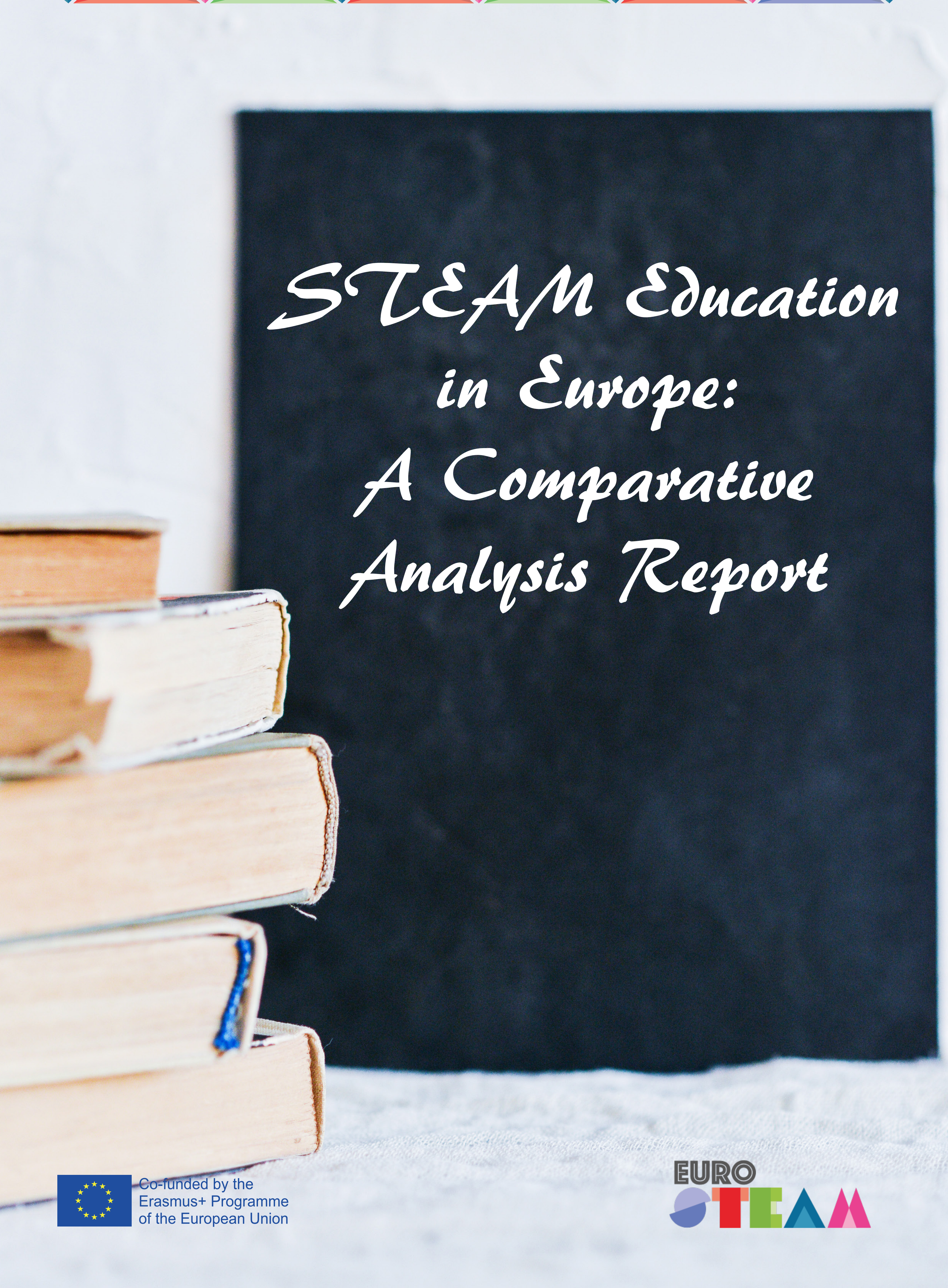
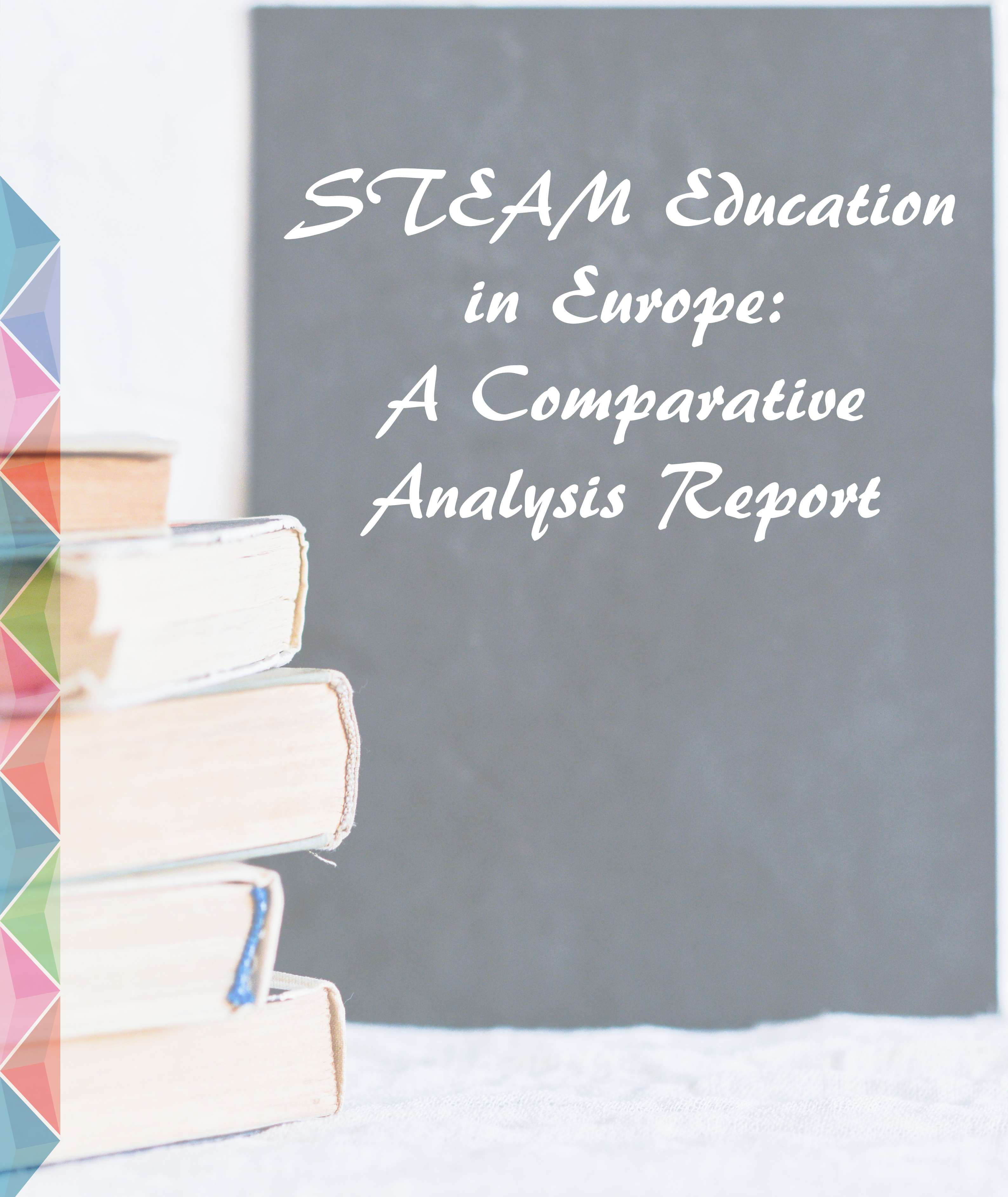
STEAM Education in Europe: A Comparative Analysis Report



Co-funded by the Erasmus+ Programme of the European Union

EURO STEAM

STEAM Education in Europe: A Comparative Analysis Report



Authors: Stefan Haesen, Erwin Van de Put

Project team: Dominic McGeown (project leader), Maria Bandeira, Sara Borrelli, Susana Bronze, Paolo de Gasperis, Patrizia Ferrari, Stjn Gebruers, Stefan Haesen, Aitziber Sarobe, Erwin Van de Put, Betty Weyns, Jon Zarraga

First Printing, September 2018

ISBN 9789090311968

Address

www.eurosteamproject.eu

Co-funded by the Erasmus+ Programme of the European Union

TABLE OF CONTENTS

Co-funded by the
Erasmus+ Programme
of the European Union

INTRODUCTION

The EuroSTEAM project brings together 7 European schools and school support partners with specific expertise in Science, Technology, Engineering, Arts & Mathematics education. Collectively the 5 EU countries participating in the EuroSTEAM consortium (The United Kingdom, Belgium, Italy, Portugal and Spain) all share a common problem; underachievements in basic maths, science and literacy skills. According to the OECD this situation is particular problematic in Italy and Portugal with over 20% of learners aged 15 demonstrating an underachievement in these basic skills. Although the situation in the UK, Belgium, and Spain is slightly better, there is still significant under performance, particularly in maths skills which prove to be a common stumbling block for learners.

To address the collective challenge faced by the participating countries and to ensure pupils across Europe gain the competences they need, the partners in the EuroSTEAM project will co-develop 3 STEAM Camps and supporting teacher materials which will be used as an innovative and effective method to directly address the underachievement in basic skills of maths, science and literacy. The consortium collectively feel that learners understand by doing, thinking, exploring, through quality interaction, intervention and relationships, founded on their interests and abilities across a variety of contexts. This viewpoint is intrinsic to the EuroSTEAM project.

This publication gives the rationale behind the project and builds its theoretical foundation. In the first part we develop our framework for STEAM education which is at the basis of our STEAM camps. In the second part we present a summary of the current state of STEM education in the various partner countries, based on existing literature. Finally, in the last part we make a literature review concerning the central question: "What works in STEAM education?".

The Authors, May 2018

Co-funded by the
Erasmus+ Programme
of the European Union

A FRAMEWORK FOR STEAM EDUCATION

Various approaches

It is commonly advocated that one of the goals of the educational system is to teach future workers how to function in a highly technical, ever changing environment. So-called 21st century skills, like problem-solving ability, communication skills and critical and creative thinking are considered to be essential for successful participants in our society. In line with this movement, STEM education emerged within the scientific disciplines. The STEM acronym stands for the disciplines Science, Technology, Engineering and Mathematics. It is nowadays recognized and widely used as an over-arching discipline that connects the various content topics and incorporates the above-mentioned 21st century skills. While educationalists consider STEM to be a better means for preparing students for the future society than the classical separate disciplines, policy makers and captains of industry use STEM as a vehicle to promote scientifically-oriented careers from an early age on (Caprille, Palmén, Sanz, & Dente, 2015) (Committee on STEM education, 2011). Nowadays STEM is common in the formal and informal learning processes in most countries, with even elementary and secondary schools designating themselves as STEM schools. All of this is based on various frameworks of what STEM actually means. Based on these frameworks a vast literature is being compiled of the successes and pitfalls of STEM education. In recent years STEM has suffered various critiques. It remains difficult to obtain a full integration of the various disciplines partly because the nature of disciplines differ fundamentally, disciplines like science and technology are over-represented with often less attention on mathematics and engineering, by focusing on STEM other important disciplines are neglected,

… . Therefore a re-conceptualization of STEM is needed in order to be able to reach the above-mentioned goals.

One possible re-conceptualization of STEM is STEAM, where the ‘A’ stands for the arts. This idea is not new and can be traced back to great universalists like Da Vinci:

Principles for the development of a complete mind: Study the science of art. Study the art of science. Develop your senses – especially learn how to see. Realize that everything connects to everything else.

Using this idea in the education process and considering the child as the central object, Dewey (1902) criticized the use of separate disciplines as means of studying the world:

The child’s life is an integral, a total one. He passes quickly and readily from one topic to another, as from one spot to another, but is not conscious of transition or break. There is no conscious isolation, hardly conscious distinction. The things that occupy him are held together by the unity of the personal and social interests which his life carries along. Whatever is uppermost in his mind constitutes to him, for the time being, the whole universe. That universe is fluid and fluent; its contents dissolve and re-form with amazing rapidity. But, after all, its the child’s own world. It has the unity and completeness of his own life. He goes to school, and various studies divide and fractionize the world for him. Geography selects, it abstracts and analyzes one set of facts, and from one particular point of view. Arithmetic is another division, grammar another department, and so on indefinitely.
(Dewey, 1902)

In recent times, STEAM was incorporated into the national curriculum in Korea in 2009 (Korean Ministry of Education, 2009). In the Western world John Maeda, former president

Co-funded by the
Erasmus+ Programme
of the European Union

of the Rhode Island School of Design, was one of the recent advocates, claiming that innovation happens when convergent and divergent thinkers join forces, translating this into STEM + Art (Maeda, 2013). But what does STEAM actually mean and how can it be used into the educational process? Due to its apparent novelty and disparate emergence, various frameworks for STEAM education are being promoted.

A first point of discussion is the interpretation of the 'A' in STEAM. A narrow view interprets 'A' as the visual and performing arts. It has been argued that these latter offer a means for conceptualizing, understanding and expressing science and that 'they cultivate a particular kind of ontology, a complex combination of being lost in the moment and utterly present, an experience that lies at the heart of inquiry-based science education' (Gershon & Ben-Horin, 2014). The special role how the arts introduce creativity, both in the inquiry process as in the final presentation of the results, has further been highlighted (Guyotte K. , Sochacka, Constantino, Walther, & Kellam, 2014) (Guyotte K. , Sochacka, Constantino, Kellam, & Walther, 2015). On the other hand, take the more holistic point of view of Dewey, 'A' is considered by others as meaning the liberal arts and humanities. Kim (2016) extends STEM with arts, history, geography and bibliography. Others, like Quigly, Herro and Jamil (2017) include the liberal arts, like English language arts and social studies. An even broader re-conceptualization was given by Krug and Shaw (2016) by introducing the concept of ST®EAMS, which includes besides the arts and humanities, also sustainability education (S) and interdisciplinarity and curriculum integration (®). In the remaining of the text, we will use this latter view and consider STEAM to be an integrated approach between the disciplines of science, technology, engineering, arts, mathematics, the humanities and ecological awareness. More important than the discussed disciplines is the use of them:

..., the subject-matter of science and history and art serves to reveal the real child to us. We do not know the meaning either of his tendencies or of his performances excepting as we take them as germinating seed, or opening bud, of some fruit to be borne. (Dewey, 1902)

What kind of topics are to be studied within STEAM? Most authors state that open-ended, real-world problems are to be considered as they most likely offer the best possibilities for a true integration of the various disciplines. Using real-world problems raises the motivation of the learners when they are related to their everyday-live experiences or offer the prospective of a meaningful solution of a valuable problem (Kim P. W., 2016). On the level of integration between the various disciplines, various approaches are being used. At the lowest level we consider what can be denoted as STEM+Art. Here, one starts from the classical STEM approach (integrated disciplines or not) and adds an art component. This component is often reflected in an artistic presentation of the results, e.g. a dance performance or video presentation at the end of the project. At best this approach can be deemed multidisciplinary since various disciplines are involved, although no interaction between the disciplines is present during the project (Kim P. W., 2016). In an interdisciplinary approach ideas from different disciplines are brought together to understand and solve the problem (Quigley, Herro, & Jamil, 2017). Although this approach goes beyond the multidisciplinary view, its findings still remain within the disciplines. On a higher level acts the transdisciplinary teaching method, which focuses on the content of one discipline and uses contexts of other disciplines, to make the context more rich. While this method is preferred, it is not always attainable (Quigley, Herro, & Jamil, 2017). A serious point of caution when selecting the problems is the level of difficulty. It is a tendency in educational circles that learning should be interesting and fun.

Human nature being what it is, however, it tends to seek its motivation in the agreeable rather than in the disagreeable, in direct pleasure rather than in alternative pain. And so has come up the modern theory and practice of the "interesting", in the false sense of that term. The material is still left; so far as its own characteristics are concerned, just material externally selected and formulated. It is still just so much geography and arithmetic and grammar study; not so much potentiality of child-experience with regard to language, earth, and numbered and measured reality. Hence the difficulty of bringing the mind to bear upon it; hence its repulsiveness; the tendency for attention to wander; for other acts and images to crowd in and expel the lesson. The legitimate way out is to transform the material; to psychologize it – that is, once more, to take it and to develop it within the range and scope of the child's life. But it is easier and simpler to leave it as it is, and then by trick of method to arouse interest, to make it interesting; to cover it with sugar-coating; to conceal its barrenness by immediate and unrelated material; and finally, as it were, to get the child to swallow and digest the unpalatable morsel while he is enjoying tasting something quite different. (Dewey, 1902)

It is within the human nature to seek the path of least resistance. Alas, for education this does not work.

Die dabei anfänglich auftretenden Schwierigkeiten liegen in der Natur der Sache. Lehrerinnen und Lehrer dürfen sich dadurch nicht abhalten lassen diesen Weg zu gehen, der im wohlverstandenen Interesse der Kinder liegt. Kinder müssen sich notwendiger Weise in die theoretische Natur der Mathematik einarbeiten, when sie Mathematik verstehen wollen. (Wittmann, 2003)[1]

That which holds for mathematics obviously holds for other disciplines also, or to paraphrase Euclid, There is no royal road to STEAM.

1 The initially occurring difficulties are in the Nature of Things. Teachers should not be deterred from taking this path, which is in the well-understood interest of children. Children must necessarily become familiar with the theoretical nature of mathematics when they want to understand mathematics.

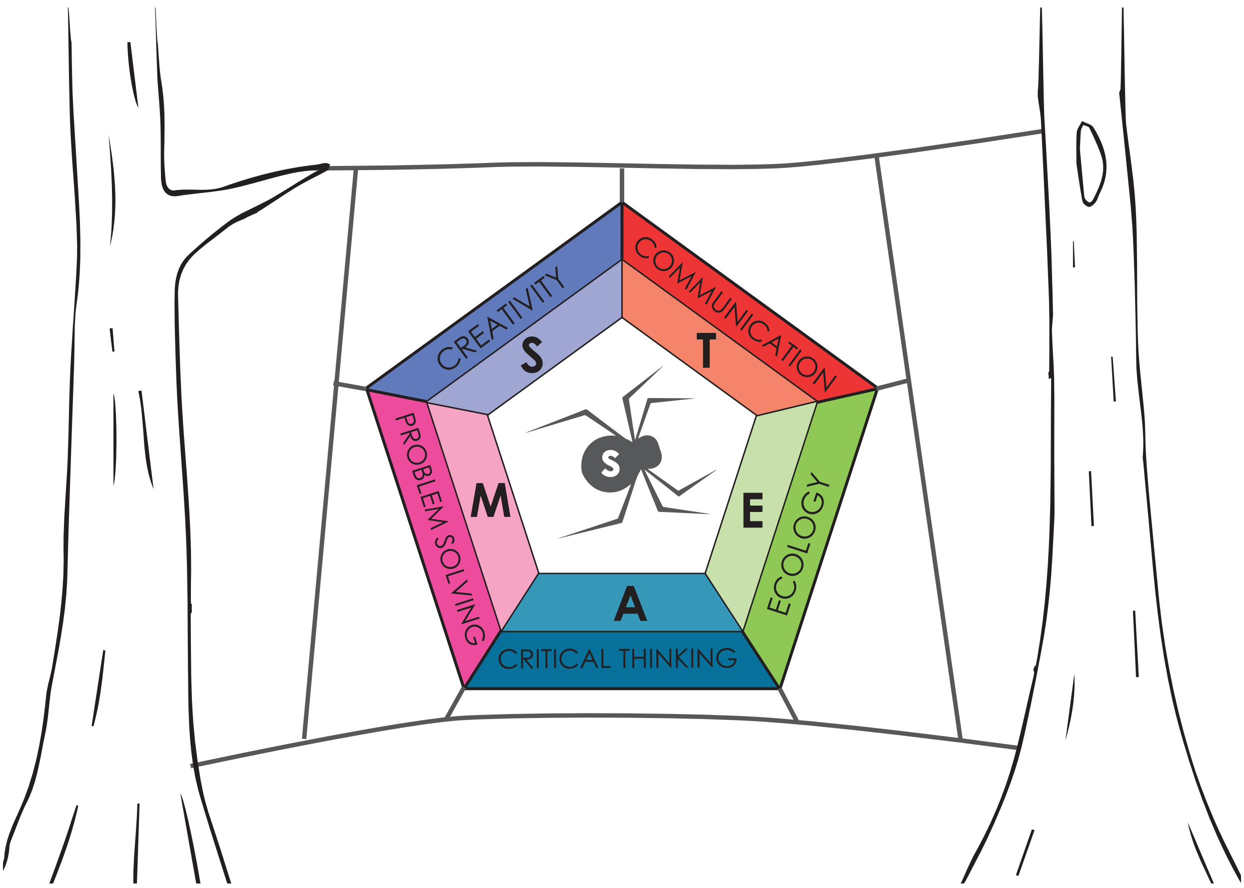
STEAM is presented almost exclusively in the form of problems to the learners. The discipline is problem-centered which means that subject-matter content and attitudes are learned through the solution of real-world problems. This already includes a radical choice in pedagogy. Although some critique has been uttered on the choice of these pedagogies (see e.g. (Kirschner, Sweller, & Clark, 2006)), various forms of problem-centered education are nowadays promoted. Kim (2016) uses the performing problem method because of the hands-on approach. In this method the advisory teacher participates actively in the project as the project manager, the relation thus being more a student-teacher dyad instead of student-centered as in e.g. problem-based learning. Quigley, Herro and Jamil (2017) (see also e.g. (Herro & Quigley, Exploring teachers' perceptions of STEAM teaching through professional development: implications for teacher educators, 2017)) promote the use of problem-based learning, with problems where there are multiple solutions (see e.g. (Hmelo-Silver, 2004), (Savery, 2006)).

As noted in the introduction, STEAM is considered to be an excellent vehicle to introduce the 21st century skills in education. Because art work is more about questioning and understanding concepts than finding answers to a given problem, it is in essence inquiry-based and as such is analogous with principles of critical thinking (Ghanbari, 2015). Based on a collaboration between students in art education, engineering and landscape architecture, Guyotte e.a. (2014, 2015) conceptualize STEAM as a social practice of doing that reflects concerns for community engagement and ecological sustainability. Building on the reflections of the participating undergraduate and graduate students, they derived three domains within the social practice. Thinking through materials helps for a better understanding of real-world, ill-structured problems, while considering the audience is essential to effectively communicate the message and empathizing with others is an integral part of the design process. Finally, engaging with the community opens up the way to the publics preferred modes of communication. As such the collaborative potential embedded in STEAM education is immense.

Co-funded by the
Erasmus+ Programme
of the European Union

A spiders' web framework for STEAM education

A spiderweb is a spiders' STEAM solution of a real-world problem. In order for a small spider to catch a prey it constructs an artistic and scientific masterpiece. It involves technology and science in the kind of threads and the way they are used, mathematics is reflected in the symmetry and shapes involved, art and engineering in the way each particular web is adapted to its surrounding.



Building on the above-mentioned points, we conceptualize STEAM as a transdisciplinary interaction between science, technology, engineering, mathematics, arts, humanities and ecological awareness. The content is delivered in a performing problem method, were students and teachers co-operate as co-researchers. It is the role of the teacher to select those problems that arouse interest by the students, meet the set goals of the educational process and are within reach of the capabilities of the learners. In this sense the problem is the center of the spiderweb out of which everything starts. The goals are always dual in nature. A first ring around the center constitutes of the content in the various disciplines. A second ring emphasizes specific attitudes and skills, like e.g. critical thinking, communication skills and creativity. These rings are connected with a multitude of threads, all linkages between content and attitude and skills. The threads represent the performing problem method. The web is attached to the world through strong treads which represent the teacher. It is the teacher who makes the difference in the learning process, who in the background regulates the process through successful selection of the problems, feedback and feed forward during the problem finding and solving process and careful and adequate evaluation afterwards (Hattie, 2012). And where is the student? The student is the spider in the web, starting from the problem and moving back and forth between the disciplines, attitudes and skills, but always safeguarded by the teacher.

Co-funded by the
Erasmus+ Programme
of the European Union

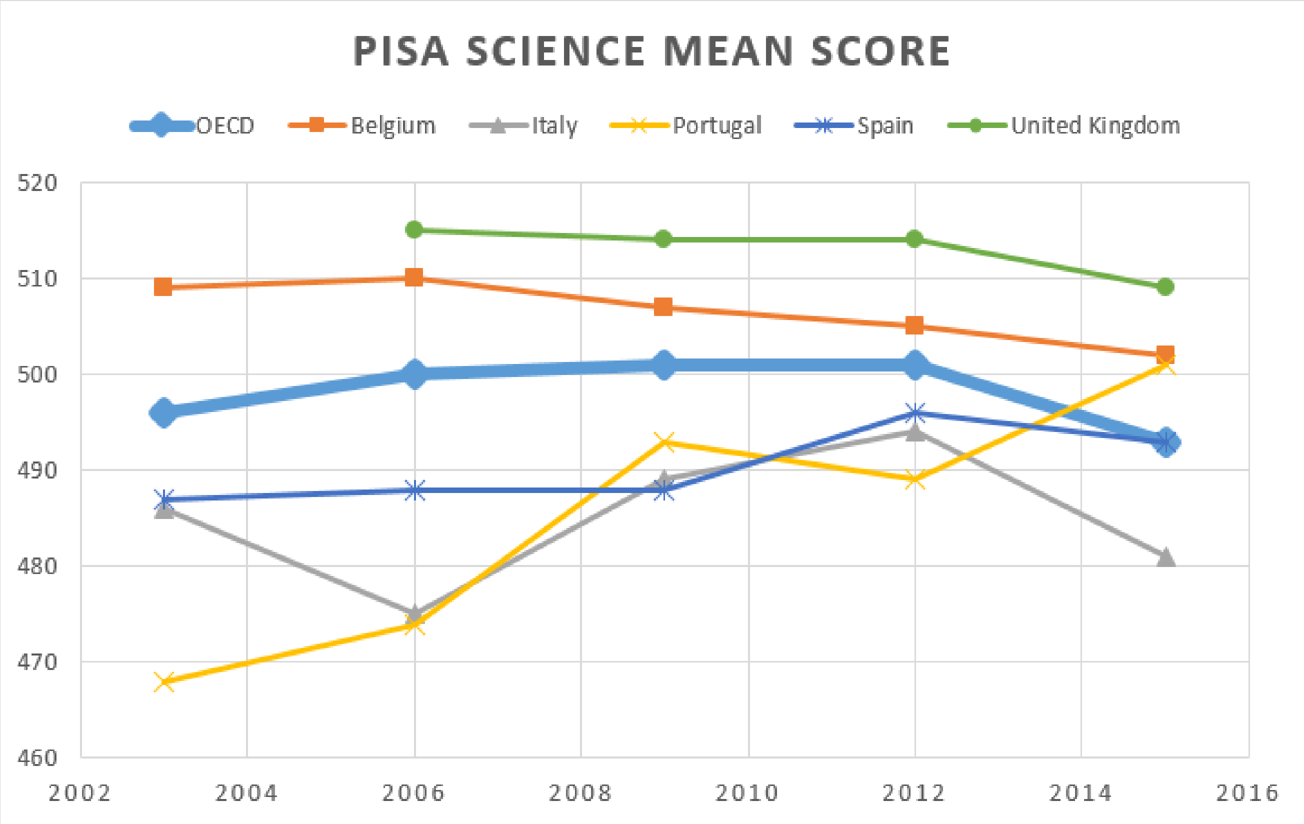
CURRENT STATE OF STEAM EDUCATION

As STEAM education is a newly emerging field in education, there is almost no data available for an international comparison. The same holds true for STEM education. Because there is no generally accepted framework, cross-country comparisons are difficult to make. Therefore, in the following sections we focus on the existing international comparison tests concerning science and mathematics. We consider data from TIMSS (Trends in International Mathematics and Science Studies) for pupils in the 4th grade of primary school and from PISA (Programme for International Student Assessment) for 15 year old students. Further, we include data from an OECD report on the number of students enrolled in STEM course in higher education. In this way we cover the broad range of all three levels of education, i.e. primary, secondary and higher education. After the data we include a critical reflection on the use and value of these international comparison tests. Because each country has its own specific characteristics and quality measures, we end this chapter with an overview of the national and regional quality measures of STEM education and trends herein.

The Programme for International Student Assessment (PISA) is an international comparison study on behalf of the Organisation for Economic Co-operation and Development (OECD). PISA tests 15 year olds about their reading skills and mathematical and scientific literacy, collaborative problem solving and financial literacy, regardless the specific grade the pupils attend. The tests are performed every three years, with each time a focus on a specific discipline, whereby the others are mildly tested. Because the test is by nature a comparison test, we present the results in comparison to the OECD average. Green cells indicate statistically above OECD average, red statistically below and white cells give no statistically difference with the OECD average. The results are first listed on the national level in alphabetical order for the participating countries in the EUROSTEAM project. Because the education system is a regional matter in some countries, we also include the relevant regional results if they are available. The results for Science show a diverse picture. In two countries, Belgium and the United Kingdom, the students performed above OECD average from the first tests in 2003 and 2006, respectively. However, these results decrease in time, notably in Belgium. In the other three countries, Italy, Portugal and Spain, the students performed substantially below the OECD average, but noticeable progress has been made in Portugal and Spain, with Portugal even performing above average in the latest tests. The results of the students in Italy in 2015 show on the other hand a serious decline in comparison with the previous tests. The data on a regional level is too limited to draw any evolutional conclusions.

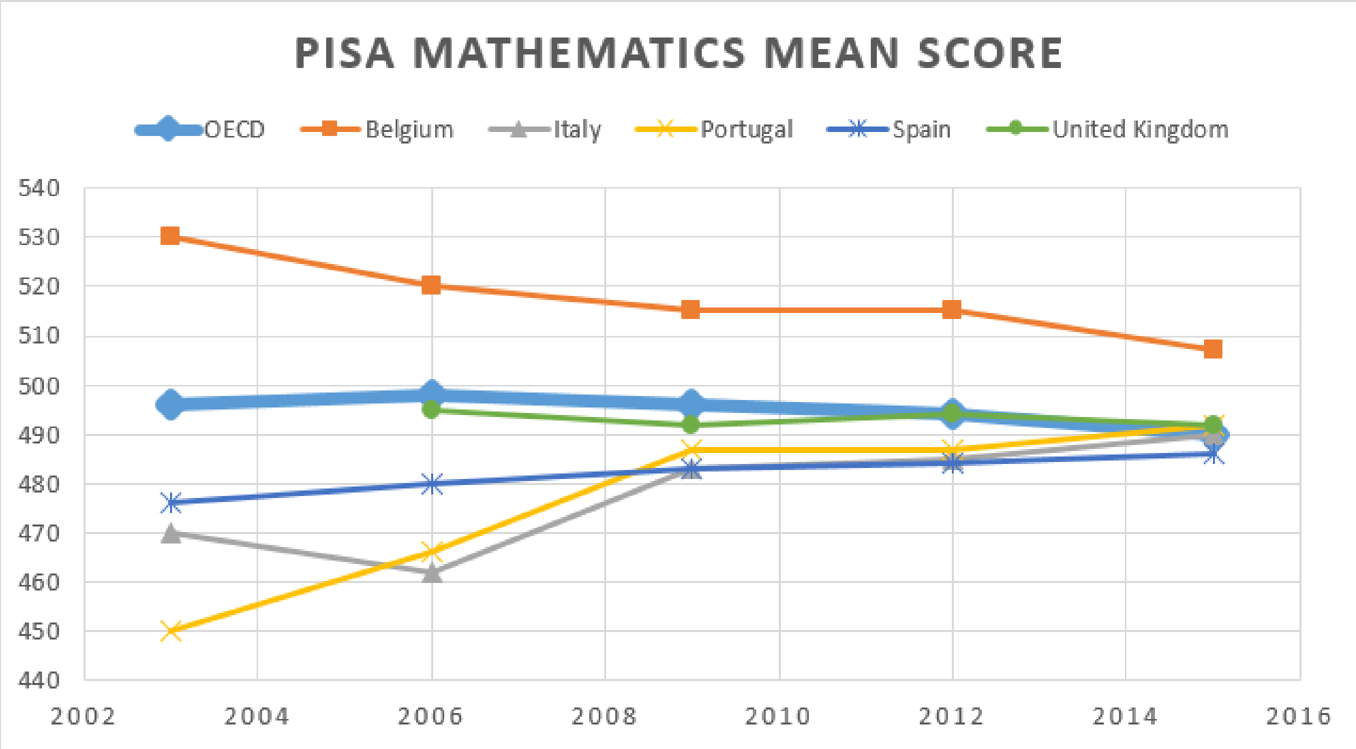
PISA Science Mean Score					
	2015 (493)	**2012 (501)**	**2009 (501)**	**2006 (500)**	**2003 (496)**
Belgium	502	505	507	510	509
Italy	481	494	489	475	486
Portugal	501	489	493	474	468
Spain	493	496	488	488	487
United Kingdom	509	514	514	515	
Flemish Community	515	518			
Basque country	483	506			
Northern Ireland	500	507			

Co-funded by the Erasmus+ Programme of the European Union



The results for the mathematics tests show an even more diverse picture. In only one of the considered countries do the students perform statistically above the OECD average, i.e. Belgium. The results here however show a remarkable decrease over the past 12 years. In the United Kingdom the students perform each test on the OECD average, while in Italy, Portugal and Spain a noticeable increase has occurred.

PISA Mathematics mean score					
	2015 (490)	2012 (494)	2009 (496)	2006 (498)	2003 (496)
Belgium	507	515	515	520	530
Italy	490	485	483	462	470
Portugal	492	487	487	466	450
Spain	486	484	483	480	476
United Kingdom	492	494	492	495	
Flemish community	521	531			
Basque country	492	505			
Northern Ireland	493	487			



Besides the various tests, PISA also measures other indicators of the participating students through questionnaires, both for the students and their teachers. One of the measured indicators is fairness and inclusion. The reason we include this indicator is that research all too often shows that the students' backgrounds influence their opportunities to learn and develop their skills. The fairness and inclusion indicator is a measure of equity in the education system. Inclusion refers to "the objective of ensuring that all students, particularly those from disadvantaged backgrounds or traditionally marginalised groups have access to high-quality education" (OECD, PISA 2015 Results (Volume I): Excellence and Equity in Education, 2016). Fairness refers to "the goal of removing obstacles to the full development of talent that stem from economic and social circumstances over which individual students have no control" (OECD, PISA 2015 Results (Volume I): Excellence and Equity in Education, 2016).

Co-funded by the
Erasmus+ Programme
of the European Union

If we look at the results of the fairness and inclusion indicator for science, we note that for the considered countries, only in Belgium the relationship between the student performance and the socio-economic status of the students stronger than the OECD average. In Italy and the United Kingdom the relationship between both indicators is below average, while in Portugal and Spain it is on the average.

A student is classified as resilient if he or she is in the bottom quarter of the PISA index of economic, social and cultural status in the country/economy of assessment and performs in the top quarter of students among all countries/economies, after accounting for socio-economic status. Looking at the five considered countries, we note that in Portugal, Spain and the United Kingdom the percentage of resilient students is above OECD average, thus indicating for ample opportunities for students with low socio-economic status. In Belgium and Italy the percentage of students is at the OECD average.

PISA 2015 Fairness and inclusion indicators in Science		
	Percentage of variation in science performance explained by students socio-economic status	**Percentage of resilient students**
OECD	12.9	29.2
Belgium	19	27.2
Italy	10	26.6
Portugal	15	38.1
Spain	13	39.2
United Kingdom	11	35.4

Trends in International Mathematics and Science Studies (TIMSS) is an international comparison assessment about the student performance in science and mathematics. The research is coordinated by the International Association for the Evaluation of Educational Achievement (IAE). In a four-yearly cycle 4th grade pupils in primary school and 2nd graders in secondary school (also called 8th graders) perform science and mathematics tests. Because not all considered countries have participated in the tests for 2nd grade secondary school, we only consider the 4th grade primary school results.

Instead of presenting one common indicator for science and mathematics, TIMSS presents the results on four benchmarks. In the following we present the results for each of the benchmarks, advanced, high, intermediate and low, and a description of each benchmark.

For Belgium and the United Kingdom no national data is available, only the regional data for Flanders and Northern Ireland can be given.

4th grade mathematics

The following results and accompanying descriptors come from (Mullis, Martin, Foy, & Hooper, 2016).

Students who reach the advanced international benchmark can apply their understanding and knowledge in a variety of relatively complex situations and explain their reasoning. They can solve a variety of multi-step word problems involving whole numbers. The students at this level show an increasing understanding of fractions and decimals. They can apply their knowledge of a range of two- and three-dimensional shapes in a variety of situations. Finally, they can interpret and represent data to solve multi-step problems.

Co-funded by the
Erasmus+ Programme
of the European Union

% of students reaching advanced international benchmark Mathematics					
	2015	**2011**	**2007**	**2003**	**1995**
Flanders Community	10	10		10	
Italy	4	5	6	6	
Portugal	12	8			1
Spain	3	1			
Northern Ireland	27	24			

Students who reach the high international benchmark can apply their knowledge and understanding to solve problems. They can solve word problems which involve operations with whole numbers, simple fractions and two-place decimals. The students demonstrate an understanding of the geometric properties of shapes and of angles that are less than or greater than a right angle. Finally, the students can interpret and use data in tables and in a variety of graphs to solve problems.

% of students reaching high international benchmark Mathematics					
	2015	**2011**	**2007**	**2003**	**1995**
Flanders Community	47	50		51	
Italy	28	28	29	29	
Portugal	46	40			11
Spain	27	17			
Northern Ireland	61	59			

Students who reach the intermediate international benchmark can apply basic mathematical knowledge in simple situations. They demonstrate an understanding of whole numbers and some understanding of fractions and decimal numbers. Further, they can relate two- and three-dimensional shapes and identify and draw shapes with simple properties. They can finally read and interpret bar graphs and tables.

% of students reaching intermediate international benchmark Mathematics					
	2015	2011	2007	2003	1995
Flanders Community	88	89		90	
Italy	69	69	67	65	
Portugal	82	80			37
Spain	67	56			
Northern Ireland	86	85			

Students who reach the low international benchmark are those who have some basic mathematical knowledge. They can add and subtract whole numbers, perform multiplications by one-digit numbers and solve simple word problems. They have some knowledge of simple fractions, geometric shapes and measurements. Finally, they can read and complete simple bar graphs and tables.

% of students reaching low international benchmark Mathematics					
	2015	2011	2007	2003	1995
Flanders Community	99	99		99	
Italy	93	93	91	89	
Portugal	97	97			70
Spain	93	87			
Northern Ireland	97	96			

Co-funded by the
Erasmus+ Programme
of the European Union

4th grade science

The resulting and accompanying descriptors come from (Martin, Mullis, Foy, & Hooper, 2016).

Students reaching the advanced international benchmark in Science communicate understanding of life, physical and Earth sciences and demonstrate some knowledge of the process of scientific inquiry. The students demonstrate knowledge of the characteristics and life processes of a variety of organisms, communicate understanding of the relationships in ecosystems and interactions between organisms and their environment, and communicate and apply knowledge of factors related to human health. They communicate understanding of properties and states of matter as well as physical and chemical changes, apply some knowledge of forms of energy and energy transfer, and show some knowledge of forces and an understanding of their effect on motion. The students communicate an understanding of Earth's structure, physical characteristics, processes, and history and show knowledge of Earth's revolution and rotation. Finally the students demonstrate basic knowledge and skills related to scientific inquiry, recognizing how a simple experiment should be set up, interpreting the results of an investigation, reasoning and drawing conclusions from descriptions and diagrams, and evaluating and supporting an argument.

% of students reaching advanced international benchmark Science					
	2015	**2011**	**2007**	**2003**	**1995**
Flanders Community	3	2		2	
Italy	4	8	13	9	
Portugal	2	7			2
Spain	5	4			
Northern Ireland	5	5			

Students reaching the high international benchmark in Science communicate and apply knowledge of the life, physical and Earth sciences in everyday and abstract contexts. They communicate knowledge of characteristics of plants, animals, and their life cycles, and apply knowledge of ecosystems and of humans' and organisms' interactions with their environment. The students communicate and apply knowledge of the states and properties of matter, and of energy transfer in practical contexts, as well as showing some understanding of forces and motion. They apply knowledge of Earth's structure, physical characteristics, processes and history, and show basic understanding of the Earth-Moon-Sun system. Finally, the students compare, contrast and make simple inferences using models, diagrams, and descriptions of investigations, and provide brief descriptive responses using science concepts, both in everyday and abstract contexts.

% of students reaching high international benchmark Science					
	2015	**2011**	**2007**	**2003**	**1995**
Flanders Community	27	24		28	
Italy	32	37	44	35	
Portugal	25	35			13
Spain	34	28			
Northern Ireland	34	33			

Co-funded by the Erasmus+ Programme of the European Union

Students reaching the intermediate international benchmark in Science show basic knowledge and understanding of life, physical and Earth sciences. They demonstrate some knowledge of life processes of plants and humans, communicate and apply knowledge of the interaction of living things with their environments as well as the impact humans can have on their environment, and communicate basic facts related to human health. They apply knowledge of some properties of matter and about some facts related to electricity and to energy transfer, and apply elementary knowledge of forces and motion. They show some understanding about Earth's physical characteristics and demonstrate some basic knowledge of Earth in the solar system. Finally the students interpret information in diagrams, apply factual knowledge in everyday situations and provide simple explanations of biological and physical phenomena.

% of students reaching intermediate international benchmark Science					
	2015	**2011**	**2007**	**2003**	**1995**
Flanders Community	73	73		79	
Italy	75	76	78	70	
Portugal	72	75			43
Spain	74	67			
Northern Ireland	76	74			

Students reaching the low international benchmark show basic knowledge of life and physical sciences. They demonstrate some basic knowledge of behavioral and physical characteristics of plants and animals as well as of the interaction of living things with their environments, and apply knowledge of some facts related to human health. Further they show basic knowledge of states of matter and physical properties of matter. Finally, the students interpret simple diagrams, complete simple tables and provide short, fact-based, written responses.

% of students reaching low international benchmark Science					
	2015	**2011**	**2007**	**2003**	**1995**
Flanders Community	96	96		98	
Italy	95	95	94	91	
Portugal	96	95			73
Spain	95	92			
Northern Ireland	95	94			

Co-funded by the
Erasmus+ Programme
of the European Union

STUDENTS IN HIGHER EDUCATION

One of the incentives to introduce STEM education in primary and secondary education was the lack of students and consequently graduates in STEM related disciplines in tertiary education. Based on data from 2015, the OECD Education at a glance report 2017, concluded that in half of the OECD and partner countries with data "the combined share of students graduating from the fields of natural sciences, mathematics and statistics, engineering, manufacturing and construction, information and communication technologies is still lower than the share of students graduating from business, administration and law. In 2015, 23% of tertiary graduates completed their degree from these fields on average across OECD countries".

If we look at the specific country details, we find the following results (OECD, Education at a glance 2017: OECD indicators, 2017).

Distribution of tertiary graduates, by field of study (2015)										
	Education	Arts and humanities	Social sciences, journalism and information	Business, administration and law	Natural sciences, mathematics and statistics	Information and communication technologies	Engineering, manufacturing and construction	Agriculture, forestry, fisheries and veterinary	Health and welfare	Services
Belgium	9	11	11	21	4	1	12	2	27	1
Italy	m	m	m	m	m	m	m	m	m	m
Portugal	7	9	11	19	6	1	21	2	19	6
Spain	16	9	7	19	5	4	16	1	15	7
United Kingdom	10	15	12	22	13	4	9	1	13	0

m= data is missing.

From the table above, we see that the total cohort of tertiary students graduating in 2015 in a STEM discipline in Belgium is 17%, in Portugal is 28%, in Spain is 25% and in the United Kingdom is 26%.

Besides the international comparative tests and data, each national or regional government takes own initiatives for the quality control of its educational system. For each of the partner countries/regions in the EUROSTEAM project, we give a short overview of the state of STEM education based on the above and local data.

FLANDERS COMMUNITY (BELGIUM)

Introduction

In Belgium education is mostly a regional matter, belonging to the Flemish, French and German-speaking regional government. Each community has its own regulations, with only minor differences. The only stipulation on the federal level is the age of mandatory education, which is set between 6 and 18, with the possibility for combining education with work from the age of 15. In the following we only consider the education system in the Flemish region. This system is scaled into the European qualifier framework for education, which is given in the table below.

Education degree	**EQF**
Primary education (between age 6-11)	1
Secondary education (between age 12-17)	4
Tertiary education: Graduate education (1,5 year)	5
Tertiary education: Professional bachelor (3 years)	6
Tertiary education: Master education (4-5 years)	7
PhD	8

The schools are grouped in three networks:

- State schools, with are directly organized by the Flemish government
- Subsidized public schools, which are organized by the provinces and municipalities

Co-funded by the Erasmus+ Programme of the European Union

- Subsidized free schools, which are themselves divided in various networks of which the Catholic network is by far the largest.

In 2017, almost two out of 3 students in primary and secondary education attended education in a Catholic subsidized free school.

The Flemish regional government stipulates the minimal end terms, i.e. the skills and knowledge each pupils must attain at the end of primary and secondary education. The various networks translate and concretize these terms in education plans. Because of the right of free education, each school has the authority to organize its education based on its own vision. Inspection by the government of the schools in light of quality control is performed on the level of the education plans. Besides these inspections, the Flemish government conducts are regular interval regional tests of specific disciplines to measure the attainment of the end terms. Because STEM is not a recognized discipline in the end terms, we take a closer look at the most recent results of the disciplines Nature and Technology (primary), Natural Sciences (secondary) and Mathematics (primary and secondary).

Nature and Technology, primary education

In 2015 the attainment of the end terms of the domains Nature and Technology were measured for the first time at the end of the primary school (Vlaamse overheid, Peiling wereldoriëntatie Natuur en Techniek in het basisonderwijs, 2016).

The test consisted of six written exams for the part Nature and one written and one practical test for the part Technology. The highest scores were obtained on the tests about health care (80%) and construction (74%). The other end terms on Nature and Technology are attained by 69 up to 72% of the students. In general there are few differences between boys and girls on the tests, although girls outperform boys on the practical test concerning elements like accuracy. Pupils whose home language is different from Dutch perform less on the tests, while pupils whose family have a positive socio-economic status perform in general better.

Natural sciences, secondary education

In 2015 the attainment of the end terms of the discipline Natural Sciences at the end of the first grade (year 2) of general secondary education was measured, i.e. those students in general secondary education (Classical languages, modern sciences and technical options) (Vlaamse overheid, Peiling natuurwetenschappen in de eerste graad secundair onderwijs, 2016).

The measurement consisted of seven written tests and one practical test wherein the students had to classify leafs, perform measurements and an experiment. In general the results on the written tests were not good. The best results were attained on the tests concerning organisms in their environment and scientific skills: two out of three students reached the end terms. On the other tests about half of the student population reached the minimum goals, except on the test about energy which only 26% of the students succeeded.

Boys outperform girls on the various tests. Students who speak another language at home, even if they also speak Dutch, perform less on the test.

Mathematics, primary education

In 2016 the attainment of the end terms of mathematics was measured for the third time (previous in 2002 and 2009) with pupils in the final year of primary education (Vlaamse overheid, Peiling wiskunde in het basisonderwijs, 2017). The test consisted of the

Co-funded by the
Erasmus+ Programme
of the European Union

written part concerning numbers, arithmetic, measurement and geometry, and of a practical exam in which the pupils were tested on the estimation, measurement and spatial orientation skills.

About 75% of the pupils reach the end terms on number value, equality and problem solving. The other items on numbers and arithmetic are only reached by 50-66% of the pupils. Concerning measurement and geometry, 90% of the pupils reach the end terms about spatial orientation, money and clock reading. The end terms on reference points and problem solving in measurement and geometry are reached by 60% of the pupils. However, only 29% of the students reach the set goals for redirection of measures in a meaningful context (e.g. 12,5 km = 12 500 m).

In general, boys outperform girls on most tests, ranging from 4% to 16%. Pupils who speak another language than Dutch at home score less on the test, adding up to 20% for some tests. Taking into account other socio-economic factors, the difference between pupils from a family with low socio-economic status (SES) and those from a family with high socio-economic status, amounts to 37%.

In comparison with the test from 2009, it is noted that on most tests concerning numbers and arithmetic, there is a decrease of the number of students who reach the set end terms. In measurement and geometry, there is only a decrease in the part of problem solving. On all tests the gender gap increases, from 2% in 2009 up to 12% in 2016.

Mathematics, first grade secondary education

In 2009 the attainment of the end terms at the end of the first grade (year 2) of secondary education was tested for those students in the A-direction, i.e. those students in general secondary education (Classical languages, modern sciences and technical options) (Vlaamse Overheid, 2010).

The best scores were reached in the domains of three-dimensional geometry (92%), number theory (73%) and geometrical concepts (66%). The domains arithmetic (28%), calculating with polynomials (28%) and geometrical procedures - calculating (45%) scored below 50%. As can be expected, large differences occur between the various types of general education.

The differences between students can be explained for 52% by the school and class factors. This leaves 48% of the difference in results to be explained by student characteristics. Some noticeable results are:

- boys outperform girls;
- students who speak another language at home (with or without Dutch) perform less on the tests;
- students from a family with a high SES score better on the test than students from a family with a low SES.

Mathematics, second grade secondary education

In 2011 the attainment of the end terms at the end of the second grade (year 4) of the general secondary education was tested (Vlaamse overheid, Peiling wiskunde in de tweede graad algemeen secundair onderwijs, 2012).

The best scores were reached in the domains statistics (76%) and real functions (75%), while the lowest scores were reached in the domains functions of the first and second degree (42%) and three-dimensional geometry (56%). These general results cloud the overall differences which exist between the various option groups that are present in the general secondary direction. The students in the option Classical languages and Sciences reach in high numbers the end terms in the various domains, with the lowest scores on functions of the first and second degree (resp. 66% and 69%). The majority of the

Co-funded by the Erasmus+ Programme of the European Union

students in the option Human sciences however fail to reach the end terms on all domains, except statistics (56%), with the lowest score again on functions of the first and second degree (8%).

The differences between schools is almost faded out completely at the end of the second grade. However, differences between classes in the same school now grow in accordance with the differences between the various options.

The same student characteristics as before return to explain further the differences between students: gender, home language and SES of the family.

Mathematics, third grade secondary education

In 2014 the attainment of the end terms at the end of secondary education (year 6) was measured (Vlaamse overheid, Peiling wiskunde in de derde graad secundair onderwijs aso-tso-kso, 2015). Due to the enormous amount of differences between the options in the third grade, it is difficult to draw large general conclusions. Concerning general mathematical concept building in the general secondary education, it was shown that the results were poor, with large differences between education options, even in the pool mathematics. For the specific end terms concerning general secondary education, a small number of students reach these terms. Within technical and art secondary education, again a small number of students reach the set end terms.

It is striking that within general secondary education there is no effect of the home language anymore at the end of the third grade, while boys still perform better on the mathematics tests than girls.

Conclusion

Based on the results of the regional tests and the international comparison tests PISA and TIMSS it is clear that on the international stage the level of STEM education in Flanders is on or above average. However, regional testing shows that there are great differences amongst the pupils and students. Further, the inequality within the Flanders educational system is worrying since it is shown in various tests that home language and the socio-economic status of the family of the child are an important factor in the knowledge and skill base of the students. In this way, not always the gifted but the lucky ones experience school success.

Co-funded by the
Erasmus+ Programme
of the European Union

ITALY

Introduction

The latest PISA survey revealed that Italian students lag behind their peers from other OECD countries in learning science topics. This gap is the sign of a disadvantage in literacy that grows in the educational system and compromises learning quality, school success, and study guidance both in higher school and university as well as the opportunity of being fit for the future working world. In addition, there still exists a gender gap in science as well as a performance gap between northern and southern students.

The Education System in Italy

Education in Italy consists of 5 years of primary school, 3 years of lower secondary school and 5 years of upper secondary school. The last 3 years of higher school can consist in vocational training and local competency courses. The educational standards, performance and social objectives that apply to all schools are defined by the Ministry of Education, Universities and Research (MIUR, Ministero dell'Istruzione, Università e Ricerca).

Education in Italy is compulsory from 6 to 16 years of age. The average number of students per classroom is 25, with one teacher, and one special education teacher, if needed.

Availability of technological equipment varies from school to school. Most schools have an Information and Communications Technology room that can be used in turn by one classroom at a time, and primary schools have an interactive whiteboard (IWB) in each class.

Primary education

Primary education covers the first stage of compulsory education, which is divided into primary school lasting five years and lower secondary school lasting three years.

Primary education is for children aged between 6 and 10 years and is compulsory. Primary schools have their own leeway in deciding their organisation and programme of study. Schools are freely organised within a general framework provided for by the MIUR, in order to ensure unity in the education system. In fact, it's up to the MIUR to define the general objectives of training, specific objectives of learning based on students' skills, disciplines making up the national curriculum as well as its yearly timetable.

The Ministerial Decree no. 254 of 2012 National curriculum recommendations for early years foundation stage and primary stage sets out the programmes of study for primary school pupils (compulsory as of 2013/2014):

- Italian
- English language
- History
- Geography
- Mathematics
- Sciences
- Music
- Arts and Image
- Physical Education
- Technology

Co-funded by the
Erasmus+ Programme
of the European Union

Secondary Education

Lower secondary education covers the first stage of compulsory education, which is divided into primary school lasting five years and lower secondary school lasting three years. Lower secondary classrooms are generally made up of at least 18 pupils and no more than 27. Children can enroll at music-oriented sections that provide for the study of a musical instrument and musical practice.

Disciplines according to the above-mentioned Ministerial Decree are as follows:

- Italian
- English language and a second EU language
- History
- Geography
- Mathematics
- Sciences
- Music
- Arts and image
- Physical education
- Technology.

The secondary stage consists of 3 years of lower secondary education and 5 years (the first 2 are compulsory) of upper secondary education, or higher education, in high schools or vocational schools. Upper secondary education can consist of as follows:

- 5 years of upper secondary education, for students aged 14 to 19 years.
- 2 years of upper secondary education, for students aged 14 to 16 years, plus 3 years of Vocational Education and Training (VET) courses for young students.

Skills and objectives for training processes refer to the key competences for lifelong learning set forth by the European Parliament and the Council of the European Union *(Recommendation dated December 18th, 2006). The key competences are listed below:

- communication in the mother tongue
- communication in foreign languages
- competence in mathematics and basic competence in science and technology
- digital competence
- learning to learn
- social and civic competences
- sense of initiative and entrepreneurship
- cultural awareness and expression.

La Buona scuola

The ever-growing information and communication technologies offer a great opportunity and represent the ultimate frontier for schools: this can be faced not only by increasing knowledge and basic skills, but also by enhancing techniques and tools, and supporting each person's development through the ability to understand the basic aspects of problems, grasp implications, assess both limits and possibilities of knowledge and the ability to act in an ever-changing world.

An answer to these needs is provided by La Buona Scuola and specifically by the National Plan for Digital Education (PNSD, Piano Nazionale per la Scuola Digitale) which was launched in October, 2015 and that allocated €1 billion for innovation.

The Plan provides for wi-fi connection to cover schools, allocates funds to bring creative ateliers (Action #7) equipped with 3D printers and advanced technologies to primary schools, and develop "key competences" in primary schools and promote lab learning through a widespread use of digital resources and environments, reducing structural and infrastructural shortages in school buildings; the Plan also allocates funds for innovative and digital school libraries (Action #24), launches tenders for digital environments and alternative learning spaces (Action #4). The Ministry appointed digital facilitators (Action #28), one for each school, who are teachers charged with the implementation of the PNSD in each school. Lastly, training programmes have also been started for digital facilitators, innovation team teachers, school managers and administrative and technical staff (Action #25).

In the last two years, on a sample of 3,500 schools, 97% of school buildings have been connected to the internet for educational activities, with a reasonably good connection in 47% of cases. As far as internal cabling of schools is concerned (Action #2), 48% of buildings are fully cabled, 75% of labs are cabled and connected, 56% of classrooms are cabled and connected. As to digital education premises, 54% of classrooms are adequate in terms of tools for digital education, 50% of schools encourage the use of personal digital tools in classrooms (the so-called BYOD, Bring Your Own Device), 30% have BYOD guidelines. 82% of schools do use the electronic register, 96% of schools use digital tools to talk to families. Digital skills: 74% of schools started up digital citizenship activities, 60% computational thinking or robotics, 59% digital creativity (e.g., creative reading and writing), 16% economy and entrepreneurship. More than 1.6 million girls and boys practised computational thinking in school thanks to the 'Programma il Futuro' project. PNSD weeks will also take place with open workshops, meetings, innovation competitions and contests for schools with the aim of involving school communities through PNSD contents and actions and sharing their experiences in digital innovation in schools.

In July, 2017, Florence hosted the first edition of Fair DIDACTA Italy attended by 4,000 teachers, with many workshops on innovation, education and work, Digital Summer. Schoolkits were also created.

Next actions and tenders: 140 million for digital training workshops; 2.5 million for innovative premises in suburban schools to counter truancy; 5.7 million for maintenance of technological tools in primary schools; 15 million to bring the e-register to all classes of primary schools; simpler and more efficient digital services for schools; launch of a new design for schools' websites; start-up of three workgroups to make digital skills structural in education systems; digital citizenship, a kit for each school; activities on STEM disciplines in each school; an online community for digital facilitators and schools' digital teams.

Current status of STEM initiatives

Projects such as creative ateliers, digital spaces, and fab-labs are starting to be developed in schools through funds made available by the government with the "La Buona Scuola" programme and the National Plan for Digital Education; for the time being, there are only a few structured activities, projects are being organised by external agencies or carried out by teachers on their own free initiative.

In addition to the initiatives promoted by the PNSD within the La Buona Scuola programme, STEM initiatives are being increasingly supported by the government through bids and tenders addressed to schools, cultural and educational organisations.

Some examples:

- IN ESTATE SI IMPARANO LE STEM (in summer STEM subjects are taught) is an initiative launched by the Government's Department for Equal Opportunities, for the creation of summer camps on science, mathematics, computer science and coding. It allowed 1,067 schools to benefit from funds to provide STEM education through resources made available in collaboration

Co-funded by the
Erasmus+ Programme
of the European Union

with other STEM-skilled partners in the 2017 summer.

- AVANGUARDIE EDUCATIVE (Educational vanguards) is a project developed jointly by INDIRE (Istituto Nazionale Documentazione, Innovazione Ricerca educativa) and 22 founding schools. Sustainable routes for school innovation have been pinpointed and described, the Innovation Manifesto has been drawn up to radically change the way learning, time, space of schools are organised;

- Maker@Scuola" is a platform set up with INDIRE that since 2014 has been monitoring, even across domesticl boundaries, the most interesting educational experiences related to the "Makers" movement;

- PALESTRA DELL'INNOVAZIONE (Phyrtual InnovationGym) is a physical-virtual environment for innovation and education, a gym for experiential learning and innovation practice in all its forms: technological, social and civic innovation. It's a space open to everyone: schools, companies, universities, where the manufacturing (traditional and digital), experimentation and creativity language is spoken to stimulate career development opportunities, self-entrepreneurship and implement the 21st-century skills. So far, 105 schools at all levels located in 17 Italian regions have been involved in the project.

- STEM IN THE CITY MILANO is an initiative sponsored by the municipality of Milan which promoted events to raise young people's awareness on the importance of digital culture and familiarise girls with science and technical subjects;

- GIRLS CODE IT BETTER is an initiative to encourage girls from lower secondary schools to take interest in coding and digital technologies in the regions of Lombardia, Veneto, Emilia Romagna, Friuli Venezia Giulia and

Tuscany. The project has reached its third edition (2017).

Companies are also investing in STEM projects and initiatives for schools and the community, such as:

- The PINK CLOUD project was developed by MICROSOFT in 2013 to expand digital skills through free training courses for thousands of young women in Italy. The initiative, organised by Microsoft in partnership with Fondazione Mondo Digitale, GrowITup and The Adecco Group, aims at helping female students explore the value of technical and scientific training and discover the opportunities offered by the STEM world for their career development, keeping them up-to-date with market trends and the ongoing digital revolution.

- HACKATHON by TIM, the TELECOM Italy's telephone company promoted, among other events, the Tim Girls Hackathon which involved female students on a day event to create an app. Hackathon by Telecom is based on App inventor, a platform that allows to create intuitively small applications.

- Coding4all, supported by Google Education, is a project by Explora The Children's Museum of Rome, whose aim is to offer out-of-school coding camps for girls and low-income suburban communities and empower them with the use of computer programming. Explora Museo dei Bambini di Roma was one of the 28 organisations that were granted the Google RISE Award 2016.

Co-funded by the
Erasmus+ Programme
of the European Union

The "Report of actions taken by the MIUR in 2017" was published on the Ministry of Education, Universities and Research (MIUR) website on February 1st, 2018. The document lists all the actions taken by the MIUR in 2017 – including those taken in the field of digital innovation and the Digital School National Plan (PNSD) – related to learning, connectivity, schools' cabling, workshop spaces, students' skills, innovative teaching methods, and teachers' training. These actions have been funded through:

- ***European Structural and Investment Funds (National Operational Programme on Education 2014-2020)*** and funds allocated pursuant to law no. 107/2015.
For the actions carried out using resources from the European Structural Funds: "For schools - skills and environments for learning" including:

Basic Skills (€ 180 mln – Communication of February 20th, 2017): strengthen the basic skills of both male and female students to offset cultural, economic and social disadvantages, enhance knowledge of their own language, foreign languages, sciences, mathematics through innovative teaching methods.
Projects funded: 7,952 projects for an amount awarded to schools of € 257,313,598.30.
Computational thinking and digital citizenship (€ 80 mln – Communication of March 3rd, 2017), for training actions primarily aimed at developing computational thinking, digital creativity, gaining skills of "digital citizenship", for a positive and conscious approach to innovation. The projects submitted were 4,565 for an available amount of € 80 million. More detailed information follows:
Digital environments: € 134 million allocated to 5,938 eligible schools;
Wi-Fi network: € 88 million allocated to 6,109 eligible schools;
Digital skills and creativity: € 80 million allocated (projects submitted: 4,565);

Digital entrepreneurship: € 40 million allocated.

- PNSD (Digital School National Plan)

"Digital training workshops" project (€ 140 million allocated);
"Creative suburban areas" tender to create innovative educational environments and innovative workshops, using digital technologies, open to everyone locally, benefiting state-run schools and educational bodies located in suburban areas of metropolitan cities and characterised by significant early leaving rates (€2.5 mln allocated).
Activities carried out by digital facilitators €17 million allocated (€ 2,000 per school).
Connectivity € 8.4 million allocated (€ 1,000 per school) as a grant for connectivity.
Technical support € 5.7 million distributed among primary stage schools (1,000 per school).

WEB radio - Miur Radio Network
The web radio of Italian schools has been created through an innovative teaching project promoted by the Ministry of Education, Universities and Research within the National Plan for Digital Education and the collaboration and coordination of the Press Office, to give voice to experiences and best practices in schools and activities of both female and male students.

National Award for Digital Education
The aim is to promote excellence and centrality of Italian schools in learning and teaching digital education.

Launch of the second phase of the school staff's digital training (€ 25 mln allocated).

Co-funded by the
Erasmus+ Programme
of the European Union

Futura: 3 days for the National Plan for Digital Education: training, discussions, experiences.
Workshops and activities in the cities of: Rieti, Brindisi, Pescara, Caltanissetta, Catania, Bologna.

Workgroup to evaluate the use of personal digital devices in the classrooms entrusted with setting up the guidelines to promote **Bring Your Own Device** (BYOD) in the classrooms, established by Ministerial Decree No. 668 of September 15th, 2017.

Workgroup to map teaching methods.
Established by Ministerial Decree No. 670 of September 15th, 2017, the workgroup is made up of digital pedagogy experts, members of the academic world, digital expert teachers who also play the role of digital facilitators in their schools, CNR (National Research Council) researchers, philosophers, specialised journalists, education representatives and MIUR specialists.

- In the framework of the #ForumPA2018, at the "**Sustainable PA**" Contest. **100 projects to achieve the goals set out in the 2030 Agenda** which took place on May 25th, 2018, the following projects, among others, were awarded a recognition:
SOFIA. Operating system for training and refreshment initiatives for teachers.
STEM-Feminine plural Contest to provide food for thought on women involved in STEM disciplines.

- Lastly, results of **Programming the Future** were presented at the MIUR on June 15th, 2018. The aim is to train the mind to the computational thought, in collaboration with the Ministry. More than 2 million students and more than 31,000 teachers were involved, more than 30 million hours were spent in coding. The programme has been recognised as an initiative of

European excellence for digital education within the European Digital Skills Awards 2016.

Webography

https://www.agendadigitale.eu/cultura-digitale/scuola-stem-e-competenze-digitali-degli-studenti-e-sempre-piu-urgente-un-intervento-di-sistema/

http://www.comune.milano.it/wps/portal/ist/it/news/primopiano/tutte_notizie/educazione_istruzione/educazione_digitale_parte_steminthecity

http://fieradidacta.indire.it/la-fiera/

http://www.indicazioninazionali.it/documenti_Indicazioni_nazionali/indicazioni_nazionali_infanzia_primo_ciclo.pdf

http://www.indire.it/progetto/avanguardie-educative/

http://www.indire.it/progetto/maker-a-scuola/

http://www.innovationgym.org

http://www.istruzione.it/scuola_digitale/prog-laboratori-territoriali.shtml

http://www.istruzione.it/scuola_digitale/prog-atelier.shtml

http://www.mondodigitale.org/it/cosa-facciamo/aree-intervento/imprenditoria-giovanile/palestra-dellinnovazione

http://www.pariopportunita.gov.it/media/3126/graduatoria-stem-del-19062017.pdf

Co-funded by the
Erasmus+ Programme
of the European Union

https://www.slideshare.net/miursocial/il-piano-nazionale-scuola-digitale-incontra-il-paese-i-prossimi-passi

https://www.wcap.tim.it/it/2017/09/tim-open-hackathon

PORTUGAL

Introduction

Portugal is a success story regarding to the evolution of the main indicators used internationally by entities such as the European Union and the OECD. However, the situation in Portugal was much more disadvantageous than any other European country in the recent past. To understand this statement better, it is necessary to know some essential historical facts.

Above all, it is necessary to understand the point of departure, namely in the year 1974 when the Portuguese revolution took place on 25 April and Portugal has gone from a dictatorship of almost 50 years to a democracy. Here are some facts:

- The illiteracy rate in northern European countries at the beginning of the 20th century was practically none. In Portugal, it was 76.5% (Canha, 2017).
- The same rate of illiteracy in the 1970s in the clear majority of European countries was already below 5%, but in Portugal it stood at 25.7%. Source: (Pordata, 2017); (data, 2017)
- The regime of dictatorship based politically on the ignorance of the people delayed the natural evolution that was happening throughout Europe.

In the 1970s, after the revolution that allowed Portugal to evolve into a democracy, the concept of compulsory schooling was implemented for the first time.

This has resulted in an exponential increase of pupils in schools without the necessary number of teachers.

Until the 1980s, the situation remained, with a significant effort by the country to train teachers who could fill the vacancies necessary for the teaching.

In the 1990s the situation was reversed and the new trained teachers ceased to enter the system due to the lack of places in the school. The situation has continued to this day, aggravating by the decline number of children in Portugal, somehow offset by immigration.

With the crisis set in the second decade of this century, many of the immigrants in Portugal emigrated and made the number of students in Portuguese schools even smaller.

At the level of the curriculum the changes that have been introduced by successive ministries of education, in a generic way have been increasing the amount of learning contents. Therefore, teachers to achieve the programs have privileged cognitive processes of memorization in detriment of other more complex processes such as critical thinking or creativity. The introduction of national exams in the first decade of this century has raised the demand for schools and teachers, with some significant gains in terms of international indicators. Once again, the introduction of standardized tests and tests, either on more basic cognitive process questions (remember, understand, apply) or on restricted correction criteria (needed to ensure equal correction across the country) reinforced the need teachers do not address more complex cognitive processes.

These facts (among many others) explain the successes and failures of teaching in Portugal and are necessary to better understand the analysis of the current data that are detailed below.

They also explain the strong concern of the various Ministries of Education in organizational aspects and explain the reluctance of teachers to move away from traditional teaching processes to apply new and innovative learning processes.

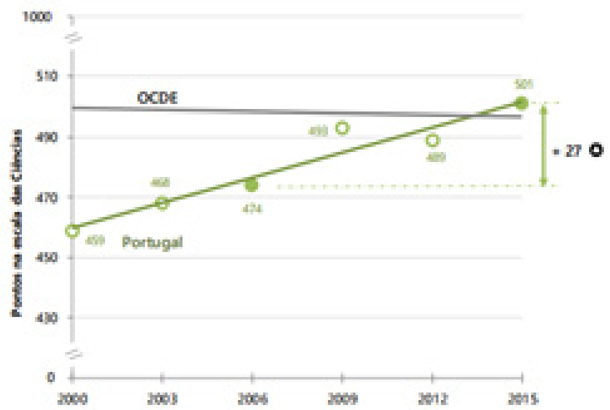


Figura 3.1 Evolução dos Resultados Médios Nacionais em Ciências entre 2000 e 2015.
Os símbolos a cheio representam os anos em que as Ciências foram o domínio principal.
Fonte: IAVE, a partir de OCDE (2016) *Programme for International Student Assessment* – PISA 2015

TIMSS and PISA

Currently, the results of Portugal in TIMSS and PISA are as follows:

In the PISA results we can present the statistical table presented by IAVE, the body government responsible for the application and analysis of the results in the international tests of PISA and TIMSS, and which reinforces the evolution of Portugal to the OECD countries in the three areas evaluated (IAVE, 2017) The results confirm the foregoing and the effort put by Portugal to recover the differences for the more developed countries. Not being a linear path, the results demonstrate the impact of the measures implemented mainly after the year 2006. Year in which the results of the PISA tests had a more mediatic expression and a more in-depth study in Portugal reverting in specific educational measures.

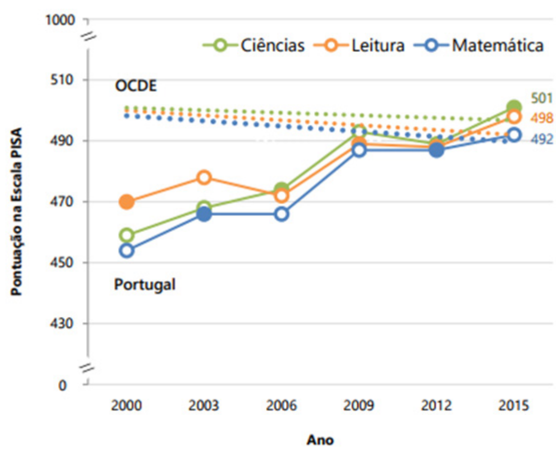


Figura 1.4 Evolução das Pontuações Médias nos Domínios do PISA em Portugal Face às Médias da OCDE.
Os símbolos a cheio indicam os anos em que o domínio foi domínio principal.
Fonte: IAVE, a partir de OCDE (2000 – 2015) *Programme for International Student Assessment* - PISA

Co-funded by the
Erasmus+ Programme
of the European Union

We can observe in more detail the results obtained in the Sciences both in terms of comparison with the OECD average, and in comparison, with other countries in the year 2015.

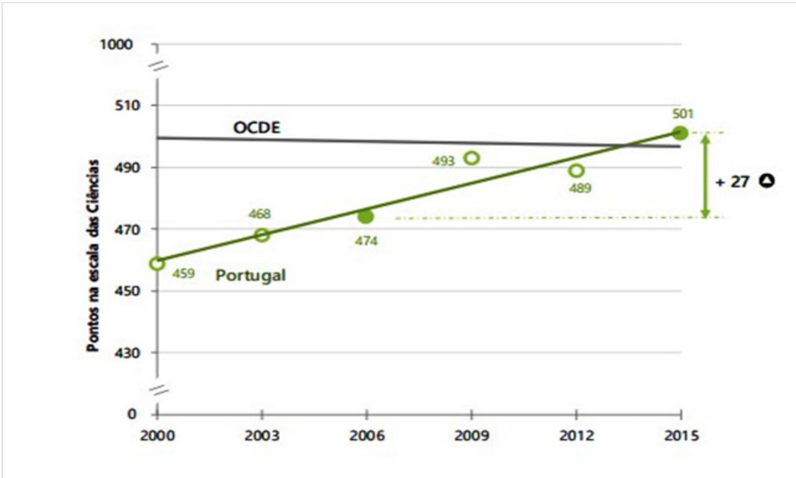


Figura 3.1 Evolução dos Resultados Médios Nacionais em Ciências entre 2000 e 2015.
Os símbolos a cheio representam os anos em que as Ciências foram o domínio principal.
Fonte: IAVE, a partir de OCDE (2016) *Programme for International Student Assessment* – PISA 2015

Países/Economias	Escala de Ciências							
	Pontuação média	I.C. 95% Média	Ordenação					
			Países da OCDE			Todos os países/economias		
			Ordem	Limite superior	Limite inferior	Ordem	Limite superior	Limite inferior
Singapura	556	553 - 558				1	1	1
Japão	538	533 - 544	1	1	2	2	2	3
Estónia	534	530 - 538	2	1	3	3	2	5
Taipé Chinês	532	527 - 538				4	2	7
Finlândia	531	526 - 535	3	2	4	5	3	7
Macau (China)	529	526 - 531				6	5	8
Canadá	528	524 - 532	4	3	4	7	5	9
Vietname	525	517 - 532				8	4	10
Hong Kong (China)	523	518 - 528				9	7	10
B-S-J-G (China)*	518	509 - 527				10	8	16
República da Coreia	516	510 - 522	5	5	8	11	9	14
Nova Zelândia	513	509 - 518	6	5	9	12	10	15
Eslovénia	513	510 - 515	7	5	9	13	11	15
Austrália	510	507 - 513	8	6	11	14	12	17
Reino Unido	509	504 - 514	9	6	13	15	12	19
Alemanha	509	504 - 514	10	6	13	16	12	19
Holanda	509	504 - 513	11	7	13	17	13	19
Suíça	506	500 - 511	12	8	17	18	14	23
Irlanda	503	498 - 507	13	11	18	19	17	24
Bélgica	502	498 - 506	14	12	19	20	18	25
Dinamarca	502	497 - 507	15	12	19	21	18	25
Polónia	501	497 - 506	16	12	19	22	18	25
Portugal	**501**	**496 - 506**	**17**	**12**	**19**	**23**	**18**	**25**
Noruega	498	494 - 503	18	14	21	24	20	27
Estados Unidos da América	496	490 - 502	19	15	25	25	21	31
Áustria	495	490 - 500	20	17	24	26	23	30
França	495	491 - 499	21	18	24	27	24	30
Suécia	493	486 - 500	22	18	25	28	24	32
República Checa	493	488 - 497	23	19	25	29	25	31
Espanha	493	489 - 497	24	20	25	30	25	31
Letónia	490	487 - 493	25	23	25	31	28	32
Federação Russa	487	481 - 492				32	30	34
Luxemburgo	483	481 - 485	26	26	27	33	32	34
Itália	481	476 - 485	27	26	28	34	32	36
Hungria	477	472 - 481	28	27	29	35	34	39
Lituânia	475	470 - 481				36	34	39
Croácia	475	471 - 480				37	35	39
Cidade Autónoma de Buenos Aires	475	463 - 487				38	32	41
Islândia	473	470 - 477	29	28	29	39	36	39
Israel	467	460 - 473	30	30	31	40	39	42
Malta	465	462 - 468				41	40	42
República Eslovaca	461	456 - 466	31	30	32	42	41	43
Grécia	455	447 - 463	32	31	32	43	42	44
Chile	447	442 - 452	33	33	33	44	44	45
Bulgária	446	437 - 454				45	43	46
Emirados Árabes Unidos	437	432 - 441				46	46	49
Uruguai	435	431 - 440				47	46	49
Roménia	435	429 - 441				48	46	50
Chipre	433	430 - 435				49	47	50
Moldávia	428	424 - 432				50	49	53

Co-funded by the
Erasmus+ Programme
of the European Union

The results obtained in Mathematics resemble those obtained in Science:

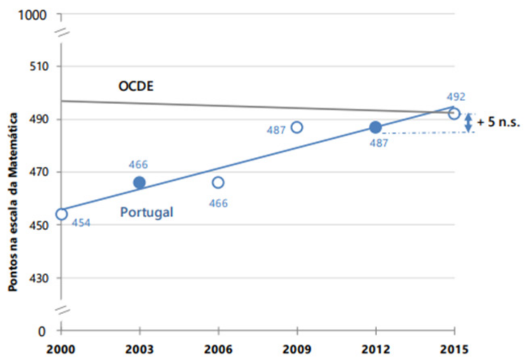


Figura 3.26 Evolução dos Resultados Médios Nacionais em Matemática entre 2000 e 2015.
Os símbolos a cheio representam os anos em que a leitura foi o domínio principal.
Fonte: IAVE, a partir de OCDE (2016) *Programme for International Student Assessment* – PISA 2015

Tabela 3.14 Resultados Médios em Matemática dos Participantes no PISA 2015.

Países/Economias	Escala de Matemática							
	Pontuação média	I.C. 95% Média	Ordenação					
			Países da OCDE			Todos os países/economias		
			Ordem	Limite superior	Limite inferior	Ordem	Limite superior	Limite inferior
Singapura	564	561 - 567				1	1	1
Hong Kong (China)	548	542 - 554				2	2	3
Macau (China)	544	542 - 546				3	2	4
Taipé Chinês	542	536 - 548				4	2	4
Japão	532	527 - 538	1	1	1	5	5	6
B-S-J-G (China)	531	522 - 541				6	4	7
República da Coreia	524	517 - 531	2	1	4	7	6	9
Suiça	521	516 - 527	3	2	5	8	7	10
Estónia	520	516 - 524	4	2	5	9	7	10
Canadá	516	511 - 520	5	3	7	10	8	12
Holanda	512	508 - 517	6	5	9	11	10	14
Dinamarca	511	507 - 515	7	5	10	12	10	15
Finlândia	511	507 - 516	8	5	10	13	10	15
Eslovénia	510	507 - 512	9	6	10	14	11	15
Bélgica	507	502 - 512	10	7	13	15	12	18
Alemanha	506	500 - 512	11	8	14	16	12	19
Polónia	504	500 - 509	12	10	14	17	14	19
Irlanda	504	500 - 508	13	10	14	18	15	19
Noruega	502	497 - 506	14	11	15	19	16	20
Áustria	497	491 - 502	15	14	21	20	18	27
Nova Zelândia	495	491 - 500	16	15	22	21	20	28
Vietname	495	486 - 503				22	18	32
Federação Russa	494	488 - 500				23	20	30
Suécia	494	488 - 500	17	15	24	24	20	30
Austrália	494	491 - 497	18	15	22	25	21	29
França	493	489 - 497	19	15	23	26	21	30
Reino Unido	492	488 - 497	20	15	24	27	21	31
República Checa	492	488 - 497	21	16	24	28	21	31
Portugal	492	487 - 497	22	16	24	29	21	31
Itália	490	484 - 495	23	17	26	30	23	33
Islândia	488	484 - 492	24	21	26	31	27	33
Espanha	486	482 - 490	25	23	27	32	29	34
Luxemburgo	486	483 - 488	26	24	27	33	31	34
Letónia	482	479 - 486	27	26	28	34	32	36
Malta	479	475 - 482				35	34	38
Lituânia	478	474 - 483				36	34	38
Hungria	477	472 - 482	28	28	30	37	35	39

Regarding the TIMSS results, they confirm the evolutionary trend of Portugal and its positioning in relation to the other countries (IAVE, 2017). Whether at the level of Mathematics:

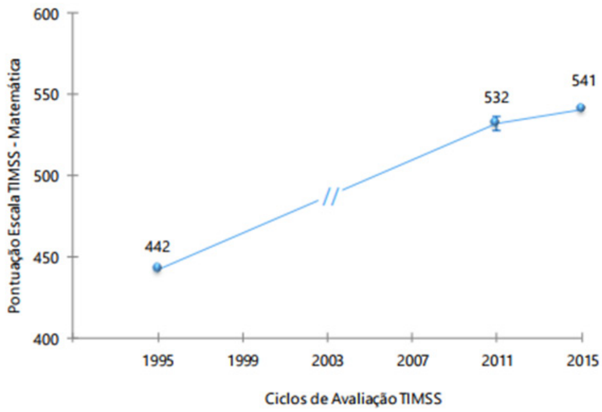


Figura 3.2 Evolução dos Resultados Médios de Matemática em Portugal
As barras de erro representam os Intervalos de Confiança a 95% para a média
Fonte: IEA - Trends in International Mathematics and Science Study – TIMSS 2015

País	Pontuação média	Distribuição dos Resultados de Matemática
[2] Singapura	618 (3,8)	
[†] Hong Kong RAE	615 (2,9)	
Coreia, Rep. da	608 (2,2)	
Taipé Chinês	597 (1,9)	
Japão	593 (2,0)	
[‡] Irlanda do Norte	570 (2,9)	
Federação Russa	564 (3,4)	
Noruega (5)	549 (2,5)	
Irlanda	547 (2,1)	
Inglaterra	546 (2,8)	
[‡] Bélgica (Flamenga)	546 (2,1)	
Cazaquistão	544 (4,5)	
[2] Portugal	541 (2,2)	
[2†] Estados Unidos	539 (2,3)	
[2†] Dinamarca	539 (2,7)	
[2] Lituânia	535 (2,5)	
Finlândia	535 (2,0)	
Polónia	535 (2,1)	
[†] Holanda	530 (1,7)	
Hungria	529 (3,2)	
República Checa	528 (2,2)	
Bulgária	524 (5,3)	
Chipre	523 (2,7)	
Alemanha	522 (2,0)	
Eslovénia	520 (1,9)	
[2] Suécia	519 (2,8)	
[3] Sérvia	518 (3,5)	
Austrália	517 (3,1)	
[12†] Canadá	511 (2,3)	
[2] Itália	507 (2,6)	
[2] Espanha	505 (2,5)	
Croácia	502 (1,8)	

Co-funded by the
Erasmus+ Programme
of the European Union

Whether at the level of science, but with a worrying drop from 2011 to 2015:

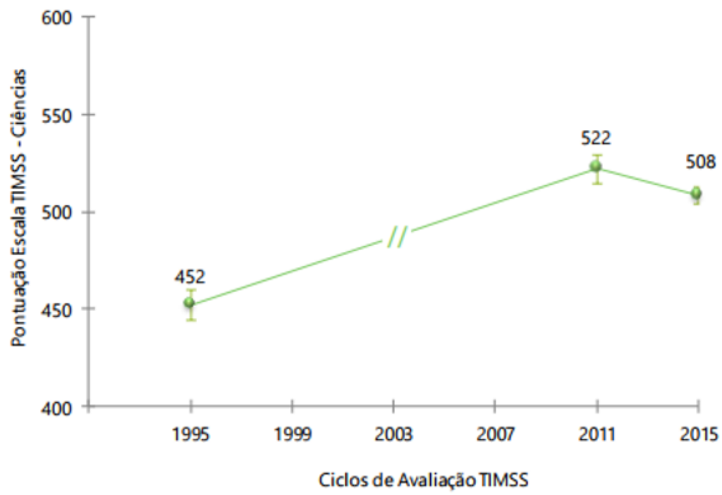
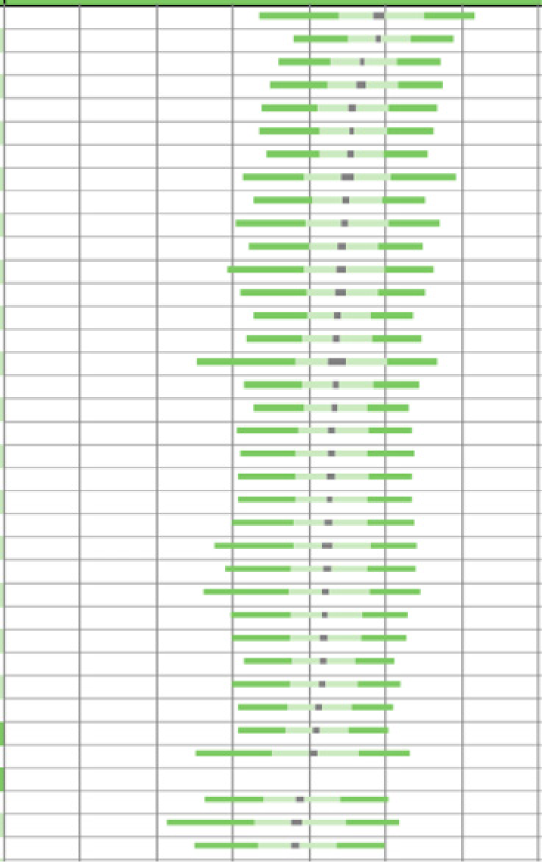


Figura 3.8 Evolução dos Resultados Médios de Ciências em Portugal
As barras de erro representam os Intervalos de Confiança a 95% para a média
Fonte: IEA - Trends in International Mathematics and Science Study – TIMSS 2015

País	Pontuação média	Distribuição dos Resultados de Ciências
[2] Singapura	590 (3,7)	
Coreia, Rep. da	589 (2,0)	
Japão	569 (1,8)	
Federação Russa	567 (3,2)	
[†] Hong Kong RAE	557 (2,9)	
Taipé Chinês	555 (1,8)	
Finlândia	554 (2,3)	
Cazaquistão	550 (4,4)	
Polónia	547 (2,4)	
[2†] Estados Unidos	546 (2,2)	
Eslovénia	543 (2,4)	
Hungria	542 (3,3)	
[2] Suécia	540 (3,6)	
Noruega (5)	538 (2,6)	
Inglaterra	536 (2,4)	
Bulgária	536 (5,9)	
República Checa	534 (2,4)	
Croácia	533 (2,1)	
Irlanda	529 (2,4)	
Alemanha	528 (2,4)	
[2] Lituânia	528 (2,5)	
[2†] Dinamarca	527 (2,1)	
[1 2†] Canadá	525 (2,6)	
[3] Sérvia	525 (3,7)	
Austrália	524 (2,9)	
República Eslovaca	520 (2,6)	
[‡] Irlanda do Norte	520 (2,2)	
[2] Espanha	518 (2,6)	
[†] Holanda	517 (2,7)	
[2] Itália	516 (2,6)	
[†] Bélgica (Flamenga)	512 (2,3)	
[2] Portugal	508 (2,2)	
Nova Zelândia	506 (2,7)	
Ponto central - escala TIMSS	500 (0,0)	
França	487 (2,7)	
Turquia	483 (3,3)	
Chipre	481 (2,6)	



In the document "Research in Education and the results of PISA (Conselho Nacional de Educação, 2017) carried out in Portugal by the National Education Council (advisory body of the Ministry of Education), composed of renowned education specialists was highlighted important aspects in reading these results.

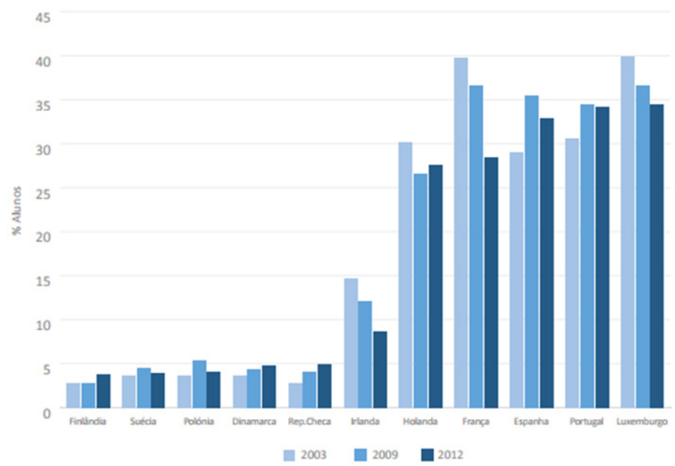
As a main positive aspect, the success of the educational policies of the various governments of Portugal in this century.

Co-funded by the Erasmus+ Programme of the European Union

As a source of concern, excessive student retention and the evolution of students with weaker performance.

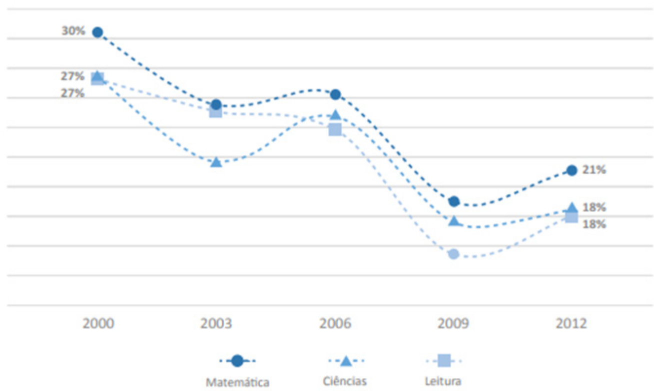
These points can be observed in the graphs below.

Figura 3. Evolução da percentagem de alunos que chumbaram pelo menos uma vez. PISA 2003, 2009 e 2012



Fonte: aQeduto | OCDE, PISA 2003, 2009 e 2012

Figura 2A. Evolução dos alunos com desempenho fraco. Portugal, PISA 2000 - 2012



Fonte: aQeduto | OCDE, PISA 2000 - 2012

Impacts at national level

To date, Portugal through the various ministries of education, have accepted the challenge of improving international indicators by implementing measures in certain areas such as:

- Curricular reformulation (with a tendency to increase and demand and the number of contents per school year)
- Human resource Management
- Increase in Portuguese and Mathematics
- Introduction of national exams and benchmarking tests
- Introduction of school evaluation indicators based on the school results obtained

As can be seen, the areas addressed are related to management (curricular management, human resource management, time management, management of control mechanisms and evaluation of the performance of school institutions).

Pedagogical practices have not been altered, nor are the cognitive processes that are currently necessary and pressing in the labor market developed.

This problem, identified by Andreas Schleicher, director of the OECD's Department of Education and Skills, who in interviews with the Portuguese newspaper "The Expresso" stated that the world "no longer rewards people for what they know - Google knows everything - but for what they can do with it " (O Expresso, 2017).

This alert may explain another negative indicator in Portugal: the NEETS rate, young people up to 24 years of age are not even studying or entering the labor market.

Co-funded by the
Erasmus+ Programme
of the European Union

Conclusion

Portugal, still preoccupied with organizational issues due to the need to adjust to the social changes that have taken place since the 1970s, has made some (still timid) steps towards changing and introducing new pedagogical forms that better prepare students for professional technical education, for higher education and the labor market.

There is now awareness that this next step of pedagogical innovation is necessary and the Ministry of Education launched a pilot innovation project this school year (17/18) allowing schools to find new pedagogical solutions contracted with the Ministry of Education.

Based on the conservatism and traditionalism of teaching in Portugal and reversing the normal process of being the higher institutions to determine what should be done in the School, this strategy seems to be positive and decisive for a paradigm shift of the pedagogies used.

United Kingdom (Northern Ireland)

International tests

The fact that Northern Ireland outscored 44 countries and was the highest rated in maths throughout Europe in the assessments where highlighted greatly. Through these assessments, it was determined that Maths has a wide spread of attainment whereas Science was not the case. With these results it was also determined that there was no real gender imbalance between the results. Throughout Northern Ireland it seems clear that there is a greater focus on Science as opposed to Maths. This was shown greatly by the fact that teachers pursued more CPD events in the areas of Maths and that there were more dedicated Maths teachers than there were Science teachers. No significant gender imbalance in the Pisa results were highlighted. Gaps between highest and lowest pupil attainment in science is equal to 8 years of schooling. Although the main findings from the results were overly positive, it was stated that the performance was slightly lower than the 2011 results.

National tests

GCSE exams take place at the end of the students 5th year at Secondary school. Schools set their own exams at the end of the 3rd year of study in order to gain an understanding of students' levels and to organize classes based of these levels.

Through these national assessments it was clear that there was a gender imbalance beginning to show with females gaining a greater percentage of A* - C grades. This was widened by 0.5% on the previous year.

Co-funded by the
Erasmus+ Programme
of the European Union

In 2016, Mathematics, A* - C performance fell by 1.7 percentage points to 64.9% of entries.

The sciences continue to perform strongly with A* - C performance in Biology rising 0.6 percentage points to 92.2% of entries, Chemistry up 0.1 percentage points to 93.6 of entries, and Physics up 0.3 percentage points to 95.9% of entries.

Entries for STEM subjects (Science, Technology, Engineering and Mathematics) have grown by 0.3% in Northern Ireland. This growth means STEM subjects here account for close to one third (31.9%) of all GCSE entries.

The increase in STEM entries is being driven by Biology (up 3.4%), Chemistry (up 1.7%) and Computing (up 106%). There were decreases in the percentage of the overall entry taking Design and Technology (down 7.7%), ICT (down 4.6%) and Physics (down 3%).

National initiatives concerning STE(A)M education

In Northern Ireland, the STEM areas are a growing economy and there is great emphasis on the need to encourage students to choose these areas for career paths.

In 2011, a strategy was put in place to stop the decline in STEM subjects. This strategy included:

Address the disparity in STEM performance amongst schools: including through the implementation of Every School a Good School; professional development for teachers; and better targeting of STEM and business education activities;

- Make STEM learning more enquiry-based: including through a focus on this in commissioning new resources for schools;

- Increase the focus on the core sciences and mathematics: including through ensuring a clear focus on attainment in mathematics from Key Stage 1 to GCSE; and by supporting opportunities for pupils to participate in competitions, exhibitions and other events;

- Develop a STEM Continuing Professional Development framework: by ensuring the provision of professional development opportunities for teachers designed to promote effective STEM teaching; and by providing opportunities for additional professional development for A level teachers of ICT and Computing;

- Increase the emphasis on STEM careers advice and guidance: including implementing a STEM Careers Strategy; and increase the number of applications for physical sciences and mathematics places in Initial Teacher Education courses: the Department is to ensure that the provision of STEM-related places matches the needs of schools.

In primary schools, the government has in place thematic units which they make readily available online to guide teachers on how to teach these in the classroom, please see below for resources and details. These are all put in place in order to encourage teachers to follow these areas and by providing the lesson plans of these, the success is high.

http://ccea.org.uk/curriculum/key_stage_1_2/connected_learning/thematic_units/stem

http://www.nicurriculum.org.uk/STEMWorks/about/

Co-funded by the
Erasmus+ Programme
of the European Union

Good practices

STEM CENTRE
http://www.swc.ac.uk/innovate/stem/Home
South West College has set up the STEM Centre in Northern Ireland in order to have a facility to encourage young students to engage more with the STEM subjects. This centre has been officially running since 2012.

Its aim is to deliver a range of interactive activities which highlight the importance of the STEM subjects and the subsequent careers that can follow from taking one of these subjects on at school or University. They offer activities to all ages from 9 years old up to 18.

Due to its success, the STEM Centre has been replicated across the UK by the Gazelle college group and there are now 4/5 functioning STEM Centres.

STEM MODULE
http://www.stemmodule.com/
This project is jointly funded by the Department of Education and The Department of Enterprise and is a state of the art modular trailer which visits schools and acts as an activity unit where students can learn about different STEM fields. More information can be found on the above website.

METHODOLGY

On August 17, 2017 we performed a search in the ERIC database with key words “STEAM education” in peer reviewed papers. We retrieved 111 search results. By scanning the abstracts various meanings of the word “STEAM” were encountered:

- Science, technology, engineering, arts and mathematics
- Science teacher education at the museum
- A physical or chemical substance, including steam engine
- Science and technology enrichment for Appalachian middle schoolers.

We only retained the articles in the first category, which reduced the list to 45 papers. Within these papers we determined three subcategories:

- Interventional studies, i.e. papers which describe the results of an intervention based on a research methodology (14 papers);
- Conceptual papers, i.e. papers which discuss a possible framework for STEAM education or give impressions of STEAM education (18 papers);
- Lesson plans / examples of STEAM activities without an extended research approach (13 papers).

Since we were interested in research-based results about what works in STEAM education, we focus in this part on the first category of 14 papers.

Co-funded by the Erasmus+ Programme of the European Union

CHARACTERISTICS OF THE PAPERS

In the table below we list all the interventional studies about STEAM education, together with the target group, research sample and country where the research took place.

We discuss the results for the various target groups separately. As a structure for the discussion of the papers we use four categories often considered in discussing curriculum reform: the student, the teachers, assessment and the context (Schildkamp & Kuiper, 2010). The category assessment includes the development of evaluation criteria and instruments, while the category context can include factors inside (e.g. school policy) and outside the school (e.g. governmental or regional policy). Within the category student we distinguish explicitly between pre-service teachers (i.e. students in teacher education) and other students in elementary, secondary of higher education. In the last group the focus lies on the acquisition of STEAM related skills and competences, while in the first subgroup the emphasis lies on their future profession as a teacher and their ability and attitudes towards the implementation of STEAM as an educational vision.

The research samples range between as low as 2 to as high as 7839. This is related to the used methodology. A majority of the papers use pre- and/or post-questionnaires and interviews, sometimes combined and supplemented with extra material analysis. Only one study was based on the results of students on standardized tests and one were the results are based on the analysis of produced material and written reflections.

The interventional studies are concentrated in two countries. Five were conducted in South Korea and nine in the USA. The retrieved studies from South Korea are mainly due to the appearance of the special volume of Eurasia Journal of Mathematics, Science & Technology Education 16(7) which was dedicated to STEAM education in South Korea.

Paper	Category	Research sample (N)	Country
Aguilar & Kalpaka Richerme (2016)	Teacher education	81	USA
Gates (2015)	Students (grade 6-12)	140	USA
Ghanbari (2015)	Students and alumni (university)	27	USA
Graham & Brouillette (2016)	Students (grade 3-5)	7839	USA
Herro & Quigley (2017)	In-service teachers	21	USA
Herro, Quigley & Dsouza (2016)	In-service teachers	2	USA
Hunter-Doniger & Sydow (2016)	In-service teachers	48	USA
Jho, Hong & Song (2016)	In-service teachers	10	South Korea
Kim & Kim (2016)	Assessment	208	South Korea
Kim & Bolger (2017)	Pre-service teachers	119	South Korea
Kim & Chae (2016)	Students (grade 11)	26	South Korea
Park, Byun, Sim, Han & Baek (2016)	In-service teachers	705	South Korea
Quigley & Herro (2016)	In-service teachers	21	USA
Yillman, An & Boren (2015)	Pre-service teachers	124	USA

Co-funded by the
Erasmus+ Programme
of the European Union

STUDENTS

In a quasi-experimental study with 7839 grade 3-5 students in 55 Californian schools, Graham & Brouillette (2016) measured the knowledge about a specific nine hour-long learning module. Approximately half the group of students received the standard lessons while the other half received an additional STEAM module where the teachers either followed a one year training course or were co-teaching with teaching artists. The scientific knowledge was measured by standardized tests, where the results were additionally filtered per grade and on an English learner subgroup. This analysis showed no difference between these specific groups. However, a significant improvement was found within the group were the teacher was co-teaching with a well-trained assistant in the STEAM curriculum.

Pre-and post-questionnaires from 140 grade 6-12 students which followed a glass-making workshop showed that students' knowledge about the specific content increased as well as their interests due to hands-on activities ((Gates, 2017). The author therefore promotes the use of non-trivial collaborations between schools and other partners. Ghanbari (2015) also noticed the importance of hands-on activities for a lasting learning effect and even a possible career choice in the future. This study with 27 students and alumni of two STEAM university programs also found the importance of formulating learning outcomes and that STEAM is an opportunity for science students to come into contact with Arts. Interpersonal relations and collaboration are important factors for learning and were explicitly used in this context. In a specially designed STEAM program based on Korean culture, Kim & Chae (2016) interviewed 26 grade 11 high school students and also found that they valued STEAM for their opportunity for problem-solving through convergent thinking and knowledge building. Although the majority (19/26) stressed the usefulness of the developed program, a substantial part of the students were reluctant about the program due to their focus on a university entrance exam and their discomfort with the strange method of teaching in the STEAM program.

PRE-SERVICE TEACHERS

The perception of future elementary school teachers about STEAM and about different methods of curriculum integration after preparing lesson plans was investigated by Kim & Bolger (2017). They studied peer-evaluations and lesson plans of 119 pre-service teachers after they followed a specific STEAM teaching course. The necessity of making lesson plans turned out to have a positive effect on the attitude of the students towards STEAM. They further identified the lack of specific content knowledge to build bridges between subjects as one of the key barriers for the implementation of STEAM. Just as other students expressed their concern of passing a general entrance exam after following a STEAM course, also these future teachers expressed their doubts whether all goals could be reached using this type of pedagogy.

In a search for a differentiated pedagogy for STEAM education between bilingual and regular pre-service teachers, Tillman, An & Boren (2016) found no evidence for such a differentiated approach, nor in their perceptions about STEAM lessons.

TEACHERS

In an online survey of 705 teachers of grade 1 till 12 in South Korea, Park e.a (2016) questioned the teachers' implementation, challenges and perception of STEAM education. They found that elementary school teachers most often implemented STEAM lessons and had the strongest conviction that STEAM has positive benefits for the learning of the students. As possible reasons why elementary school teachers differ from

Co-funded by the
Erasmus+ Programme
of the European Union

secondary school teachers in these aspects, the authors identified the integrated curriculum in the elementary schools as a positive context and the university standardized entrance exam at the end of secondary school as a negative context for its implementation. The teachers identified a lack of time and the extra work load as possible factors which could hinder the implementation of STEAM education. The same reluctance about STEAM education was found by Hunter-Doniger & Sydow (2016) in their research with 48 middle school teachers in the USA. Also there, after the implementation STEAM in a studio-like environment has raised the satisfaction of the teaching staff, but there remained a resistance waiting the results of the students on national standardized tests.

One way of getting teachers enthusiastic about STEAM education is through dedicated STEAM professional development courses. Herro and Quigley (2017) analyzed pre- and post-questionnaires and materials from a PD course followed by 21 in-service teachers. They found that technology aided co-operation (e.g. blog, Google education …) is an effective way of understanding the various disciplines and reaching inter- and transdisciplinarity. As educational methods, project-based learning and collaborative technologies can assist in understanding the STEAM principles, although a thorough integration of 'A' in STEM needs the involvement of arts and humanities educators. They further concluded that a one week intensive course is not sufficient to give teachers the necessary confidence to fully implement STEAM. In a follow-up research, Quigley and Herro (2016) and Herro, Quigley and Dsouza (2016) investigated how these teachers actually implemented STEAM in their classroom and looked for the longterm effects of the STEAM PD course. Through the analysis of teacher reflective journals and classroom observations, they identified five long-lasting elements: relevance, student choice, integration of technology, problem-based learning and authentic education. Missing elements were the transdisciplinarity, the integration of arts and the productive collaboration of the students.

Besides a dedicated PD course, Graham & Brouilllette (2016) found that teachers working with a coach identified this as a more effective professional development experience than after-school workshops of meetings away from the school site.

Jho, Hong and Song (2016) looked for successful conditions for the implementation of STEAM through observations and interviews with 10 teachers in two leading STEAM schools in South Korea. They identified four necessary conditions of a well-functioning community of practice around STEAM: shared values, freedom of speech, equality amongst all participants and a collaboration between non-science and science teachers. The fact that there is still work do be done to arouse the interest of non-science teachers into the concept of STEAM, was shown by Aguilar & Kapalka Richerme (2016), who showed that undergraduate music teacher educators are mostly interested in themes which a closely connected with their field of expertise and that STEAM was not mainstream within this group of teacher educators.

ASSESSMENT

We could not identify studies which treated the assessment of STEAM competences within learners, such as co-operation, critical thinking and creativity. Kim & Kim (2016) developed and validated 35 evaluation indicators for teachers for good STEAM teaching in secondary schools, based on the South Korean framework of STEAM.

CONTEXT

No explicit studies concerning the context for STEAM education could be retrieved.

Co-funded by the
Erasmus+ Programme
of the European Union

CONCLUSIONS

The first conclusion which can be drawn from this systematic review is that there is little empirical research about the effects and implications of STEAM education. Moreover, within the limited available results, few a based on an explicitly described framework of STEAM education. Moreover, the studies are culturally biased due to the fact that they are all conducted in two countries with a slightly different STEAM approach.

The studies show that a concentrated effort on STEAM education has a positive effect on the motivation and learning effect of the teachers and learners. On the other hand, both groups also expressed concern about the STEAM pedagogy in relation to standardized tests in both countries.

Further longitudinal research (like e.g. (Quigley & Herro, 2016)) is necessary on the lasting effect of STEAM education on the knowledge building of students and the practices of teachers.

BIBLIOGRAPHY

Aguilar, C., & Kalpaka Richerme, L. (2016). A descriptive study of music teacher educators' beliefs about policy. Journal of music teacher education, 25(2), 37-49.

Canha, S. (2017, 09 09). A alfabetização da Europa. Retrieved from www.dnoticias.pt: http://www.dnoticias.pt/opiniao/artigos/403117-a-alfabetizacao-da-europa-EODN403117

Caprille, M., Palmén, R., Sanz, P., & Dente, G. (2015). Encouraging STEM studies for the labour market. European Union: Directorate General for Internal Policies.

Committee on STEM education. (2011). The Federal Science, Technology, Engineering and Mathematics (STEM) Education Portfolio. Washington, DC: National Science and Technology Council.

Conselho Nacional de Educação. (2017, setembro 09). Conselho Nacional de Educação. Retrieved from www.cnedu.pt: http://www.cnedu.pt/content/edicoes/seminarios_e_coloquios/PISA_Investiga%C3%A7%C3%A3o_em_Portugal_dezembro_2014.pdf

Corbi, A., & Burgos, D. (2017). Open distribution of virtual containers as a key framework for open educational resources and STEAM subjects. The electronic journal of e-learning, 15(2), 126-136.

data, O. w. (2017, setembro 9). Our world in data. Retrieved from www.ourworldindata.org: https://ourworldindata.org/literacy/

Dewey, J. (1902). The child and the curriculum. Chicago: University of Chicago Press.

Co-funded by the Erasmus+ Programme of the European Union

English, L. (2017). Advancing elementary and middle school STEM education. International journal of science and mathematics education, 15(Supplement 1), S5-S24.

Gates, A. (2017). Benefits of a STEAM collaboration in Newark, New Jersey: Volcano simulation through a glass-making experience. Journal of geoscience education, 65(1), 4-11.

Gershon, W., & Ben-Horin, O. (2014). Deepening inquiry: what processes of making music can teach us about creativity and ontology for inquiry based science education. International Journal of Education & the Arts, 15(19), - .

Ghanbari, S. (2015). Learning across disciplines: A collective case study of two university programs that integrate the arts with STEM. International Journal of Education & the Arts, 16(7), 1-21.

Graham, N., & Brouillette, L. (2016). Using arts integration to make science learning memorable in upper elementary grades: a quasi-experimental study. Journal of learning through the arts, 12(1), 1-17.

Guyotte, K., Sochacka, N., Constantino, T., Kellam, N., & Walther, J. (2015). Collaborative creativity in STEAM: Narratives of art education students' experiences in transdisciplinary spaces. International Journal of Education & the Arts, 16, (15).

Guyotte, K., Sochacka, N., Constantino, T., Walther, J., & Kellam, N. (2014). STEAM as a socal practice: cultivating creativity in transdisciplinary spaces. Art Education, 67(6), 12-19.
Hattie, J. (2012). Visible learning for teachers: Maximizing impact on learning. Routledge.

Herro, D., & Quigley, C. (2017). Exploring teachers' perceptions of STEAM teaching through professional development:

implications for teacher educators. Professional development in education, 43(3), 416-438.

Herro, D., Quigley, C., & Dsouza, N. (2016). STEAM enacted: A case study exploring middle school teachers implementing STEAM instructional practices. Journal of computers in mathematics and science teaching, 35(4), 319-342.

Hmelo-Silver, C. (2004). Problem-based learning: What and how do students learn? Educational Psychology Review, 235-266.

Hunter-Doniger, T., & Sydow, L. (2016). A journey from STEM to STEAM: A middle school case study. The Clearing House: A journal of educational strategies, issues and ideas, 89(4-5), 159-166.

IAVE. (2017, setembro 9). IAVE. Retrieved from www.iave.pt: http://iave.pt/np4/file/310/Relatorio_PISA2015.pdf

IAVE. (2017, setembro 9). IAVE. Retrieved from www.iave.pt: http://iave.pt/np4/file/310/Relat_rio_TIMSS4.pdf

Jho, H., Hong, O., & Song, J. (2016). An analysis of STEM/STEAM teacher education in Korea with a case study of two schools from a community of practice perspective. Eurasia journal of mathematics, science & technology education, 12(7), 1843-1862.

Keane, L., & Keane, M. (2016). STEAM by design. Design and technology education, 21(1), 61-82.

Kim, B.-H., & Kim, J. (2016). Development and validation of evaluation indicators for teaching competency in STEAM education in Korea. Eurasia journal of mathematics, science &

technology education, 12(7), 1909-1924.

Kim, D., & Bolger, M. (2017). Analysis of Korean elementary pre-service teachers' changing attitudes about integrated STEAM pedagogy through developing lesson plans. International journal of science and mathematics education, 15(4), 587-605.

Kim, H., & Chae, D.-H. (2016). The development and application of a STEAM program based on traditional Korean culture. Eurasia journal of mathematics, science & technology education, 12(7), 1925-1936.

Kim, P. W. (2016). The Wheel model of STEAM education based on traditional Korean scientific contents. Euroasia Journal of Mathematics, Science & Technology Education, 12(9), 2353-2371.

Kirschner, P., Sweller, J., & Clark, R. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiental and inquiry-based teaching. Educational psychologist, 75-86.

Korean Ministry of Education. (2009). The high school curriculum. National curriculum of Korea, 2009 revision, 79-81.

Krug, D., & Shaw, A. (2016). Reconceptualizing ST®E(A)M(S) education for teacher education. Canadian Journal of Science, Mathematics and Technology Education, 16(2), 183-200.

Maeda, J. (2013). STEM + Art = STEAM. The STEAM journal, 1(1), Article 34.

Martin, M., Mullis, I., Foy, P., & Hooper, M. (2016). TIMSS 2015 International results in Science. Boston College: TIMSS & PIRLS International Study.

Mullis, I., Martin, M., Foy, P., & Hooper, M. (2016). TIMSS 2015 International results in Mathematics. Boston College: TIMSS & PIRLS International Studies.

O Expresso. (2017, setembro 9). Expresso. Retrieved from www.expresso.sapo.pt: http://expresso.sapo.pt/sociedade/2016-04-30-As-escolas-portuguesas-ainda-nao-fizeram-a-transicao-do-ensino-do-seculo-XX-para-o-seculo-XXI

OECD. (2016). PISA 2015 Results (Volume I): Excellence and Equity in Education. Paris: PISA, OECD Publishing.

OECD. (2017). Education at a glance 2017: OECD indicators. Paris: OECD Publishing.

Park, H., Byun, S.-y., Sim, J., Han, H., & Baek, Y. S. (2016). Teachers' perceptions and practices of STEAM education in South Korea. Eurasia journal of mathematics, sciences & technology education, 12(7), 1739-1753.

Pordata. (2017, Setembro 9). https://www.pordata.pt/DB/Portugal/Ambiente+de+Consulta/Tabela. Retrieved from www.pordata.pt: https://www.pordata.pt/DB/Portugal/Ambiente+de+Consulta/Tabela

Quigley, C. F., Herro, D., & Jamil, F. M. (2017). Developing a conceptual model of STEAM teaching practices. School Science and Mathematics, 117(1-2), 1-12.

Quigley, C., & Herro, D. (2016). "Finding the joy in the unknown": Implementation of STEAM teaching practices in middle school science and math classrooms. Journal of science education and technology, 25(3), 410-426.

Savery, J. (2006). Overview of problem-based learning: Definitions and distinctions. Interdisciplinary journal of problem-based learning, Article 3.

Schildkamp, K., & Kuiper, W. (2010). Data-informed curriculum reform: which data, what purposes, and promoting and hindering factors. Teaching and teacher education, 26, 482-496.

Sharapan, H. (2012). From STEM to STEAM: How early childhood educators can apply Fred Rogers' approach. Young Children, 67(1), 36-40.

Tillman, D., An, S., & Boren, R. (2015). Assessment of creativity in arts and STEM integrated pedagogy by pre-service elementary teachers. Journal of technology and teacher education, 23(3), 301-327.

Torras-Melenchon, N., Grau, D., Font-Soldevilla, J., & Freixas, J. (2015). EXPLORE: An action to bring science and technology closer to secondary school. Journal of technology and science education, 5(2), 75-86.

Vlaamse Overheid. (2010). Peiling wiskunde in de eerste graad secundair onderwijs (A-stroom). Brussel: Vlaams ministerie van Onderwijs en Vorming.

Vlaamse overheid. (2012). Peiling wiskunde in de tweede graad algemeen secundair onderwijs. Brussel: Minsterie van onderwijs en vorming.

Vlaamse overheid. (2015). Peiling wiskunde in de derde graad secundair onderwijs aso-tso-kso. Brussel: Ministerie van onderwijs en vorming.

Vlaamse overheid. (2016). Peiling natuurwetenschappen in de eerste graad secundair onderwijs. Brussel: Ministerie van

Onderwijs en Vorming.

Vlaamse overheid. (2016). Peiling wereldoriëntatie Natuur en Techniek in het basisonderwijs. Brussel: Ministerie van Onderwijs en Vorming.

Vlaamse overheid. (2017). Peiling wiskunde in het basisonderwijs. Brussel: Ministerie van onderwijs en vorming.

Wittmann, E. (2003). Was ist Mathematik und welche pädagogische Bedeuting has das wohlverstandene Fach für den Mathematikunderricht auch in der Grundschule? In M. Baum, & H. Wielpütz, Mathematik in der Grundschule. Ein Arbeitsbuch (pp. 1-28). Seelze: Kallmeyer.

Co-funded by the
Erasmus+ Programme
of the European Union