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Scientific literacy of portuguese students: results of a pilot test

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ABSTRACT

This study aimed to assess the scientific literacy level of Portuguese students at the end of the 3rd cycle of Basic Education by applying the pilot version of an assessment instrument. The instrument used was a pilot version of a questionnaire for assessing scientific literacy, which is being developed within the scope of an ongoing doctoral thesis. The questionnaire was answered by 176 10th grade students from eight schools in the southern region of Portugal. The methodological procedures adopted were simple descriptive statistics, Item Response Theory and Student's t-test. The results indicated that most students had a moderate level of scientific literacy and that 137 students were classified as scientifically literate. It was also revealed that few students attained the high and very high levels on the instrument scale. The best performance was in the nature of science subtest and the worst in the content of science subtest. The difference in performance may be associated with the correspondence between the average value of the students' skills in each subtest and its item difficult index.

KEYWORDS: Assessment. Scientific literacy. Basic education.

INTRODUCTION

Scientific literacy is a term that emerged in the 1950s, right after the Second World War and the beginning of the competition for hegemony in the space conquest. A period in which government rulers and scientists, impressed and apprehensive with the power of scientific-technological and military assets used, recognized the need to make the population aware of the potential, positive and negative, of the application of science and technology in society, valuing the development of scientific literacy of the general public.

In this context, "was born a loosely structured but highly visible movement toward what came to be called 'scientific literacy'" (SHAMOS, 1995, p. 76). At that time, science teaching for the general public was not a new idea, but that the core of this teaching became the socio-political dimension of the use of scientific-technological knowledge in society.

However, it was only after 1980 that scientific literacy started to be studied in a more objective and concrete way. From this decade onwards, several studies were carried out in order to define the concept and establish processes to assess it (LAUGKSCH, 2000). According to Miller (1983), one of the pioneers in these initiatives, many researchers focused their studies on the levels of basic understanding of scientific terms and expressions. The author claims, for example, that "a growing number of studies, epitomized by the standardized tests of the Educational Testing Service (ETS) and the College Board, attempted to chart the level of cognitive scientific knowledge among various groups in the population" (MILLER, 1983, p. 31).

Since then, the public knowledge of science gained a boost, turning scientific literacy into the main goal of science teaching in schools (SHAMOS, 1995). After four decades, the expression scientific literacy still remains as a polysemic term. In English-speaking countries, for example, the polysemy of the term might be related to the meaning of the word "literate". A literate person can be a knowledge bearer (to be learned) and can also be able to read and write (to be literate) (Miller, 1983).

Laugksch (2000) reinforces the inconsistency and imprecision in the meaning of the word literate. According to the author, in the English language, an individual can be considered literate as learned, assuming to be literate; literate as competent, considered to be competent; and literate as able to function minimally in society, considered not only as competent, but able to act in specific activities in society (Laugksch, 2000).

On the other hand, in Portuguese-speaking countries, the main issue is the translation of the word literacy, which can originate the Portuguese words *letramento, literacia* (Martins, 2010) and *alfabetização* (BERTOLDI, 2020; TEIXEIRA, 2013). Letra*mento and literacia*, according to Soares (2002) and Dionísio (2007), specialists in the *field of linguistics*, have the same meaning, being *letramento* used in Brazil and *literacia* in Portugal. *Alfabetização*, meanwhile, is widely used in Brazil, but is used in Portugal only in specific contexts, such as adult education (DIONÍSIO, 2007).

Analyzing the definition of these three words in Portuguese language dictionaries, Martins (2010) found that, in most of them, the concepts are taken as synonyms. However, linguists attribute different meanings to them (BERTOLDI, 2020; TEIXEIRA, 2013). Benavente, Rosa, Costa and Ávila (1996) and Soares (2004), for example, consider that, while *alfabetização* translates the act of teaching and learning the conventional writing system, *letramento/literacia* refers to the competent use of reading and writing in social practices. For Soares (2004), *alfabetização* and *letramento/literacia* "are distinguished both in relation to the objects of knowledge and in relation to the cognitive and linguistic processes of learning and, therefore, also of teaching these different objects" (SOARES, 2004, p. 97).

However, there are authors who argue that *alfabetização* is a component of *literacia/letramento* (KRASILCHIK; MARANDINO, 2004); LIMA SANTOS; GOMES, 2004; MARTINS, 2010). Krasilchik and Marandino (2004), although they agree with the distinction between *alfabetização* and *literacia/letramento*, justify the use of the term *alfabetização científica* by the fact that, in Brazil, this term is already consolidated in social practices.

For their part, Sasseron and Carvalho (2011), who also choose to use the term *alfabetização científica*, justify their choice based on the concept idealized by Paulo Freire. According to the authors, for Paulo Freire, alfabetização is understood as "a process that allows the establishment of connections between the world in which the person lives and the written word; and from such connections are born the meanings and constructions of knowledge" (SASSERON & CARVALHO, 2011, p. 61).

In this perspective, it is observed that both the meaning and the translation of the words literacy and literate contribute to the polysemy of the term scientific literacy and constitute a reason for debate among researchers in the area (COPPI; FIALHO; CID, 2023). Indeed, this meets the perspectives of DeBoer (2000), Laugksch (2000) and Miller (1998), that scientific literacy is, in fact, a socially and culturally constructed concept and that evolves continuously, following the changes of context and times.

Nevertheless, the Organisation for Economic Co-operation and Development (OECD) defines it as “The ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person is willing to engage in reasoned discourse about science and technology” (OECD, 2017, p. 15). In this sense, science teaching in schools demands the development of skills related to the scientific explanation of natural, artificial and everyday phenomena, to the evaluation and projection of scientific enterprise and investigation, and to the scientific interpretation of data and evidence.

In Portugal, the compulsory teaching of subjects in the area of Physical and Natural Sciences ends after the end of the 3rd cycle of Basic Education. Hence the fundamental importance of this cycle of education in the development of students' scientific literacy. In this cycle, the subject area of Physical and Natural Sciences is currently governed by three main curriculum documents, namely: the Curricular Guidelines for Physical and Natural Sciences, the Profile of Students Leaving Compulsory Education (MARTINS et al., 2017) and the Essential

Apprenticeships of Natural Sciences (DGE, 2018a, 2018b, 2018c) and of Physical-Chemistry (DGE, 2018d, 2018e, 2018f).

Of these documents, only the Curricular Guidelines and the Essential Apprenticeships of Physical-Chemistry make explicit the development of scientific literacy through science teaching. In the Curricular Guidelines, it is stated that

> the subject area 'Physical and Natural Sciences', through the scientific contents it explores, focuses on diversified fields of knowledge. It appeals to the development of various skills, suggesting diverse learning environments. It is intended to contribute to the development of students' scientific literacy, allowing their learning to take place according to their different paces (GALVÃO et al., 2001, p. 4).

Similarly, the Essential Apprenticeships of Physical-Chemistry assume that, by the end of the 3rd cycle of Basic Education, the students

> are equipped with scientific literacy skills that enable them to mobilise the understanding of scientific processes and phenomena for decision-making, aware of the implications of science in today's world, so as to exercise a participatory citizenship (DGE, 2018d, p. 2, 2018e, p. 2, 2018f, p. 2).

Although the Essential Apprenticeships of Natural Sciences does not make explicit reference to scientific literacy, it clarifies the objectives of teaching Natural Sciences, which are in line with the assumptions of scientific literacy. According to the documents, the subject of Natural Sciences aims to

> develop a general and comprehensive understanding of the main ideas and explanatory structures of Earth and Life Sciences, of aspects of the History and Nature of Science, of scientific research procedures, as well as question human behaviour towards 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).

As for the Profile of Students Leaving Compulsory School, although it also does not specify the term scientific literacy, it refers to the development of multiple literacies, including scientific literacy. The document states that the school, "as an environment conducive to learning and the development of skills, 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).

As it is possible to perceive, although not fully explicit and with some divergence of objectives, most Portuguese curriculum documents highlight scientific literacy in science teaching. Structured in four thematic axes – "Earth in Space", "Earth in transformation", "Sustainability on Earth" and "Living better on Earth" (GALVÃO et al., 2001) –, science teaching in Portugal assumes an interdisciplinary perspective, providing students with a holistic view of science and scientific knowledge (GALVÃO et al., 2001).

According to the same authors, this organization makes it possible to "broaden the horizons of learning, providing students not only with access to the products of science but also to its processes, by understanding the potential and limits of science and its technological applications in society" (GALVÃO et al., 2001, p. 9) and "allows an awareness of the scientific, technological and social significance of human intervention on Earth, which may constitute an important dimension in terms of a desirable education for citizenship" (GALVÃO et al., 2001, p. 9).

The development of these skills seems to be having a positive effect. Regarding the performance of Portuguese students in international assessments, PISA and TIMSS, which measure, among others, the respondents' level of scientific literacy, the results have shown a continuous trend improvement over the years. In the case of PISA 2018, even though there was a slight drop in the average score of students compared to the previous assessment, a result that "follows the downward trend of the OECD average score in the science assessment" (LOURENÇO et al., 2019, p. vi), there was an increase from 75% to 80% in the percentage of students who reached level 2 of proficiency. In the logic of PISA, by reaching this level in the science test, the student "has the basic knowledge and skills to understand science in today's world" (SARAIVA, 2017, p. 12). Moreover, according to Lourenço et al. (2019), "when analysing the average variation in three-year cycles, Portugal is one of the 13 countries that shows a positive and significant variation of more 4.3 points in the science assessment" (p. vi), demonstrating the country's prominence in the area of science.

Regarding the performance of Portuguese 8th grade students in TIMSS 2019, a significantly higher result was observed than the one obtained in 1995, the last edition in which there was participation of Portuguese students of this school year (DUARTE et al., 2020). According to the authors, this score places Portugal as one of the best performing countries with an average score above the midpoint of the TIMSS Science scale.

Based on the exposed results, the trend of improvement in science education in Portugal is evident. However, still in 2017, Galvão et al. (2017) claimed that these results are below expectations. According to the authors, "a discrepancy continues to persist between what would be expected in terms of students' performances in international examinations (such as PISA, constructed in the light of international recommendations) and what students actually achieve (OECD, 2006)" (GALVÃO et al., 2017, p. 15).

Therefore, it is necessary to monitor the students' scientific literacy level more frequently and periodically than every three or four years, like PISA and TIMSS. This requires the use of several scientific literacy assessment instruments in order to gather data that will inform teachers and authorities about the state of science education in Basic Education. This information is also capable of supporting the proposal of more specific changes in the teaching plans, methodologies and practices of the Natural Sciences and Physical Chemistry subjects, envisioning future paths for an adequate scientific and technological education in schools in Portugal, aiming at the development of students' scientific literacy skills (COPPI; FIALHO; CID, 2023).

Furthermore, as stated above, in the Portuguese education system, the 3rd cycle of Basic Education is the last cycle in which students' attendance of scientific subjects orientated towards the formal development of scientific literacy, Natural Sciences and Physical Chemistry, is compulsory. In secondary education, the stage following the 3rd cycle of Basic Education, students can choose to study courses in different areas, many of which do not include scientific subjects that have as their main objective the development of students' scientific literacy, further increasing the importance of assessing students' scientific literacy at the end of the 3rd cycle.

In this scenario, the aim of this study was to assess the level of scientific literacy of students at the end of the 3rd cycle of Portuguese Basic Education, from the application of a pilot questionnaire for the assessment of scientific literacy, which was developed as a diagnostic tool, based on the main Portuguese curriculum documents.

On the basis of the foregoing, the following research questions were asked: 1) What is the level of scientific literacy of Portuguese students at the end of the 3rd cycle of Basic Education? 2) Is there a difference in performance and score between male and female students? 3) Is there a difference in performance and scores between students from schools with different socioeconomic contexts? 4) What is the value of the average difficulty index of the items of each subtest of the instrument? 5) What is the value of the average skill level of the students evaluated? 6) The index of difficulty of the items is adequate to the level of average ability of the analysed sample?

The results of the level of scientific literacy obtained through the application of this instrument, in the pilot test, are discussed and contrasted with those reported by studies that used instruments which, although different, used the same assumptions of scientific literacy as the study presented here, that is, those proposed by Miller (1983). The results are also confronted with the latest PISA and TIMSS results.

METHODS

Instrument

The study used a pilot version of an instrument for assessing scientific literacy, which is being developed within the scope of an ongoing doctoral thesis, and whose content validity evidence was presented by Coppi, Fialho and Cid (2022). The instrument is composed of a total of 35 items, in the "true-false-don't know" format, grouped into three distinct subtests, in the following distribution: six items belonging to the subtest of the nature of science (NS); six items composing the subtest of the impact of science and technology on society (ISTS); and 23 items corresponding to the subtest of the content of science (CS). Items were scored dichotomously, with one point being attributed for those items answered correctly and zero points for those answered incorrectly or marked in the "don't know" option.

The set of items of the instrument includes the competencies present in the following Portuguese curriculum documents of Physical and Natural Sciences of the 3rd cycle of Basic Education: Curricular Guidelines for Physical and Natural Sciences, Essential Apprenticeships of Natural Sciences and of Physical-Chemistry Sciences and Profile of Students Leaving Compulsory Education. The items assess the cognitive domains of understanding, analysis and evaluation of problems and everyday situations involving a set of skills in the area of Physical and Natural Sciences for their solution and/or explanation.

The instrument was validated (COPPI; FIALHO; CID, 2022) through the collection of content-based validity evidence, as proposed by Pasquali (2009). This process was carried out in seven stages: 1) definition of the cognitive domains, in which the cognitive or psychological processes that it was intended to assess were determined; 2) definition of the universe of the content, by delimiting the content in teaching units and sub-units; 3) definition of the representativeness of the content, in which the proportion of representation of each content in the instrument was established; 4) preparation of the table of specifications, which establishes the correspondence between the dimension of the content, the cognitive domains and the number of items; 5) construction of the instrument, a stage in which the format and configuration of the wording of the items and the technical guidelines for their development were decided; 6) theoretical analysis of the items, which involved 10 experts in the areas of Education Sciences, Biology, Geology, Physics and Chemistry who assessed the representativeness, relevance and quality of the items in relation to the content areas and the objectives of the instrument; and 7) empirical analysis of the items, which consisted in the evaluation of psychometric characteristics of the items, more specifically, indexes of difficulty and discrimination.

Participants

The instrument was administered to a total of 176 10th grade students from eight schools in the southern region of mainland Portugal. Out of these students, 89 (50.57%) are male and 87 (49.43%) are female. The average age of the students is 15.18 years (SD = 2.5).

Of the eight selected schools, selected by convenience (HILL; HILL, 2005), six have intermediate socio-economic contexts, in which 25% to 50% of students are covered by the School Social Action program, and two have favorable socio-economic contexts, in which less than 25% of students are covered by the School Social Action program (DGEEC, 2023).

Instrument application proceedings

With the authorisation of the Directorate-General for Innovation and Curricular Development (DGICD), Monitoring of Surveys in the School Environment, under the registration no. 0740900001, and the directors and teachers of the participating educational institutions, the link to access the instrument was made available to the students, through the teachers responsible for the application.

The assessment was carried out at the beginning of the 2020/2021 academic year, in digital format, in the classroom and in the presence of the teachers. The average response time was 30 minutes.

Data analysis procedure

Simple descriptive statistics were used to analyse the students' scientific literacy level, by means of frequency and mean number of correct answers, using the SPSS software, version 27, and RStudio, version 4.2.2. Five levels were determined, which are presented in Table 1, along with the percentage and number of items that should be answered correctly in each subtest to fit into the respective levels.

Table 1 – Levels of scientific literacy according to the percentage and number of correct answers per subtest

Levels	Percentage	Number of hits		
		NC	ISTS	CS
1 – Very low	< 20%	≤ 1	≤ 1	≤ 4
2 - Low	20 ≤ 49%	2	2	5 ≤ 10
3 - Moderate	50 ≤ 69%	3 ≤ 4	3 ≤ 4	11 ≤ 15
4 - High	70 ≤ 89%	5	5	16 ≤ 19
5 – Very High	≥ 90%	6	6	≥ 20

Source: Elaborated by the authors (2022).

The classification of the students' general scientific literacy level, which follows the same categorization, was obtained by calculating the average of the scientific literacy levels of the three subtests, as shown in Table 2. It is worth noting that this classification procedure corresponds to the logic of the instrument's design, according to which, to be considered scientifically literate, the student must obtain a minimum level of correct answers in the items of each subtest. Those who reached at least a moderate level of scientific literacy were considered scientifically literate.

Table 2 – General science literacy levels according to the average of the subtest levels

Levels	Average subtest levels
Very low	< 1.00
Low	1.0 to 2.49
Moderate	2.5 to 3.49
High	3.5 to 4.49
Very High	≥ 4.5

Source: Elaborated by the authors (2022).

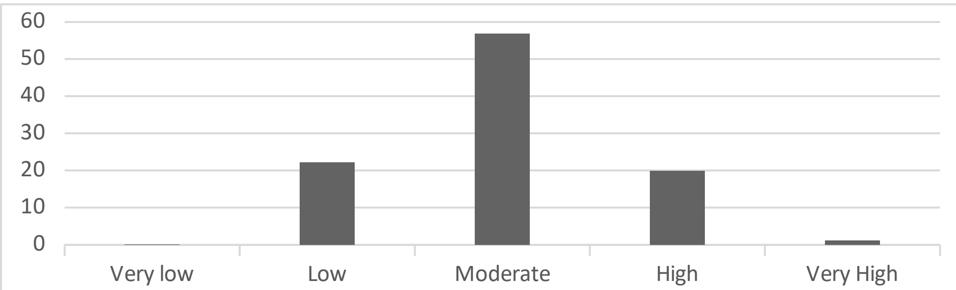
The analysis of comparison of the means of the results between the sexes and socio-economic context of students’ schools used the Student's t-test. As for the analyses of the parameters of difficulty of the items and ability of the students (θ) were conceived and treated by the two-parameter logistic model of Item Response Theory (IRT). Even though the number of participants is reduced, IRT has the advantage that, even in non-representative samples, the parameters of difficulty, discrimination and ability of individuals can be estimated correctly (EMBRETSON; REISE, 2000), because the calculations are independent of the subjects (not group-dependent) and the test (not test-dependent) (BAKER; KIM, 2017; PASQUALI; PRIMI, 2003).

The two-parameter logistic model of IRT was chosen because, when compared with the one and three-parameter models, through the analysis of variance, it was the one that best fitted the data ($p < .05$). It should be noted that the model chosen evaluates, besides the difficulty of the items, its discrimination. In this study, only the difficulty of the items will be analysed, because it refers to the results of applying an instrument that does not aim to "differentiate subjects with different magnitudes of [latent] trait of which the item is the behavioural representation" (PASQUALI, 2009, p. 139), function of the parameter of discrimination, but to provide information for teachers to reflect on the performance of students regarding the skills being assessed (COPPI; FIALHO; CID, 2022).

RESULTS AND DISCUSSION

The results revealed that most students presented a moderate level of scientific literacy, as shown in Figure 1. Of the total of 176 students, 100 (56.82%) were classified at this level, 39 (22.16%) at the low level, 35 (19.89%) at the high level, 2 (1,14%) at the very high level. No students were classified at the very low level.

Figure 1 – Levels of scientific literacy according to the percentage and number of correct answers per subtest



Source: Elaborated by the authors (2022).

According to the established criteria, 136 (77.27%) students can be classified as scientifically literate. Although this is a positive result, a certain limitation in the students' scientific knowledge is evident, determined by the low quantity of students categorised in the high and very high levels of scientific literacy (20%). These results, although they cannot be generalized to the Portuguese population, are in line with those presented by the reports of Portuguese students in PISA 2018 (LOURENÇO et al., 2019) and TIMSS 2019 (DUARTE et al., 2020).

In PISA 2018, 80% of Portuguese students reached level 2 of proficiency in the science test (LOURENÇO et al., 2019). In the PISA logic, by reaching proficiency level 2, the student "has the basic knowledge and skills to understand science in today's world" (SARAIVA, 2017, p. 12) and is able to, among other factors, "use everyday knowledge about content and elementary knowledge about procedures to identify an appropriate scientific explanation" (MARÔCO et al., 2016, p. 29), which is in line with what is assessed by the instrument applied in this research. However, only 5.1% and 0.5% of students managed to reach levels 5 and 6, respectively, on the science proficiency scale, compared to the average of 5.9% and 0.8%, respectively, of OECD countries (LOURENÇO et al., 2019). According to the authors, these proficiency levels require mastery of more complex tasks and "at these proficiency levels students are able, for example, to apply their knowledge of and about science autonomously and creatively to a wide variety of situations, even less familiar ones" (LOURENÇO et al., 2019, p. vii).

In the case of Portuguese students' performance in TIMSS 2019, Duarte et al. (2020) point out that while 73% of students reached at least the intermediate level of performance on the TIMSS science scale, only 34% and 7% of them reached the high and advanced levels, respectively. These results show that, according to the TIMSS performance levels, most students demonstrate some knowledge of Biology and Physics – intermediate level skills – and that the minority is able to apply knowledge of concepts from Biology, Chemistry, Physics and Earth Sciences – high level skills – and to understand the concepts of these areas in a variety of contexts – advanced level skills (DUARTE et al., 2020).

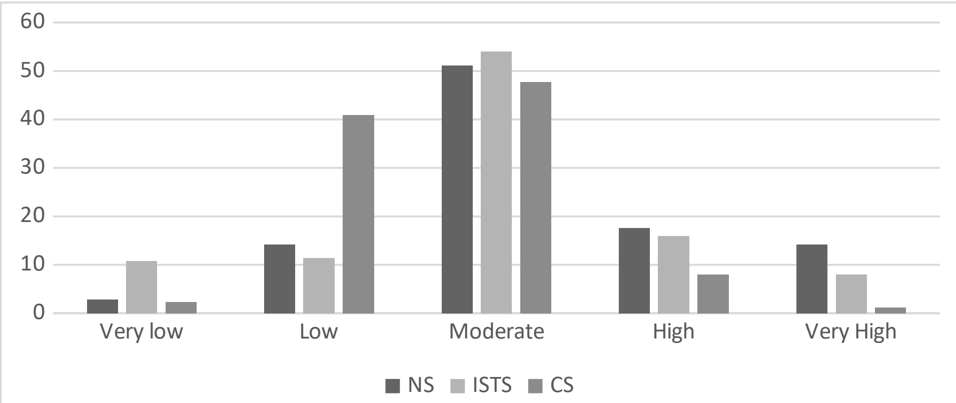
Soobard and Rannikmäe (2011) argue that it is normal to expect a small number of individuals to be located at the higher levels when applying instruments that address all levels of science literacy. According to the authors, "it is not yet clear whether students are capable to give answers at higher levels of scientific literacy where questions require this, or whether students are not able to answer at this level" (SOOBARD; RANNIKMÄE, 2011, p. 141).

The results found in the present study are similar to those presented by Oliveira and Silva-Forsberg (2012), who applied a reduced version of the Test of Basic Scientific Literacy to students in the 3rd cycle of Brazilian Basic Education. The authors found that 66% of students scored the minimum number of correct answers to be classified as scientifically literate, being located in the regular category of scientific literacy. However, only 23.5% of them were categorized in the levels above, that is, satisfactory, good and very good. Özdem et al. (2010), applying an adapted version of the Test of Basic Scientific Literacy in Turkey, also came to the conclusion that most of the assessed 3rd grade students had moderate level of scientific literacy.

Comparing the results with studies that evaluated the scientific literacy level of students in this cycle of education, it is observed that the amount of scientifically literate students found in this research is higher than those cases. The results of Coppi and Sousa (2019b), Rachmatullah, Diana and Rustaman (2016), Koedsri and Ngudgratoke (2018), Jufri, Hakim and Ramdani (2019), Vizzotto et al. (2020) and Utami and Hariastuti (2019) evidenced that most of the students assessed were not considered scientifically literate. It is worth noting that this comparison should be made with caution, since the instruments used, the number of participants and the contexts of application were not the same.

Regarding the analysis of the levels of scientific literacy by subtest, as in the general analysis, it revealed that most students are also at the moderate level of scientific literacy, as shown in Figure 2. The results also point out that, while 146 (88.63%) and 137 (77.84%) students scored the minimum number of items to be considered scientifically literate in the NS and ISTS subtests, respectively, only 100 (56.82%) of them scored the minimum number of items to be considered so in the CS subtest.

Figure 2 – Levels of scientific literacy according to the percentage and number of correct answers per subtest



Source: Elaborated by the authors (2022).

As regards the percentage of students who correctly answered the set of items of each subtest, Table 3 shows that the NS subtest had the highest mean of 64.4%. The subtests of the ISTS and the CS obtained averages of 57.6% and 48.1%, respectively. The items with the highest percentage of correct answers, above 80%, were items 3 and 4, which assess competences related to the scientific enterprise, item 17, which assesses the competence related to external geodynamics, and item 18, whose assessed competence is the change of physical states of matter. The mean score of correct answers for the items of the NS subtest was 3.86 (SD = 1.36), for the ISTS subtest was 3.45 (SD = 1.45) and for the CS subtest was 11.07 (SD = 3.28).

Table 3 – Percentage of correct answers, incorrect answers and "don't know" option marked per subtest

NS subtest				CS subtest			
Item	Correct answers (%)	Incorrect answers (%)	"Don't know" option (%)	Item	Correct answers (%)	Incorrect answers (%)	"Don't know" option (%)
1	35.2	41.5	23.3	16	32.4	54.5	13.1
2	61.4	27.8	10.8	17	86.4	7.4	6.3
3	88.6	6.3	5.1	18	87.5	7.4	5.1
4	87.5	5.7	6.8	19	46.0	15.3	38.6
5	59.7	29.0	11.4	20	56.3	29.0	14.8
6	54.0	36.4	9.7	21	19.3	53.4	27.3
% Mean	64.4	24.4	11.2	22	43.8	43.8	12.5

NS subtest				CS subtest			
Item	Correct answers (%)	Incorrect answers (%)	"Don't know" option (%)	Item	Correct answers (%)	Incorrect answers (%)	"Don't know" option (%)
				23	29.0	49.4	21.6
ISTS subtest				24	26.7	56.8	16.5
7	63.6	21.0	15.3	25	64.2	21.6	14.2
8	48.3	44.3	7.4	26	35.8	54.0	10.2
9	69.9	20.5	9.7	27	15.9	73.9	10.2
10	62.9	22.2	15.9	28	59.1	19.9	21.0
11	30.7	60.8	8.5	29	32.4	40.3	27.3
12	72.0	14.8	14.2	30	51.7	31.3	17.0
% Mean	57.6	30.6	11.8	31	33.0	52.3	14.8
				32	31.8	57.4	10.8
CS subtest				33	69.9	17.0	13.1
13	68.8	16.5	14.8	34	55.1	31.3	13.6
14	57.4	28.4	14.2	35	58.0	23.9	18.2
15	46.6	38.1	15.3	% Mean	48.1	35.8	16.1

Source: Elaborated by the authors (2022).

Similarly, the NS was also the subtest that presented the lowest mean percentage of students (24.4%) who answered the items incorrectly. The average percentages of students who got the items of the ISTS and CS subtests wrong were 30.6% and 35.7%, respectively. Although no item showed a percentage of incorrect answers above 80%, six items obtained values above 50%, these are: item 11, which assesses the relationship between scientific-technological knowledge and society; item 16, related to internal geodynamics, a competence of the geology area; item 21, whose chemistry competence involves the content of substances and mixtures; item 24, which refers to the transformation of energy, a competence of the physics area; and items 26 and 27, related to the physics competences on force, gravity and movement. In TIMSS 2019, the content area of Physics was also the one with the lowest scores, significantly below the overall average on the TIMSS science scale (DUARTE et al., 2020).

As for the answers marked in the "don't know" option, the results presented in Table 4 indicate that the CS subtest presented the highest average percentage (16.1%), followed by the subtests of the ISTS (11.8%) and the NS (11.2%). It is noted that items 1, 19, 21, 23, 28 and 29 were those that presented values above 20% of responses in this option. Item 1 comprises the competence on scientific enterprise, items 19, 21 and 23 correspond to chemistry competences, more specifically in the areas of atoms and chemical elements, substances and mixtures and chemical reactions, respectively, and items 28 and 29 cover biology competences, in the areas of ecology and evolution, respectively.

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Table 4 – Mean performance and scores among male and female students

Variable	Sex	n	Mean	Standard deviation	t(gl)	p
NS subtest score	Female	87	3.93	1.35	0.648 (174)	.518
	Male	89	3.80	1.38		
ISTS subtest score	Female	87	4.18	1.64	0.704 (174)	.483
	Male	89	4.00	1.82		
CS subtest score	Female	87	10.89	3.00	-0.729 (174)	.467
	Male	89	11.25	3.56		
Test score	Female	87	18.34	4.39	-0.114 (174)	.909
	Male	89	18.43	5.13		
Scientific literacy level in the NS subtest	Female	87	3.32	0.95	0.819 (174)	.414
	Male	89	3.20	0.99		
Scientific literacy level in the CS subtest	Female	87	3.05	0.94	0.741 (174)	.460
	Male	89	2.93	1.08		
Scientific literacy level in the ISTS subtest	Female	87	2.54	0.61	-1.019 (174)	.310
	Male	89	2.64	0.69		
Scientific literacy level	Female	87	2.97	0.67	-0.117 (174)	.907
	Male	89	2.98	0.69		

Source: Elaborated by the authors (2022).

The data reveal that students showed better results in the NS subtest, followed by the ISTS and CS subtests. When compared to the studies that performed this type of analysis, even though used the Test of Basic Scientific Literacy, a difference in the students' scores in the subtests is perceived. In all these studies (CAMARGO et al., 2011; COPPI; SOUSA, 2019b, 2019a; LIMA; GARCIA, 2015; NASCIMENTO-SCHULZE; CAMARGO; WACHELKE, 2006; ÖZDEM et al., 2010; RIVAS; MOÇO; JUNQUEIRA, 2017; VIZZOTTO; DEL PINO, 2020a, 2020b; VIZZOTTO; MACKEDANZ, 2018), it was found that the subtest in which students obtained the best performance was in that of the CS and the worst was among the subtests of the NS and ISTS.

The difference in performance between the subtests reveals that students show more skills and knowledge related to the basic foundations of scientific research, such as the scientific view of phenomena, research methods and the nature of the scientific enterprise, and to the association between science and technology and the effects arising from the use of knowledge from these two areas in the development of society than to the application of knowledge from the Natural Sciences and Physical-Chemistry to explain everyday phenomena.

This fact may be associated with the difference in emphasis that is given among the competencies of the three subtests by the science subjects of the schools that applied the instrument. Camargo et al. (2011) and Coppi and Sousa

(2019a) argue that, in Brazil, much importance is given to the contents and competencies belonging to the CS subtest, leaving aside those referring to the NS and ISTS subtests. However, in the Portuguese schools that participated in this study, there seems to be greater dedication to the competences of the latter two subtests. It is worth noting that further studies are needed to verify whether, in fact, this may be the explanation for what was observed.

A more plausible hypothesis uses the average of the difficulty index of the items and the average of the ability (θ) of the students for the explanation of such difference, which is presented in Table 5. It was observed that the average students' θ for the three subtests was 0.00 and that the average of the difficulty index of the items of the subtests of the NS, the ISTS and the CS was -1.29 (SD = 1.58), -0.04 (SD = 1.93)and 1.03 (SD = 2.71), respectively.

Table 5 – Average of the index of difficulty and ability of the students for subtest

Subtest	*b* (SD)	θ (SD)
NS	-1.29 (1.58)	0.00 (0.78)
ISTS	-0.04 (1.93)	0.00 (0.72)
CS	1.03 (2.71)	0.00 (0.79)

Source: Elaborated by the authors (2022).

Taking into account the categories of the difficulty index of the items proposed by Ferreira (2018) (Table 6), it can be seen that the items of the subtests of the NS, the ISTS and the CS proved to be, in general, very easy, medium and difficult, respectively.

Table 6 – Categories of difficulty level of items

Level	Range of values
Very low	< -1.28
Low	-1.27 a -0.52
Moderate	-0.51 a 0.51
High	0.52 a 1.27
Very High	> 1.28

Source: Elaborated by the authors (2022).

Therefore, it is possible to state that the difference between the number of correct answers in the three subtests is more related to the students' ability and to the difficulty of the items than to the emphasis given to the respective competencies. This is because, unlike the studies cited above, which used instruments developed for contexts different from the ones in which they were applied, this research used an instrument built and validated based on the main curricular documents of this educational cycle. Thus, it is assumed that, at first, the competencies required by the items of each subtest are worked throughout the 3rd cycle of Basic Education.

Regarding the analysis of the difference in average performance and scores between male and female students in the sample, no significant differences were observed for the dependent variables analysed (Table 4). The results related to the level of scientific literacy and the students' scores in the test resemble those presented in Portugal's PISA 2018 report in which, although boys performed better, the difference was not statistical. However, both diverge from the average OECD results in which, "for the first time, girls performed better than boys – a significant difference of two points" (LOURENÇO et al., 2019, p. 71).

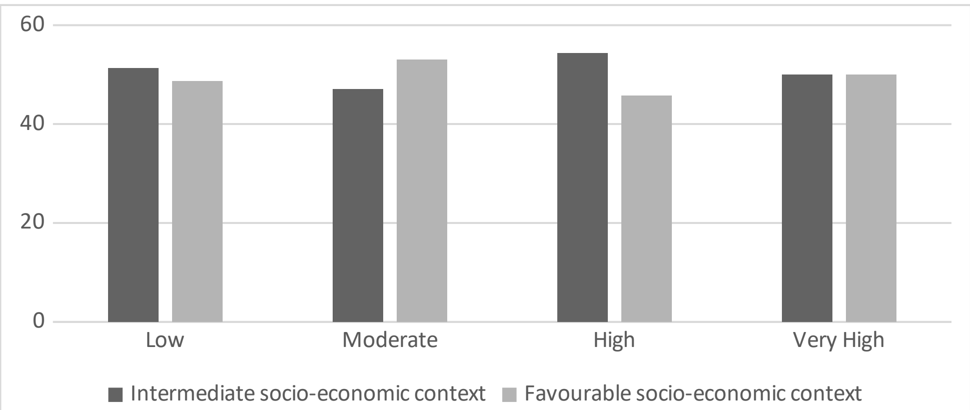
Analysing the national results of the previous cycles, it is observed that this is a common trend for Portugal, but not for the other OECD member countries (LOURENÇO et al., 2019). According to the authors, "the average OECD results according to gender show less marked differences than those observed in Portugal and mainly favourable to girls in 2018" (LOURENÇO et al., 2019, p. vii).

In TIMSS 2019, the difference in the average score between the two groups was statistical, more than six points in favour of boys (DUARTE et al., 2020). This fact, as in PISA, is the opposite of "what happens in a large number of participating countries" (DUARTE et al., 2020, p. 31), where girls are the ones who perform better in the 8th grade in science.

For Lourenço et al. (2019), the sex differences found in the Portuguese results in the assessment of scientific literacy may be somehow associated with the students' expectations regarding the professions they intend to pursue in the future. According to the authors, "among the best-performing Portuguese students, 1 in every 2 boys thinks of developing a profession in science and engineering, while 1 in every 7 girls thinks of doing so" (LOURENÇO et al., 2019, p. 71).

As in the previous analysis, the result of the analysis regarding socio-economic context of students' schools revealed no significant differences between the average scientific literacy level of students from schools with intermediate and favorable socio-economic contexts. Furthermore, the distribution of students in the different levels of scientific literacy was balanced, as shown in Figure 3.

Figure 3 – Levels of scientific literacy of students according to the socio-economic context of students' schools



Source: Elaborated by the authors.

This lack of difference may be associated with the fact that there are no students from schools with an unfavorable socioeconomic background in the sample analyzed. Several studies have shown that students with lower performance belong to schools with an unfavorable socioeconomic context (PINTO et al. 2019; COPPI; FIALHO; CID, 2023).

Furthermore, it is worth noting that, in Portugal, there is a constant concern with the socio-economic issue of schools and students, and the effect of the school's socio-economic context on student performance, time to conclude study cycles and success in national exams are some of the factors explored by the Directorate for Statistics on Education and Science of Portugal (DGEEC). According to the last two reports, in the 3rd cycle of Basic Education, the results of students from schools with a favorable socio-economic context were slightly higher than those of students from schools with an unfavorable context (DGEEC, 2022, 2023).

These findings support those observed in the PISA and TIMSS international test reports. In the 2018 edition of PISA, in Portugal, "the probability that a student from among the 25% most disadvantaged obtain a score below proficiency level 2 is approximately three times higher than that of a student with higher socio-economic status obtaining that score" (LOURENÇO et al., 2019, p. VIII). As for the 2019 edition of TIMSS, in the science test, students from schools with a more-advantaged socio-economic composition scored, on average, 34 points more than students attending more-disadvantaged schools.

CONCLUSIONS

In order to assess the level of scientific literacy of Portuguese students at the end of the 3rd cycle of Basic Education, this study applied the pilot version of a developing scientific literacy assessment instrument to 176 10th grade students from eight public schools in mainland Portugal. The results revealed that 57% of the students were classified in the moderate level, 22% in the low level, 19% in the high level, 1% in the very low and very high levels. It was also found that 137 (77%) students could be classified as scientifically literate, even though few of them reached the high and very high levels of scientific literacy, with no significant difference between sexes and school socio-economic contexts. It should again be noted that the sample included students from schools in only two socio-economic contexts, intermediate and favorable.

It has been observed that students performed better on the NS and ISTS subtests than on the CS subtest. These results indicate that students have more competencies for understanding processes related to the scientific enterprise and awareness of the consequences of using scientific-technological knowledge for society than for using scientific concepts in solving everyday problems and issues.

According to the data analysed, this fact seems to be associated with the correspondence between the average value of students' skills in each subtest, which was found to be 0.00 in the three subtests, and the average level of difficulty of the items that compose them, which proved to be -1.29 (very easy) for the NS subtest, -0.04 (medium) for the ISTS subtest, and 1.03 (difficult) for the CS subtest. This difference in performance may also be associated with the emphasis that is given to the competences referring to the three subtests by the science subjects in the schools participating in the study. However, further studies are needed to verify whether this factor can be used as the explanation for the observed difference.

Considering that the results found in this study are consistent with those published in the national reports of Portugal in PISA and TIMSS, even if it is not possible to make a direct comparison due to their natures, the instrument demonstrates its strengths in measuring students' scientific literacy level and in ascertaining the constructs with the greatest potential and those that need to be revisited in order to have the most complete development of students' scientific literacy.

This fact strengthens the justification for the construction of this instrument, which will be able to produce data and information that might allow teachers to adjust their methodologies, contents, lesson plans for the best development of the scientific literacy constructs and skills that are expected for students at the end of the 3rd cycle of Basic Education.

As the instrument was applied in a pilot version only, it is recommended that, for its final and definitive version, the items, especially those of the NS and CS subtests, be revised aiming at better fitting them to the average value of the students' skills and reducing the differences in performance between subtests resulting from this mismatch. Consequently, after the revision of the items, the instrument needs to be forwarded to the panel of experts, which should re-evaluate it, contributing to the validation process of the use of the instrument results.

It is also recommended that the instrument be submitted to a process of gathering validity evidence based on internal structure, in order to determine the dimensions assessed by the instrument, being able to indicate the degree to which the items conform to the constructs on which the interpretations proposed for the instrument scores are based (AERA; APA; NCME, 2014).

The study presented a limitation in the number of students assessed. Therefore, it is suggested that future research should apply the instrument to a larger number of individuals and, preferably, from different regions of the country, in order to obtain data from a representative sample of the students' scientific literacy level at the end of the 3rd cycle of Portuguese Basic Education. Although the results are not generalizable to the Portuguese population, they are important information that can be added to the results of other studies, allowing for a greater reflection on the scientific literacy of students in this cycle of education.

Another limitation is related to the fact that the choice of schools was by convenience, which restricted the comparison of the results of the application of the questionnaire in terms of the socio-economic context of the students' schools, since only schools with intermediate and favorable contexts were present in the sample. It is therefore recommended that the application of the final version of the instrument overcome this limitation, ensuring that students from schools in the three different socioeconomic contexts, favorable, intermediate and unfavorable, are present in the sample.

Finally, it is suggested that the application of the final version of the instrument that is being developed incorporate independent variables which allow exploring reasons that justify or enable the discussion about the level of scientific literacy of the students. Among these variables, it can be mention, for example: failure in Natural Sciences and Physical Chemistry; liking for the subjects; and annual grade score in the subjects.

Letramento científico de alunos portugueses: resultados de um teste piloto

RESUMO

Este estudo teve como objetivo avaliar o nível de letramento científico dos estudantes portugueses no final do 3º ciclo do Ensino Básico, mediante a aplicação da versão piloto de um instrumento de avaliação. O instrumento utilizado foi uma versão piloto de um questionário que avalia o nível do letramento científico dos alunos deste ciclo, que está sendo desenvolvido no âmbito de uma tese de doutorado em andamento. O questionário foi respondido por 176 alunos da 10ª série de oito escolas da região sul de Portugal. Os procedimentos metodológicos adotados foram a estatística descritiva simples, a Teoria da Resposta ao Item e o teste-t de Student. Os resultados indicaram que a maioria dos estudantes apresentou um nível moderado de letramento científico e que 137 estudantes foram classificados como cientificamente letrados. Revelaram também que poucos estudantes atingiram os níveis altos e muito altos na escala do instrumento. O melhor desempenho se deu no subteste da natureza da ciência e o pior no subteste do conteúdo da ciência. A diferença de desempenho pode estar associada à correspondência entre o valor médio da habilidade dos alunos em cada subteste e o índice de dificuldade dos itens que o compõem.

PALAVRAS-CHAVE: Avaliação. Letramento científico. Educação básica.

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