Scientific Literacy and the Science Curriculum Reorganisation in Portugal

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ABSTRACT – Scientific Literacy and the Science Curriculum Reorganisation in Portugal. The study analyses the curricular reorganisation in science teaching in the Portuguese 3rd cycle of basic education, explores how scientific literacy is embraced in the curriculum and analyses the evolution in the students' results in the external assessments PISA and TIMSS. The curriculum reforms have culminated in two documents in force in science education: Essential Apprenticeships and Profile of Students Leaving Compulsory Schooling. In both, the development of scientific literacy is one of the main goals to be achieved. During the curricular changes, the emphasis on the importance of scientific literacy for the students' education has increased, which is reflected in the relevant growth of Portugal's results in external assessments.
Keywords: **Scientific Literacy. Curriculum Reforms. Science Education. 3rd Cycle of Basic Education. Science Curriculum.**

RESUMO – Literacia Científica e a Reorganização Curricular em Ciências em Portugal. O estudo analisa a reorganização curricular no ensino de ciências do 3.° ciclo do Ensino Básico português, explora como a literacia científica está abarcada no currículo e analisa a evolução nos resultados dos alunos nas avaliações externas PISA e TIMSS. As reformas curriculares culminaram em dois documentos em vigor na área das ciências: Aprendizagens Essenciais e o Perfil dos Alunos à Saída da Escolaridade Obrigatória. Em ambos, o desenvolvimento da literacia científica é um dos principais objetivos a ser alcançado. No decorrer das mudanças curriculares ampliou-se a ênfase na importância da literacia científica para a formação dos alunos, facto que se reflete no crescimento relevante dos resultados de Portugal nas avaliações externas.
Palavras-chave: **Literacia Científica. Reformas Curriculares. Ensino de Ciências. 3.° Ciclo do Ensino Básico. Currículo de Ciências.**

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Introduction

Since the late 1950s and especially after the 1980s, several science curriculum around the world have undergone changes to better adapt science education to the prerequisites of what has come to be called scientific literacy, defined by the OECD as the “individual’s ability to engage in questions about science and to understand scientific ideas as a reflective citizen capable of engaging in rational discourse about science and technology” (Marôco et al., 2016a, p. i). Portugal was part of this group of countries, initiating a process to reorganise the Basic Education curriculum in the 2001/2002 academic year that began to implement new organisational guidelines and curriculum designs.

As a consequence of this restructuring, the science curriculum of Basic Education was developed based on international guidelines and recommendations and aligned with the curriculum of the countries that ranked highest in the Programme for International Student Assessment (PISA) (Galvão et al., 2017). These curriculum documents define educational policy as it relates to science education and reveal the principles, objectives, emphasis, organisation, and expected learning outcomes (Rebola, 2015, p. 62).

According to Galvão et al. (2017, p. 12), the great debate in science education in Portugal ensues in order to “raise students’ interest in science and develop all students’ scientific literacy from a perspective of public engagement with science”. However, Serra and Galvão (2015) state that decisions involving the science curriculum are endowed with ideologies and power relations since curriculum reorganisations were related to continuous administration changes in the Portuguese government. They also argue that “in the last fifteen years, the debate over the curriculum in Portugal has focused essentially on a dichotomy of ‘objectives versus competencies’” (Serra; Galvão, 2015, p. 256).

Within the context of these principles, this paper presents a study based on the following research questions: 1) What curriculum reforms have occurred in science education in the 3rd cycle of Basic Education in Portugal since 1977? 2) What are the implications of these reforms for science education in Basic Education? 3) How is scientific literacy introduced in the curriculum documents currently in effect in the area of Physical and Natural Sciences of the 3rd cycle of Basic Education in Portugal? 4) How do Portuguese students perform in the science tests of the PISA and TIMSS international tests over the years of participation?

A qualitative approach was applied in the study to analyse the main Portuguese curriculum documents for science in the 3rd cycle of Basic Education and the national PISA and TIMSS reports. The following were analysed: the *Currículo Nacional do Ensino Básico – Competências Essenciais* (CNEB) (National Curriculum for Basic Education – Essential Competencies) (DEB, 2001); the *Orientações Curriculares de Ciências Físicas e Naturais do 3.° ciclo do Ensino Básico* (Curricular Guidelines for the 3rd cycle of Basic Education – Physical and Natural Sciences) (Galvão et al., 2001); the *Metas de Aprendizagem* (MA) (Learning Goals) for Natural Sciences (DGIDC, 2010b) and Physical Chemistry (DGIDC, 2010a) for the 3rd cycle of Basic Education; the *Metas Curriculares* (MC) (Curriculum Goals) for teaching Natural Sciences in the 5th, 6th, 7th, and 8th school years (Bonito et al., 2013) and for teaching Physical Chemistry in the 3rd cycle of Basic Education (Fiolhais et al., 2013); the *Perfil dos Alunos à Saída da Escolaridade Obrigatória* (PASEO) (Students' Profile by the End of Compulsory Schooling) (Martins et al., 2017); the *Aprendizagens Essenciais* (AE) (Essential Learnings) for Natural Sciences (DGE, 2018a; 2018b; 2018c) and for Physical Chemistry (DGE, 2018d; 2018e; 2018f) in the 7th, 8th, and 9th years; the 2000 to 2018 editions of the PISA national reports; and the 1995, 2011, 2015, and 2019 editions of the TIMSS national reports.

For the curriculum documents, the following common variables were considered: a) date of approval and withdrawal (if applicable); b) educational approach (by objectives/descriptors or by competencies); c) objectives for science education; and d) mention of scientific literacy. As for the reports on the international PISA and TIMSS tests, the following variables were analysed: a) the average performance of Portuguese students in science tests and its comparison to the OECD average and b) progress of Portugal's results in these events.

In order to be a contribution to research in the area of Physical and Natural Sciences in the 3rd cycle of Portuguese Basic Education, from the perspective of scientific literacy, this article is organised into three sections: firstly, curriculum changes in the teaching of science in Primary Education, in which the main curriculum reforms that have occurred since 1977, post-revolutionary period, in science teaching at this level of education are presented; secondly, scientific literacy in the current curriculum documents of Physical and Natural Sciences in the 3rd cycle of Basic Education. Secondly, scientific literacy in the current curriculum documents of Physical and Natural Sciences at the 3rd cycle of Basic Education, which is dedicated to identifying how scientific literacy is embedded and presented in the two curriculum documents currently in effect in the area of Physical and Natural Sciences at the 3rd cycle of Basic Education; and thirdly, the evolution of Portuguese students' performance in scientific literacy in international tests, which discusses the performance of Portuguese students in scientific literacy in the PISA and TIMSS assessments..

Curricular changes in science education in Basic Education

In Portugal, as well as in other countries, several reforms have taken place in the education system to meet needs and correct the most relevant problems. In order to analyze the curriculum development in science education, Serra and Galvão (2015) compared the official natural science documents from 1977 to 2001 and observed that the 1977 and 1991 programmes establish the correspondence between general objectives, content, didactic suggestions, and year of schooling. They noticed, however, that neither programme stipulated specific objectives, leaving it up to the teachers to define them (Serra; Galvão, 2015).

In the 1996/1997 academic year, the Ministry of Education's Department of Basic Education deployed the Participatory Reflection on Curriculum for Basic Education project, which gave rise to a process of curriculum reorganisation at this education level (Abelha et al., 2007). This restructuring aimed to better contextualise and consequently adapt the curriculum and education for the students' integral development through significant learning (Abelha et al., 2007).

A new curriculum reorganisation took place in 2001. Two guiding documents were published: the National Currículum for Basic Education – Essential Competencies (CNEB) (DEB, 2001) and the Curricular Guidelines for the 3rd cycle of Basic Education – Physical and Natural Sciences (Galvão et al., 2001). The former establishes the set of essential competencies for developing the national curriculum for the various subjects of Basic Education, while the latter defines the specific competencies for each subject.

The CNEB aimed to bring together the different subjects and subject areas (Rebola, 2015), establishing content and learning experiences by topic, subject, and teaching cycle, rather than by year of schooling (Serra; Galvão, 2015). However, the authors claim that "[…] given the inoperability of this formulation, in 2002/2003, the Ministry of Education distributed (in agreement with the Publishers and Booksellers Associations) the topics and program contents by year of schooling in the 3rd Cycle" (Serra; Galvão, 2015, p. 263).

Besides articulating the various disciplines, the CNEB presented innovative ideas and principles, such as "[…] the notion of competencies, the development of appropriate learning experiences, an emphasis on formative assessments, and flexible management of the curriculum" (Galvão et al., 2017, p. 18). Competency-based learning, described as knowledge in use (DEB, 2001), aimed to extrapolate the prevailing vision of the curriculum in effect at the time, which focused on objectives (Serra; Galvão, 2015).

According to the authors, objective-based learning presented a reductionist, technical, mechanistic vision based on behavioural learning theories, in which "[…] the curriculum and education are developed by breaking down complex learning (general objectives) into simpler knowledge and processes (behavioural objectives), which should be developed in sequential instalments" (Serra; Galvão, 2015, p. 260). Competency-based learning, on the other hand, focuses on a more integrative approach based on social constructivism learning theories, in which education is organised around learning experiences that apply more closely to the actual context of the students' daily lives, requiring them to mobilise a set of resources simultaneously (Serra; Galvão, 2015).

Like the CNEB, the Curricular Guidelines, more specifically for the area of Physical and Natural Sciences (Galvão et al., 2001), also came into effect in the 2002/2003 academic year. Its implementation was part of a broader curriculum reorganisation process that involved a movement for participatory management of the curriculum, which began in 1997 (Galvão et al., 2017). In this sense, one of the main goals of the science curriculum became to challenge teachers to view education in a different way, valuing a more constructivist perspective; the Science, Technology, Society, and Environment (CTSA) approach; and investigative activities (Galvão et al., 2017, p. 16).

However, implementation did not proceed as planned. The initial idea was to apply the curricular innovations in a few Portuguese schools and, little by little, expand them to the entire national territory (Galvão et al., 2017). Nevertheless, due to the change in the government's administration in 2002, the Curricular Guidelines for Physical and Natural Sciences came into effect for the entire national territory and, therefore, there was no time to prepare schools, to create a systematic monitoring for schools and teachers, and to evaluate the changes, as previously planned (Galvão et al., 2017).

Later, in the 2009/2010 academic year, a new set of curriculum documents was developed and enabled. The Learning Goals (MA) of the 3rd cycle of Basic Education was among them. They were designed to be connected to the CNEB and with the subject area programs (DGIDC, 2010a; 2010b), and that translated the topics and subtopics set forth in the CNEB into domains and subdomains of the learning goals (Rebola, 2015).

The MA of Natural Sciences (DGIDC, 2010b) and of Physical Chemistry (DGIDC, 2010a) for the 3rd cycle of Basic Education present scientific literacy as the goal of science education. Both documents aimed to elucidate the learning that, in the field of sciences, should be achieved by the end of basic education, so that students are scientifically literate for their age, enabling them to understand the world in which they live (DGIDC, 2010a; 2010b).

Nevertheless, in 2011, the following year, the Ministry of Education and Science revoked the CNEB by means of Order no. 17169/2011 of December 23rd (Portugal, 2011). According to the Order, the CNEB contained several shortcomings and was unclear in its guidelines, introducing

> [...] a series of educational recommendations that turned out to be harmful. Firstly, by erecting the category of 'competencies' as a way to guide all education, it has diminished the role of knowledge and the transmission of knowledge, which is essential to all learning. Secondly, it disregarded the importance of information acquisition and the development of automatisms and memorisation. Thirdly, it has replaced clear, precise, and measurable objectives with seemingly generous but vague objectives that are difficult, if not impossible, to measure. Consequently, it hindered the formative and summative assessment of learning. Competencies should not be presented as a category that encompasses all learning objectives; they should be clearly broken down into knowledge and skills. Knowledge and its acquisition have their own value, regardless of whether that knowledge is mobilised for immediate application (Portugal, 2011, p. 50080).

Antunes (2021) reinforces that the rationale for the revocation of the CNEB were based on the fact that this document's text was extensive, repetitive, confusing, and disperse and on a denunciation of competency-based learning, which was thought to be harmful because it underestimates memorisation and hinders formative and summative assessments in schools by not presenting clear, precise, and measurable objectives. The author also emphasizes that the suppression of the CNEB made the reading of the Curricular Guidelines for Physical and Natural Sciences, until then in force, meaningless, to the extent that the references to the CNEB present in them are no longer interpreted based on this document (Antunes, 2021).

Subsequently, in 2013, the Curriculum Goals (MC) for teaching Natural Sciences in the 5th, 6th, 7th, and 8th years (Bonito et al., 2013) and for teaching Physical Chemistry in the 3rd cycle of Basic Education (Fiolhais et al., 2013) were developed and approved by Order no. 5122/2013 of April 16th (Portugal, 2013). The Natural Sciences MC's for the 9th year (Bonito et al., 2014) were subsequently approved in 2014 by Order no. 110-A/2014 of January 3rd (Portugal, 2014). According to the authors of the documents, the organising topics and the essential content of the program of the Nature Sciences subjects in the 2nd cycle of Basic Education, as well as the Curricular Guidelines for Physical and Natural Sciences in the 3rd cycle of Basic Education, were taken into consideration to prepare the MC (Bonito et al., 2013; Fiolhais et al., 2013).

The Physical and Natural Sciences MC's are organized in domains, subdomains, general objectives, and descriptors. A domain is understood as "[...] a unifying area of content, which corresponds to a topical unit, that may be divided into smaller clusters called 'subdomains'" (Bonito et al., 2013, p. 1). The objectives correspond to the intended learning and comprehend the descriptors for the performance levels that should be demonstrated by students (Bonito et al., 2013).

However, the Natural Science MC's received several critical reviews. For example, they resume objective-based learning in science and add specific objectives, represented by descriptors (Serra; Galvão, 2015). According to the authors, too much emphasis has been placed on memorisation in the learning process. This was verified by the higher frequency in the appearance of verbs such as "indicate", "refer", "describe", and "give examples" in the descriptors, evidencing an "[...] explicit and assumed return to the objective-based curriculum, which had characterised the Portuguese curriculum until 2001" (Serra; Galvão, 2015, p. 266).

In 2017, the Ministry of Education developed the Students' Profile by the End of Compulsory Schooling (PASEO) (Martins et al., 2017), approved by Order no. 6478/2017 of of July 26th (Portugal, 2017). This curriculum document adopted a constructivist perspective, a practical approach, which included investigative learning, and an encouraging aspect of interdisciplinarity – elements that were already embedded in the fundamental principles of the CNEB, which was repealed in 2011 (Galvão et al., 2017). Revealing itself as a reference for decision-making by education policy managers and educational actors at the level of educational establishments, PASEO is "[…] a common matrix for all schools and educational offerings within compulsory education, namely at the curricular level, in the planning, implementation, and internal and external assessment of teaching and learning" (Martins et al., 2017, p. 1).

Endowed with transversality, PASEO enables each curricular area to develop all of its competencies. To this end, it is structured into: principles, which give meaning to the actions related to the implementation and management of the curriculum at the school in all subject areas; vision, which presents its intention for young people, as citizens, at the end of their compulsory education; values, which comprehend the ethical characteristics that justify the students' way of being and actions; and competency areas, i.e., the combinations of knowledge, skills, and attitudes that enable effective action in various contexts (Martins et al., 2017).

In 2018, the following year, the Essential Learnings (AE) for Basic Education document was approved by Order no. 6944-A/2018 of July 19th. AE constitute a set of disciplinary knowledge that all students are required to acquire, as well as skills and attitudes they must develop, in each subject of their year of schooling or training (Portugal, 2018b).

The main goal of AE is to ensure equal opportunities and promote the educational success of students throughout compulsory schooling. As for science education in the 3rd cycle of Basic Education, AE is represented by AE for Natural Sciences (DGE, 2018a; 2018b; 2018c) and for Physical Chemistry (DGE, 2018d; 2018e; 2018f) in the 7nth, 8th, and 9th years.

The AEs are in convergence with PASEO, since they aim to develop the stipulated competencies and demonstrate the specific content of the subjects and learning strategies. In this sense, both curriculum documents constitute benchmarks for the decisions made by the school concerning the adequacy and contextualisation of planning, teaching and learning, and the internal and external assessments of students (Portugal, 2018b).

The curriculum revision, which began in 2012, gave rise to the publication of a new curriculum defined by Decree-Law no. 55/2018 of July 6th (Portugal, 2018a). Within this, new curricular matrices were redesigned for the 3rd cycle of Basic Education

> […] to give the school autonomy to organise its timetables (course load distribution by weekly school hours) and to encourage the use of free time to reinforce the class's learning activities through a discourse intended to articulate the curriculum, so as to develop the Students' Profile by the End of Compulsory Schooling, by offering schools the possibility of organising its school hours at the unit they consider most appropriate (Antunes, 2021, p. 145).

It is worth noting that these two official documents, PASEO and Essential Learnings, present diverging perspectives of the MC. Antunes

(2021) highlights the guiding principles of the curriculum changes by stating that "[...] the coherence and sequentiality in the articulation between cycles, the diversity of offerings, and the reduced curricular dispersion" in the curriculum revision instituting the MC gave way "[...] to the school's curriculum management, to a multilevel approach, to guaranteeing inclusive schools, and to formative assessments" (Antunes, 2021, p. 149) included in PASEO and in Essential Learnings. The author also notes that, while the MC reduced curricular dispersion, reinforced core subjects, focused on the content for central subjects, and made a progressive bet on the schools' autonomy, the homologation of PASEO followed the reorganization of the curricular matrices, the proposal of an interdisciplinary approach and the flexible management of the curriculum.

Finally, in 2021, Order no. 6605-A/2021 of July 6th (Portugal, 2021) revokes all the documents considered to be unaligned with these rules. In the area of sciences, the following were revoked: the Natural Sciences Programme for the 2nd cycle of Basic Education (Curricular Organization and Programmes and the Nature Sciences Programme: Teaching-Learning Organisation Plan); the Natural Sciences Programme for the 3rd cycle of Basic Education (Physical and Natural Sciences Curriculum Guidelines); and the MC for Natural Sciences and Physical Chemistry of Basic Education.

Currently, science education in Basic Education is divided into three cycles. The area of Environmental Studies is approached in the 1st cycle, the subject of Nature Science is developed in the 2nd cycle, and in the 3rd cycle, the sciences are divided into the subjects of Natural Sciences and Physical Chemistry, constituting the area of Physical and Natural Sciences. The following curriculum guides are currently in effect: AE for Environmental Studies in the 1st cycle (1st to 4th school years), AE for Natural Sciences in the 2nd cycle (5th and 6th school years), and AE for Natural Sciences and Physical Chemistry in the 3rd cycle (7th to 9th school years) of Basic Education. At all cycles, the AE are articulated with PASEO.

Scientific literacy in the curriculum documents in effect for Physical and Natural Sciences in the 3rd cycle of Basic Education

This section addresses how scientific literacy is embedded and presented in the two curriculum documents in effect in the area of Physical and Natural Sciences in the 3rd cycle of Basic Education, AE and PASEO.

Scientific literacy appears at three moments in AE for Physical Chemistry in the 7th, 8th, and 9th years. The first instance sustains in the introduction of the document that "the subject of Physical Chemistry in Basic Education aims to contribute to the development of scientific literacy in students, to awaken their curiosity about the world around us and interest in Science" (DGE, 2018d, p. 1; 2018e, p. 1; 2018f, p. 1). The two other references are found in the dual perspective which serves as the basis for AE for Physical Chemistry.

The second reference indicates that students will develop scientific literacy competencies that will allow them to "[…] mobilise their understanding of scientific processes and phenomena for decision-making and to become aware of the implications of Science in today's world, in order to exercise participatory citizenship" (DGE, 2018d, p. 2; 2018e, p. 2; 2018f, p. 2), upon completing this subject by the end of the 3rd cycle. Whereas the third reference assumes that "students who choose to pursue studies in the area of sciences in the compulsory 12 years of schooling are equipped with scientific literacy that allows them to deepen their knowledge in this area" (DGE, 2018d, p. 2; 2018e, p. 2; 2018f, p. 2). It also states the need to develop competencies related to scientific literacy, such as reasoning, problem-solving skills, autonomy, personal development, teamwork, and interpersonal relationships (DGE, 2018d; 2018e; 2018f).

Regarding the Natural Sciences AE, although it does not explicitly refer to the term "scientific literacy", it addresses relevant competencies by informing in the introduction that the subject aims

> […] to develop a general, comprehensive understanding of the main ideas and explanatory structures of the Earth and Life Sciences, aspects of the History and Nature of Science, scientific research procedures, as well as to question human behaviour in the world and the impact of science and technology on the environment and on living beings (DGE, 2018a, p. 1; 2018b, p. 1; 2018c, p. 1).

Moreover, aligned with the aims of scientific literacy, Natural Sciences AE sets out to provide students with an understanding of the limits, possibilities, and effects of applying their knowledge of science and technology to society, as well as an awareness of the need to adopt behaviours that are consistent with sustainable development (DGE, 2018a; 2018b; 2018c).

It is important to note that AE for Physical Chemistry and for Natural Sciences – in agreement with the Curriculum Guidelines and in disagreement with the MC for the area, both of which have been repealed – aspires to competency-based learning and highlights the importance of the learning required for the meaningful construction of knowledge and the development of attitudes and cognitive processes associated with science (DGE, 2018a, 2018b, 2018c). Furthermore, it aims to assimilate the knowledge and competencies that allow students to intervene as active citizens in scientific and technological issues that arise in today's society, as well as to awaken their interest and curiosity for science based on a perspective of lifelong learning (DGE, 2018a; 2018b; 2018c).

Since they are articulated with the PASEO, the Natural Sciences and Physical Chemistry AE support the development of the competences included in it. Although it is a document that encompasses all areas of the curriculum, not only the area of Physical and Natural Sciences, PASEO addresses aspects related to this area, such as the relationship between scientific and technological knowledge and security and society's sustainability (Martins et al., 2017).

Like the Natural Sciences AE, PASEO does not specify the term "scientific literacy". However, it refers to multiple literacies, including scientific literacy. According to the document, the school, "[…] as an environment conducive to learning and developing competencies, where students acquire the multiple literacies they need to mobilise, has to be reconfigured to meet the demands of these times of unpredictability and accelerated changes" (Martins et al., 2017, p. 7). By developing these competencies, PASEO endorses schooling that enables students to actively, consciously, and responsibly participate and intervene in society and make informed decisions about natural, social, and ethical issues surrounding current debates (Martins et al., 2017).

Performance evolution of Portuguese students in scientific literacy in international tests

Portugal began its participation in international large-scale assessments in the 1990s (Fernandes; Gonçalves, 2018). Mostly, studies were related to literacies in reading, maths, and sciences (Fernandes, 2009). However, Fernandes (2009) claims that Portugal's participation had no clear purpose and was disassociated from education policy actions.

Silva (2014) corroborates this claim by noting that the data obtained from the evaluations, although relevant, were not taken into consideration as they should have been. According to the author, the data was often ignored, its publication was scarce and the few news reports emphasized the fact that Portuguese students were in the bottom ranks. Moreover, the information rarely indicated the aspects that needed improvement or that set Portugal apart from other countries.

It was not until the 2000s that the results of international external assessments, mainly PISA and TIMSS, began to be integrated into the political discourse in Portugal in a way that was unprecedented (Fernandes; Gonçalves, 2018). Since then, based on the students' performances in these two assessments, several programmes and projects for the quality of education have emerged (Rodrigues, 2010), such as the Training Programme in Experimental Science Education, whose goal was to develop the investigative skills and attitudes of students and teachers in training (Saraiva, 2017).

Nevertheless, Fernandes and Gonçalves (2018) argue that the development of programmes and projects to improve the quality of education had its real start in 1986, with the approval of the National Educational Bases and Guidelines Law. According to the authors, was from this year on,

> [...] long before the first edition of PISA, that programmes and projects with clear purposes to modernise and improve quality and equity in education were launched in a systematic, consistent manner, as demonstrated below (e.g., *Projeto Minerva* (Minerva Project), *Educação Para Todos* (Education for All) Project, *Ciência Viva* (Live Science) Programme, *Plano Nacional de Leitura* (National Reading Plan), *Novas Oportunidades* (New Opportunities) Programme, *Plano de Ação para a Matemática* (Action Plan for Mathematics)) (Fernandes; Gonçalves, 2018, p. 4).

In the specific case of science education, Saraiva (2017) points out that it drew greater attention after the publication of Mariano Gago's *Manifesto para ciência em Portugal* (Manifesto for Science in Portugal) (Gago, 1990), in which the author presents science education as a central component of education policies. From then on, science education received a huge boost, especially with the creation of the *Ciência Viva* Programme, which encouraged to build a national network of interactive science centres – currently 22 *Ciência Viva* Centres in the country – focused on informal science education.

Portuguese students' performance in scientific literacy in PISA

Since the students' performance in PISA and TIMSS is one of the major topics for public debate related to the quality of Portuguese education, Portugal's results on the science tests, which assess scientific literacy, throughout its years of participation are provided below.

Portugal is part of the OECD group of countries that have participated in PISA since its first edition, in 2000, and until the 2012 assessment, Portuguese students' average performance in science was below the average of the OECD countries (Marôco et al., 2016a). Despite this, Portuguese participation showed a positive growth trend, with a slight drop between 2009 and 2012, which was recovered and overcome in 2015 (Marôco et al., 2016a) and maintained in the 2018 edition.

In the editions between 2006 and 2015, Portuguese students' average performance in the science test improved, while performance in this domain in most countries remained practically unchanged. Portugal also presented an increase in the number of top performers (proficiency levels 5 and 6) and a decrease in the number of low performers (proficiency levels below proficiency level 2) (OECD, 2016).

This improvement culminated in 2015, the first time that Portuguese students' average performance significantly exceeded the OECD average on the science test (Marôco et al., 2016a). This becomes even more relevant given the exceptional performance in PISA's science domain that same year.

Marôco et al. (2016a) argue that the most appropriate comparison between the results of scientific literacy is the one in which the average values of Portuguese students in the years in which the emphasis of the PISA assessment was the science test are analyzed, 2006 and 2015 cycles. Comparing the results of these two years, Portugal made a significant and positive progression of 27 points, with an average increase of 2.8 points per year, exceeding the OECD average, which decreased slightly (Marôco et al., 2016a).

As for proficiency level, the PISA assessment identifies seven levels: 1b (261 to 334 points), 1a (335 to 409 points), 2 (410 to 483 points), 3 (484 to 558 points), 4 (559 to 632 points), 5 (633 to 707 points), and 6 (over 708 points). Based on the PISA's logic, a student demonstrates that they possess the basic knowledge and competencies to understand science in today's world – scientific literacy – by reaching proficiency level 2 on the science assessment (Saraiva, 2017, p. 12). At this level,

> […] students are able to use their everyday knowledge about content and their basic knowledge about procedures to identify an appropriate scientific explanation, interpret data, and identify the research question in a simple experimental design. They are able to use their basic or everyday scientific knowledge to identify a valid conclusion drawn from a simple set of data. Students whose performance is at level 2 demonstrate basic epistemological knowledge by being able to identify questions that can be investigated scientifically (Marôco et al., 2016a, p. 29).

Portugal's PISA 2015 results revealed that the students' average score was 501, placing the country in the group of participants that obtained a significantly higher result than the OECD average, which was 493 in this cycle (Marôco et al., 2016a). Also, 82.6% of Portuguese students reached proficiency level 2 or above, and 75% placed between proficiency levels 2 and 4 (Marôco et al., 2016a).

In PISA 2018, the latest result available so far, there was a decrease in Portuguese students' average scores in comparison to the previous cycle, dropping by nine points from the 2015 test (Lourenço et al., 2019). However, Portuguese students' average score of 492 points was above the OECD average, which was 489 points. The result follows the downward trend of the OECD average score, which already dropped four points in 2015 compared with the average score in 2006 (Lourenço et al., 2019).

Despite the drop in scores, the percentage of students achieving level 2 proficiency rose from 75% to 80% in this latest edition, which was higher than the average for the OECD countries, which was 78% (Lourenço et al., 2019). In addition, an analysis of the average variation in three-year cycles showed that Portugal stands out in the area of sciences, demonstrating a significant, positive variation of 4.3 points (Lourenço et al., 2019).

Portuguese Students' Performance in Scientific Literacy in TIMSS

In 2019, TIMSS conducted the 7th edition of the study. Portugal participated in only four editions: 1995, 2011, 2015, and 2019 (1st, 5th, 6th and 7th editions, respectively). However, Portugal's participation was not the same every year. In the 1st edition, Portuguese students participated in the two levels assessed: 3rd and 4th grades and 7th and 8th grades (Ferreira et al., 2012). In the 2nd and 3rd editions, only 4th grade students took the assessment, and in the last edition, 4th and 8th grades students participated (Marôco et al., 2016b).

Since the first edition, TIMSS literacy scale is standardised and ranges from 0 to 1000 points, in which the mean value is 500 points, with a standard deviation of 100 points (Marôco et al., 2016b). In addition, TIMSS establishes four levels of performance: low (400 to 474 points), intermediate (475 to 549 points), high (550 to 624 points), and advanced (over 625 points) (Ferreira et al., 2012).

In the 1st edition, in 1995, Portugal's average in the science test was positioned at the basic level. Students in the 3rd and 4th grades scored an average of 452 points (IEA, 1996), while 7th and 8th grade students scored an average of 454 points (IEA, 1997). When Portugal participated the second time in 2011, the 4th grade students presented an average of 522 points, a significant increase of 70 points from the first time, raising Portugal's position to the intermediate level (Ferreira et al., 2012). In that same year, Portugal was one of eight countries whose performance exceeded that of 1995 (Ferreira et al., 2012).

In the 2015 results, Portuguese 3rd and 4th grade students' average scores were below those of the previous edition. The average was 508 points, 14 points below the average obtained in 2011, resulting in a drop from 19th to 32nd position in the international ranking (Marôco et al., 2016b). These results revealed an inverse trend to that of the international context, in which many countries achieved significant increases in the science test results between the two previous cycles (Marôco et al., 2016b). Saraiva (2017) argues that this discrepancy has gone almost unnoticed in the public debate and that perhaps the country's prominence in Mathematics and Portuguese in international rankings has minimised this situation.

In the 2019 edition, 4th grade students scored an average of 504 points, occupying 33rd place in the international rankings (Duarte et al., 2020a). Although the result was four points lower than in the previous cycle, this difference is not statistically significant. Furthermore, around 67% of Portuguese 4th grade students reached the intermediate level of performance, and more than a quarter of Portuguese students reached the high or advanced level (Duarte et al., 2020a).

The 8th grade students, on the other hand, achieved an average of 519 points, placing Portugal in 13th place in the ranking of participating countries (Duarte et al., 2020b). This result is significantly higher than that obtained in the 1995 assessment, by more than 46 points, ensuring one of the best average scores, which was statistically above the midpoint of the TIMSS science test scale (Duarte et al., 2020b). The report indicates that about 73% of students reached at least the intermediate level and that only 7% reached the advanced level of performance on the scale (Duarte et al., 2020b).

Given the students' progress in their average scores on the international PISA and TIMSS assessments over the years, it is possible to infer that the several curricular reforms that have taken place since 1977 have had a positive impact on science education in Portugal. Despite this, Galvão et al. (2017) state that, overall, although there has been progress, the results of Portuguese students still drop short of expectations. The authors argue that although the implementation of the curriculum for the 3rd cycle of Basic Education in the 2001/2002 school year followed international recommendations for improving the quality of science education, "[…] a discrepancy remains between what is expected in terms of the students' performance in international examinations (such as PISA, based on international recommendations) and what students actually achieve" (Galvão et al., 2017, p. 15).

Final Considerations

Triggered by a set of reforms in the Portuguese education system, the curriculum reorganisation process in the area of Physical and Natural Sciences for the 3rd cycle of Basic Education culminated in the establishment of two curriculum documents into effect: PASEO and AE. PASEO, constituted by a common matrix, is a benchmark for decision-making by all the educational actors of the educational and teaching establishments. In articulation with PASEO, the AE consist of fundamental and indispensable competencies (knowledge, skills, and attitudes) to be acquired and developed by all students in each component of the curriculum throughout the school or training year.

In PASEO, scientific literacy is part of the multiple literacies, whose development is considered as one of the main goals, given the demands of the contemporary world. In the AE of the area of Physical and Natural Sciences of the 3rd cycle of Basic Education, composed of the disciplines of Physical Chemistry and Natural Sciences, scientific literacy is presented as the main objective in order to awaken curiosity and interest in science and also enable the deepening of knowledge in these areas for those who choose to continue their studies in the area of science in secondary education.

Regarding the performance of Portuguese students in external assessments, there has been considerable progress over the years of Portugal's participation in the PISA and TIMSS external assessments. Although some researchers consider that the evolution of results is still below the desired and expected, there is a notable growth in the assessment scales and, consequently, in the international rankings.

In summary, the study highlighted the dimension and the relevance of the enchainment of the curricular reforms that took place in the Portuguese educational system, specifically in the area of Physical and Natural Sciences, for the development of scientific literacy of students in the 3rd cycle of Basic Education, contributing to the continuous improvement of Portugal's results in PISA and TIMSS.

To conclude, we mention possible limitations of the study developed, associating them with suggestions for future research. Therefore, an in-depth analysis of possible impacts on the two disciplines that make up this area, Natural Sciences and Physical Chemistry, beyond the change in approach and objectives, was not included. It is suggested, therefore, that future research might be able to analyze and establish correspondences between such reforms and the eventual consequences and repercussions on these two scientific subjects, as in the change of methodologies, teaching strategies, assessment instruments, among others.

A second limitation of the study refers to the fact that, because it is not the central objective of the article, it does not analyze and discuss the conformation of curriculum reforms to standardized tests. However, recognizing the importance of such analysis, it is recommended to investigate the influence of the conditions and requirements imposed by the standardized instruments on the process of curricular reorganization of the Physical and Natural Sciences area in Portugal.

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