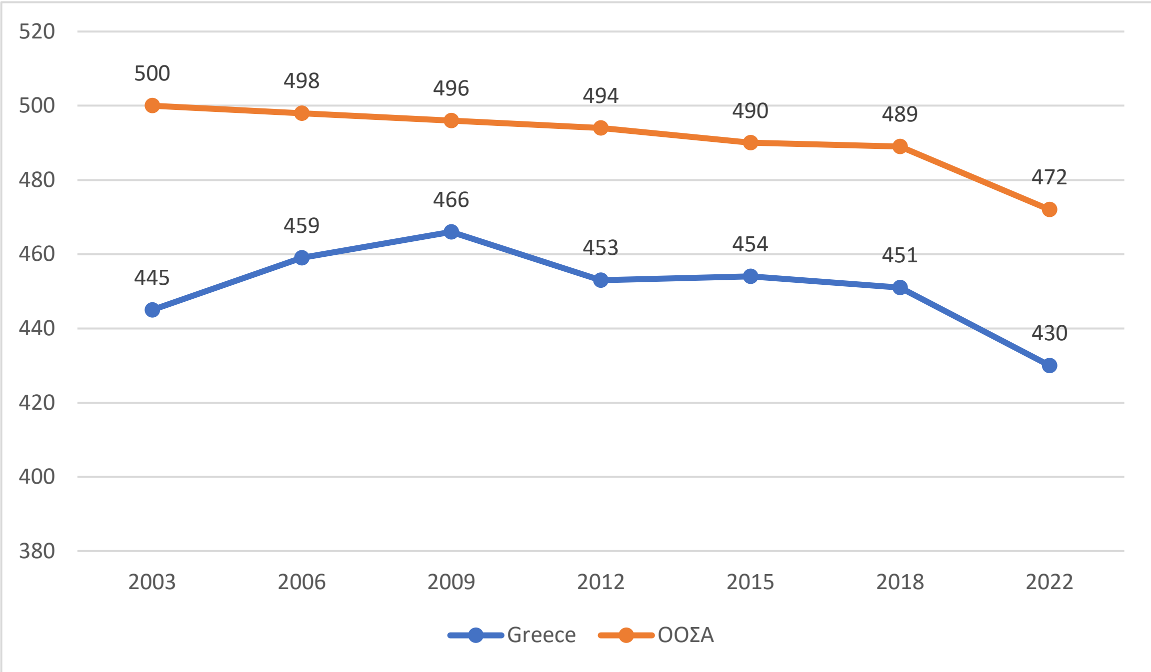

Figure 1. Greece's score and OASA average in Mathematics, in the PISA Competitions from 2003 to 2022. (OECD, PISA 2022 Results (Volume I): The State of Learning and Equity in Education, PISA, 2023; OECD, PISA 2018 Results (Volume I): What Students Know and Can Do, 2019; Sofianopoulou, Emvalotis, Pitsia, & Karakolidis, 2017; OECD, PISA 2015 Results (Volume I): Excellence and Equity in Education,, 2016; OECD, PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science (Volume I, Revised edition, February 2014, 2014; OECD, PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science (Volume I), 2010; OECD, PISA 2006 VOLUME 2 DATA, 2007; OECD, Learning for tomorrow' s world. First results from PISA 2003, 2004).

In math, the gap between the OECD average and the Greek average ranges between 30 and 55 points. The largest gap is observed in 2003 and the smallest in 2009. In more detail, the 2009 gap reaches 39 points, the 2012 one 41 points, the 2015 one 36 points, the 2018 one 38 points and lastly the 2022 gap reaches 42 points. As far as these intermediate years are concerned, no noticeable difference is observed. From 2003 to 2009, there is an increase in the performance of Greek students while the OECD average shows a slight decline, which nevertheless cannot be characterized as important, since from 2000 to 2009 it only amounts to 4 points. Since 2009, the year with the best performances of Greek students in mathematics, we observe a decline but no noticeable difference in performances from 2012 to 2018. Greece recorded its worst results in math in the latest 2022 test.

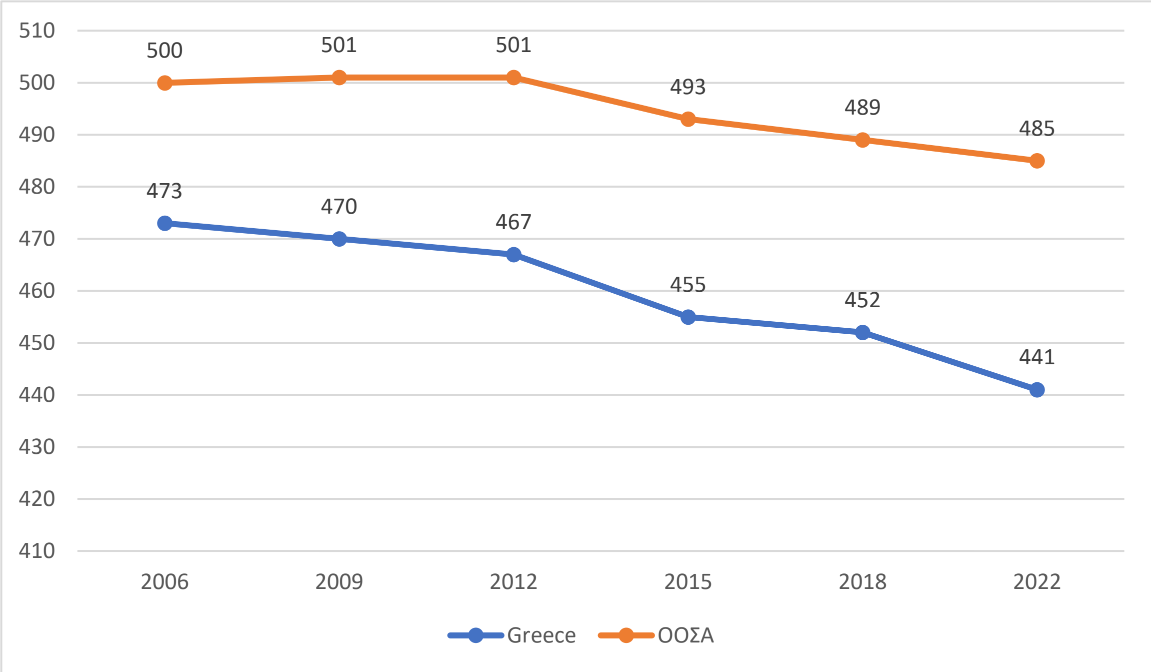

Figure 2. Greece's score and OASA average in Science, in the PISA Competitions from 2003 to 2022. (OECD, PISA 2022 Results (Volume I): The State of Learning and Equity in Education, PISA, 2023; OECD, PISA 2018 Results (Volume I): What Students Know and Can Do, 2019; Sofianopoulou, Emvalotis, Pitsia, & Karakolidis, 2017; OECD, PISA 2015 Results (Volume I): Excellence and Equity in Education,, 2016; OECD, PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science (Volume I, Revised edition, February 2014, 2014; OECD, PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science (Volume I), 2010; OECD, PISA 2006 VOLUME 2 DATA, 2007; OECD, Learning for tomorrow' s world. First results from PISA 2003, 2004).

In science, the gap between the performances of Greek students and the OECD average was between 28 and 44 points. We observe the biggest gap in 2022 and the smallest in 2006. As for the rest of the competition years, the gap was 37 points in 2018, 34 points in 2012, and 31 points in 2009. The performances of Greek students in science were consistently in decline with the starkest decline observed in 2018 and in 2022.

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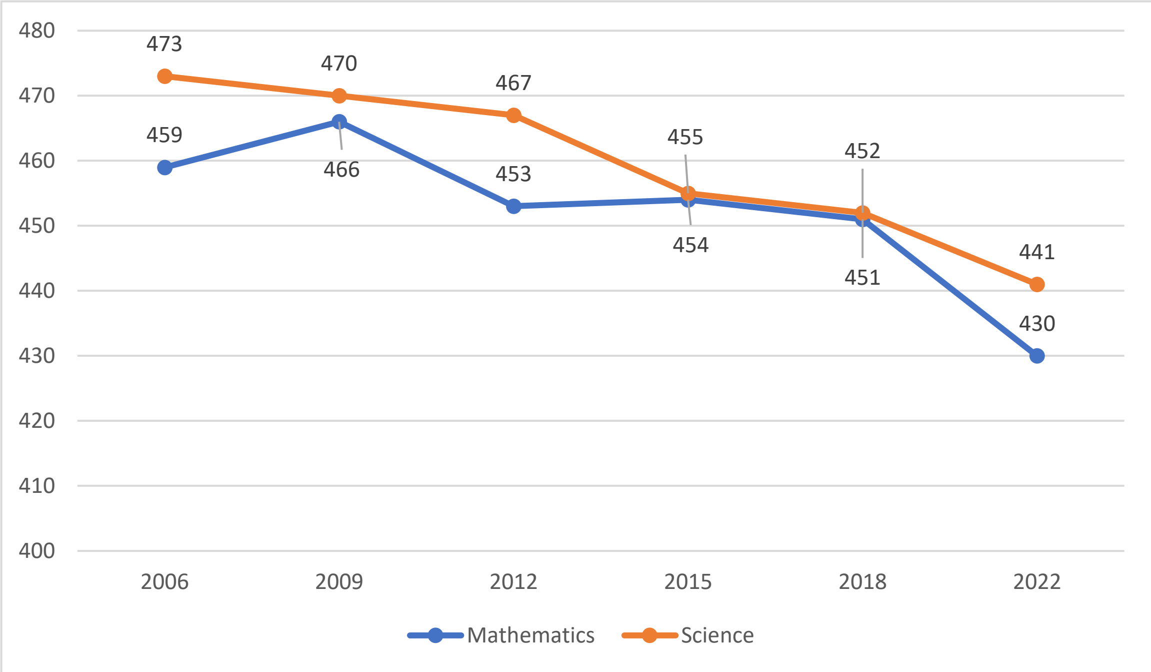
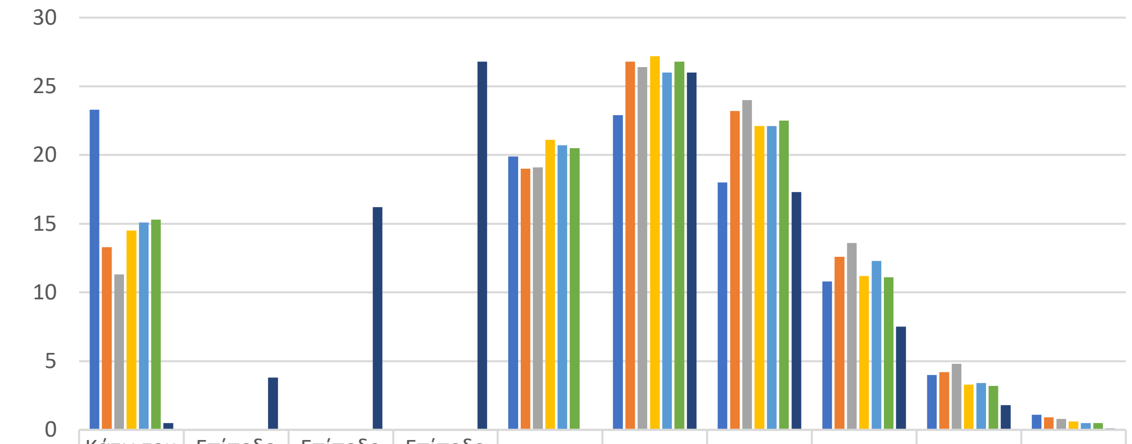


Figure 3. Comparative table of PISA scores of Greek students in Mathematics and Science from 2006 to 2022. (OECD, PISA 2022 Results (Volume I): The State of Learning and Equity in Education, PISA, 2023; OECD, PISA 2018 Results (Volume I): What Students Know and Can Do, 2019; Sofianopoulou, Emvalotis, Pitsia, & Karakolidis, 2017; OECD, PISA 2015 Results (Volume I): Excellence and Equity in Education,, 2016; OECD, PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science (Volume I, Revised edition, February 2014, 2014; OECD, PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science (Volume I), 2010; OECD, PISA 2006 VOLUME 2 DATA, 2007; OECD, Learning for tomorrow' s world. First results from PISA 2003, 2004).

Comparing the two disciplines, their performances in mathematics from 2006 to 2018 were worse than in science. We can observe a decline in both in the most recent competitions. The largest difference between the two disciplines is observed in 2012. At the 2015 and 2018 competitions the difference was only one point. The 2015 difference was the result of a significant decline in performances in mathematics : from 462 in 2012 to 455 in 2015. Respectively, the performances in science were at 453 and 454 points. The bridging of the gap between the disciplines is not due to better performances in science but to the decline of performances in math. The worst performances in both disciplines were recorded in PISA 2022.



	Κάτω του 1	Επίπεδο 1c	Επίπεδο 1b	Επίπεδο 1a	Επίπεδο 1	Επίπεδο 2	Επίπεδο 3	Επίπεδο 4	Επίπεδο 5	Επίπεδο 6
2003	23.3				19.9	22.9	18	10.8	4	1.1
2006	13.3				19	26.8	23.2	12.6	4.2	0.9
2009	11.3				19.1	26.4	24	13.6	4.8	0.8
2012	14.5				21.1	27.2	22.1	11.2	3.3	0.6
2015	15.1				20.7	26	22.1	12.3	3.4	0.5
2018	15.3				20.5	26.8	22.5	11.1	3.2	0.5
2022	0.5	3.8	16.2	26.8		26	17.3	7.5	1.8	0.1

Figure 4. Performance of Greek Students by Level in Mathematics for the PISA Competitions from 2003 to 2022. (OECD, PISA 2022 Results (Volume I): The State of Learning and Equity in Education, PISA, 2023; OECD, PISA 2018 Results (Volume I): What Students Know and Can Do, 2019; Sofianopoulou, Emvalotis, Pitsia, & Karakolidis, 2017; OECD, PISA 2015 Results (Volume I): Excellence and Equity in Education,, 2016; OECD, PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science (Volume I, Revised edition, February 2014, 2014; OECD, PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science (Volume I), 2010; OECD, PISA 2006 VOLUME 2 DATA, 2007; OECD, Learning for tomorrow' s world. First results from PISA 2003, 2004).

Comparing the performances of Greek students by level of proficiency year after year, it is evident that in all competitions the largest number of students were ranked at level 2 and the next largest at level 3, with the exception of the latest performances. Indeed, the levels of proficiency in PISA 2022 were changed slightly and the largest number of Greek students scored at level 1a. Despite good performances of Greek students at levels 3 and 4, the overall average was not as good. These good performances were not enough to raise the average of the country. The percentage of students attaining the 6th and highest level was very small throughout the years. The same can be said of the performances at level 5. Of significance is also the fact that the percentage of students ranked even below level 1 was high. As a result, the combination of a high percentage of low performances and of a low percentage of high performances determined the overall ranking of Greece below the OECD average.

Given the ranking of the largest numbers of Greek students in the first three levels of literacy in mathematics, it can be said they are generally capable of:

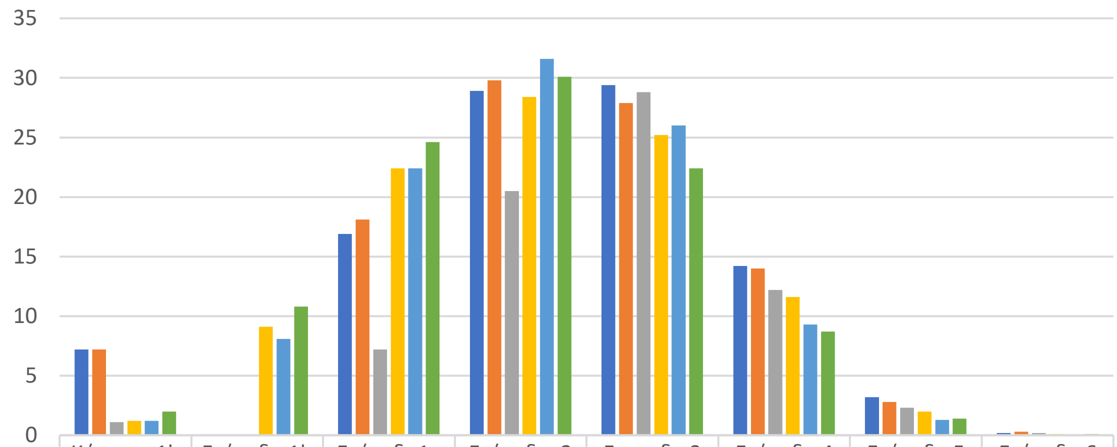
- Answering simple, clearly defined questions;
- Following simple and direct instructions;
- Performing obvious actions;
- Drawing simple conclusions;
- Making use of a single representational mode;
- Extracting relevant information from a single source ;

- Employing basic formulae and or conventions ;
- Performing sequential actions to solve problems that are clearly defined;
- Solving problems by applying simple strategies;
- Presenting and explaining briefly their actions.

  Part of the students – those ranked at level 4 – can:
- Use models for situations that require taking into account constraints and making assumptions;
- Use different representations and link them to real-world situations;
- Construct arguments and explanations for their actions.

Finally, given the very small percentage of students having attained levels 5 and 6, it can be said that the vast majority of Greek students are incapable of:

- Using complex models and identifying constraints;
- Developing well-structured thinking and reasoning;
- Using insight with regard to interpretations they have already presented;
- Conceptualizing, generalizing and utilizing information within the context of complex problem-solving;
- Utilizing information from multiple sources and representations;
- Solving problems relating to novel situations;
- Deciding, through discussion whether their interpretations, findings, approaches and actions are appropriate for the solution of original problems.



	Κάτω το 1b	Επίπεδο 1b	Επίπεδο1a	Επίπεδο 2	Επιπεδο 3	Επίπεδο 4	Επίπεδο 5	Επίπεδο 6
2006	7.2		16.9	28.9	29.4	14.2	3.2	0.2
2009	7.2		18.1	29.8	27.9	14	2.8	0.3
2012	1.1		7.2	20.5	28.8	12.2	2.3	0.2
2015	1.2	9.1	22.4	28.4	25.2	11.6	2	0.1
2018	1.2	8.1	22.4	31.6	26	9.3	1.3	0
2022	2	10.8	24.6	30.1	22.4	8.7	1.4	0.1

2006 2009 2012 2015 2018 2022

Figure 5. Performance of Greek Students by Level in Science for the PISA Competitions from 2003 to 2022. (OECD, PISA 2022 Results (Volume I): The State of Learning and Equity in Education, PISA, 2023; OECD, PISA 2018 Results (Volume I): What Students Know and Can Do, 2019; Sofianopoulou, Emvalotis, Pitsia, & Karakolidis, 2017; OECD, PISA 2015 Results (Volume I): Excellence and Equity in Education,, 2016; OECD, PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science (Volume I, Revised edition, February 2014, 2014; OECD, PISA 2009 Results: What Students Know and Can Do – Student Performance in Reading, Mathematics and Science (Volume I), 2010; OECD, PISA 2006 VOLUME 2 DATA, 2007; OECD, Learning for tomorrow' s world. First results from PISA 2003, 2004).

As far as performances in science are concerned, the largest percentage of students performed at level 2 in the 2009, 2015, 2018 and 2022 competitions, and at level 3 in 2006 and 2012. The percentage of students having attained level 4 can be deemed satisfactory. However, the percentage of students scoring at level 6 has consistently been very low. From 2012 on, the same can be of the percentage of students below level 1. Compared to mathematics, students ranked below the lowest level but also at the highest level in science are fewer.

Based on the learning objectives of each level of proficiency in science, and given that most Greek students were ranked at level 3 or below, we can safely conclude that the majority of Greek students are able to :

- Present scientific explanations that are obvious and follow from given evidence ;
- Provide possible scientific explanations in familiar contexts ;
- Develop direct reasoning ;
- Make literal and limited interpretation of the results of scientific inquiry ;
- Apply simple strategies to explain phenomena ;
- Use concepts from different disciplines and apply them to the explanation of phenomena ;
- Use facts and make decisions based on scientific knowledge.

Part of the students – ranging from 9,3% to 14,2% – ranked at level 4 have demonstrated further skills such as :

- Making inferences about the role of science and technology in everyday life ;
- Integrating explanations from different disciplines of science or technology and linking them directly to aspects of life situations ;
- Making decisions based on scientific knowledge and communicating those decisions.

On the contrary, given the small percentages of students having attained levels 5 and 6, we can ascertain that the majority of Greek students are unable to :

- Identify the scientific aspects or components of complex situations they may be faced with in their everyday life ;
- Apply scientific knowledge to solve complex problems ;
- Use critical thinking to approach any given problem ;
- Combine different sources to justify decisions ;
- Come up with solutions to problems they are unfamiliar with ;
- Develop arguments to support and justify their decisions at each stage of problem-solving.

PISA and STEM Education

Given the results of the PISA competitions and the direct link between 21st century skills as defined by the OECD and the goals of STEM education, we can ascertain that the latter needs to be reinforced. We should mention nevertheless the view that STEM education is part of a global strategy aimed at supporting the work of the OECD. According to this view, the almost simultaneous appearance of the PISA competition and STEM education at the beginning of the 21st century is not a coincidence. The link between the economic growth and success of a country and the educational system is evident and leads to a link between the success of an entire country with the teacher (G. O. Pugliese and V. De Macedo Santos, 2022).

The PISA competition results have in many cases led to changes in curricula. One of the proposed solutions has been precisely the inclusion of STEM education (G. O. Pugliese and V. De Macedo Santos, 2022). Germany's performance in the 2000 PISA competition was not very good, so immediate action was taken to encourage teachers to focus more on achieving specific learning objectives rather than on curricula. This gave teachers more freedom in how they approached each learning objective. In this context, STEM education and the multidimensional goals it represents were implemented while ensuring the high quality of this type of teaching. Assignments are an important tool for STEM education, despite the fact that German physics and mathematics textbooks do not provide any motivation for their implementation (Schiepe-Tiska, Heinle, Duming, Reinhold, & Reiss, 2021). The impact of this type of education on learning outcomes appears to vary across regions, with

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N.A. of Asia showing higher rates of improvement than the rest. While the effect on students' acquisition of higher order motivation and reasoning appears to be significant and higher than the other two categories. Another important conclusion of the research was the finding that the improvement due to the use of STEM was greater in the lower performing areas of PISA than in the higher performing areas. Therefore, we conclude that STEM education may be more beneficial for those students who lack the ability to develop higher-order thinking. An important role in the effectiveness of STEM education is also played by the time that students spend on it: the longer it lasts, the more results it brings in terms of the criteria set out in this research. It is worth noting that the results are influenced by the teaching method and the pedagogical approach chosen by the teacher. In conclusion, the results of STEM education in Asia are considered positive (Wahono, Lin, & Chang, 2020).

In order to demonstrate the relationship between the PISA competition and STEM education, it is useful to compare and contrast simultaneously the skills that a student may acquire through this type of education, the 21st century skills and the skills that students need to have to attain high scores at the competition.

The basic objective of STEM education is to help solve problems in everyday life, which more often than not are highly complex. The ultimate goal is the amelioration of everyday life through novel solutions. Problem-solving is related mostly to engineering and the designing of a solution and of engineering models. In engineering, solving a problem requires the combination of multiple skills, such as the identification of the problem, finding different possible solutions, applying possible solutions so that the students can estimate which is the preferable one – after having evaluated each one of them (C. Sen, Z. S. Ay and S. S. Kiray, 2018).

Figure 6 illustrates the direct link between 21st century skills and STEM education skills and finally the skills required to succeed at each level of the PISA competition. Thus, we can conclude that STEM education may help to improve a country's performances at the competition. The correlation is also made worldwide in literature. For instance, in Germany, STEM education was integrated in the educational system after the low scores of German students at the PISA competition (A. Schiepe-Tiska, A. Heinle, P. Dümig, F. Reinhold and K. Reiss, Oct. 2021). On the other hand, the high scores achieved by Singapore at the competition are attributed to the application of STEM education (Teo, 2019). At the same time, it is suggested that STEM education can contribute to the improvement of scores of low-ranking countries at the competition (B. Wahono, P. Lin and C. Chang, 2020).

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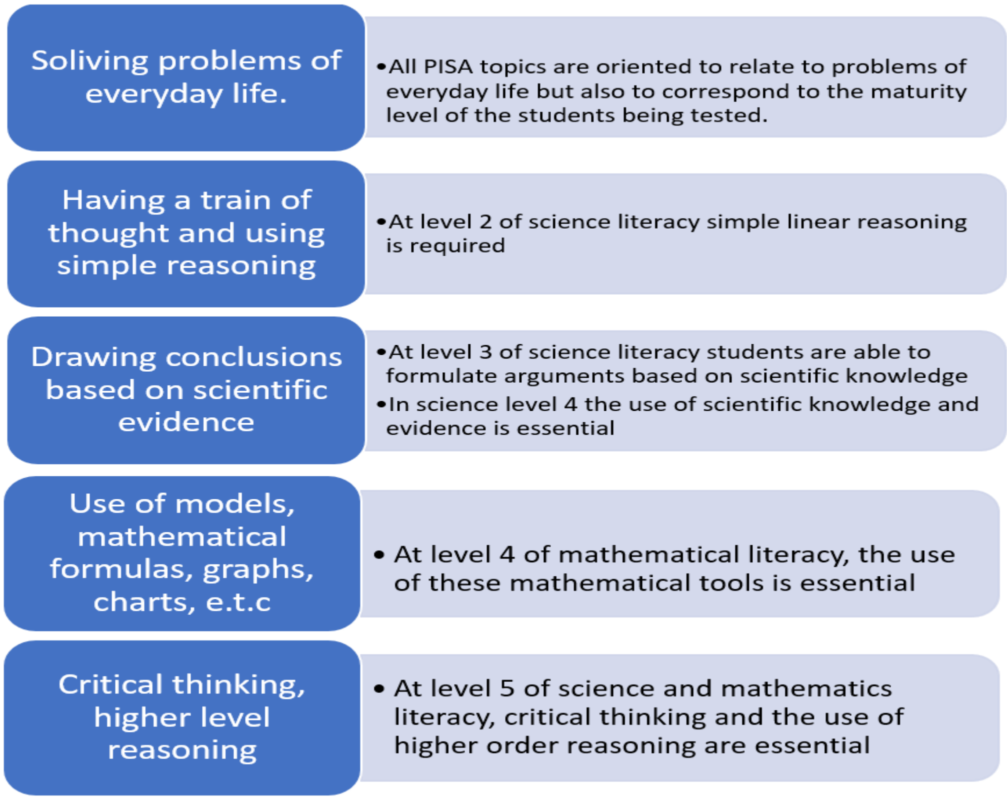

Figure 6. Link between 21st century skills and STEM education.

Taking into account this literature, we can conclude that applying STEM education can contribute to the improvement of Greek students' performances at the PISA competition. Given however the objections as regards the goals set by the OECD, specifically linked with the economic growth of a country, the low scores should by no means be seen as an indictment of the entire educational system.

Conclusions

STEM education focuses on solving everyday problems. Achieving this goal therefore requires the mastery of 21st century skills, such as critical thinking to sort out initial information, the ability to cooperate between team members, the development of leadership skills so that there is one person who inspires the rest. There is also a need to develop creativity, as the proposed solution should be optimal, but also incorporate principles such as environmental protection and sustainability. Creative thinking, which is included in the basic skills of the 21st century, will help the person to modify the proposed solution and try again until the desired characteristics are achieved (Khalil, Tairab, Qablan, Alarab, & Mansour, 2023). The interdisciplinary teaching that characterises STEM education can contribute to the development of the required skills (Khalil, Tairab, Qablan, Alarab, & Mansour, 2023). Competition is a method of measuring skill acquisition, and therefore STEM education can help to improve outcomes. However, given the objections to the targets set by the OECD, which are clearly linked to the economic development of each country, the low scores can in no way be seen as a failure of the education system as a whole. These skills will help people in their social and professional lives. This strengthening of skills will in turn lead to a possible improvement in results in competition, an improvement that cannot be an end in itself. Finally, STEM education does not only help students to develop their skills when it takes place in the school environment. It can also contribute with the same degree of success if it takes place in non-formal settings (Lesseig, Slavit, & Simpson, 2023). The approach required in each of these settings is different, but they can contribute equally (Lesseig, Slavit, & Simpson, 2023). Finally, the positive impact of extracurricular activities on the development of students' skills is now accepted (Norris, Taylor, & Lummis, 2023) (Ab Ghan, Awang, Ajit, & Rani, 2020) .This in turn means that parents' associations, local authorities, cultural associations and sponsors can contribute by creating STEM activities. The low scores in the competition should concern decision-makers, but it is not considered necessary to make changes solely to improve them. On behalf of the authors, it is suggested that students are exposed to STEM education both through the curriculum in the school environment and through extracurricular activities in non-formal learning environments. Therefore, we encourage both teachers to implement STEM teaching scenarios and parents to involve their children in extracurricular STEM activities. It is the state that must ensure the participation of students in STEM programmes, without restrictions that may be related to the student's grade, nationality, place of residence or economic status. The central purpose is to develop the necessary skills for the 21st century. Because of the linearity between these skills and the objectives of the PISA test, STEM education is also expected to improve test results. An improvement which, as already mentioned, is not an end in itself for the curriculum.

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