



COMPLEXITY OF PRACTICAL WORK IN PORTUGUESE PRIMARY SCIENCE TEXTBOOKS

Complexidade do trabalho prático em manuais escolares de ciências do 1.º ciclo do ensino básico português

Sílvia Ferreira [silvia.ferreira@ese.ips.pt]

*Escola Superior de Educação, Instituto Politécnico de Setúbal
UIDEF, Instituto de Educação, Universidade de Lisboa*

Leonor Saraiva [leonor.saraiva@ese.ips.pt]

*Escola Superior de Educação, Instituto Politécnico de Setúbal
CIEF, Instituto Politécnico de Setúbal*

Abstract

Practical work and textbooks have an important role in primary science education. This study analyses the complexity of practical work in Portuguese primary science textbooks. The level of complexity was appreciated by the level of conceptual demand of practical work, as given by the type of practical work, the complexity of scientific knowledge, the complexity of cognitive skills and the degree of relation between theory and practice. The explicitness of practical work was also analysed. The study followed an approach that combines quantitative and qualitative methods of analysis and a total of 176 units of analysis were evaluated from six science textbooks, chosen among the most selected in Portuguese primary schools. The results showed that textbooks evidence a tendency towards a low level of conceptual demand of practical work, considering the proposals for practical activities and the related evaluation questions. Practical activities, mainly focused on practical exercises and illustrative experiences, tend to mobilize scientific knowledge and cognitive skills of a low level of complexity and point out to an apparent relation between theory and practice. The evaluation questions present a lower level of conceptual demand. The results also showed a weak concern with the explicitness of the practical work. However, findings also indicated that there are differences between the textbooks.

Keywords: Conceptual demand; Practical work; Primary school; Textbook analysis.

Resumo

O trabalho prático e os manuais escolares desempenham um importante papel no ensino das ciências do 1.º ciclo do ensino básico. Este estudo analisa a complexidade do trabalho prático em manuais escolares de ciências do 1.º ciclo português. O nível de complexidade foi apreciado através do nível de exigência conceptual do trabalho prático, que considerou o tipo de trabalho prático, a complexidade do conhecimento científico, a complexidade das capacidades cognitivas e o grau de relação entre a teoria e a prática. A explicitação do trabalho prático também foi analisada. O estudo seguiu uma abordagem que combina métodos de análise quantitativos e qualitativos. Foram avaliadas 176 unidades de análise de seis manuais escolares, escolhidos de entre os mais adotados nas escolas portuguesas. Os resultados mostram que os manuais tendem a evidenciar um baixo nível de exigência conceptual do trabalho prático, quando analisado em função das propostas de atividades práticas e das respetivas questões de avaliação. As atividades práticas, sobretudo focadas em exercícios práticos e experiências de verificação, tendem a mobilizar conhecimento científico e capacidades cognitivas de baixo nível de complexidade e apontam para uma aparente relação entre teoria e prática. As questões de avaliação apresentam um nível de exigência conceptual inferior. Os resultados também evidenciam uma fraca preocupação com a explicitação do trabalho prático. No entanto, os resultados indicam ainda que existem diferenças entre os manuais escolares.

Palavras-Chave: Exigência conceptual; Trabalho prático; 1.º ciclo do ensino básico; Análise de manuais escolares.

INTRODUCTION

Practical work presented in science textbooks is an important resource in science education. Textbooks are still being widely used in classrooms and continue to be major curriculum resources that provide the subject matter content for what is taught in classrooms, and how the content is taught (Dogan, 2020; Kahveci, 2010). On the other hand, practical work in science education is a unique learning environment and it performs an important role in the teaching of both scientific knowledge and science processes (Abrahams, 2017; Hofstein, 2017; Lunetta, Hofstein, & Clough, 2007). From this, it derives the importance of studying practical work in science textbooks.

In Portugal, practical work has been on the educational agenda in the last five decades and was gradually included in the science curricula since late 1970s. In 1975, some science topics were included in the primary education curriculum (this school level includes the first four compulsory grades, with children aged approximately between 6 and 10 years old), in an interdisciplinary subject area including themes of natural and social sciences, called Environment Study. This interdisciplinary area involves different branches of knowledge, namely Biology, Geology, Chemistry, Physics, Geography, and History. The Portuguese national curriculum includes two guiding documents: the national program (Ministry of Education, 2004) and, more recently, the Essential Learnings (DGE, 2018). The national program is divided into six themes: Discovering yourself; Discovering others and institutions; Discovering the natural environment; Discovering inter-relations between spaces; Discovering materials and objects; and Discovering the inter-relations between nature and society. The Essential Learnings document reorganized most of the content present in the national program, dividing it into four areas: Society; Nature; Technology; and Society/Nature/Technology. The actual Portuguese textbooks were based on the national program and developed previously to Essential Learnings.

When we consider primary science education, the empirical research on science textbooks is less frequent than other levels of education, namely secondary education (Vojříř & Rusek, 2019). In this study we intend to contribute to this research field through the analysis of the level of complexity of practical work in primary science textbooks.

The level of complexity of practical work can be appreciated by its level of conceptual demand. The concept of conceptual demand is related the complexity of scientific knowledge and skills and also the strength of intra-disciplinary relations, that is the strength of boundaries between distinct knowledges within a given discipline (Morais & Neves, 2016). Following former research developed by the ESSA Group¹, the study addresses the following research problem: What is the level of conceptual demand of practical work and its explicitness in primary science textbooks? From this problem the following research questions, focused on Portuguese primary science textbooks, were derived: (a) What is the type of practical work that is suggested in the textbooks? (b) What is the level of complexity of knowledge and skills of practical work and the relation between theory and practice?; and (c) What is the extent to which the messages contained in the textbooks are made explicit to the teachers?

PRACTICAL WORK IN SCIENCE EDUCATION

Practical work is considered as a relatively broad concept, going beyond laboratory work, and generally includes activities in which the students are actively involved and interact with materials or secondary sources of data to observe and understand the natural world (e.g., Hodson, 1993; Hofstein, 2017; Lunetta, Hofstein, & Clough, 2007). The meaning of practical work in the present study follows former research (Ferreira & Morais, 2014) and is defined as: All teaching and learning activities in the sciences in which the student is actively involved and that allow the mobilization of science processes skills and scientific knowledge and that may be materialized by paper and pencil activities or observing and/or manipulating materials.

The science process skills are considered to be ways of thinking more directly involved in scientific research, such as observing, formulating problems and hypotheses, controlling variables, and predicting (Chiappetta, 1997; Duschl, Schweingruber, & Shouse, 2007; Harlen, 1999). Science process skills “*focus on thinking patterns that scientists use to construct knowledge, represent ideas, and communicate information*” (Chiappetta, 1997, p. 24). Chin and Malhotra (2002) point out six cognitive processes used in authentic scientific inquiry (the research that scientists actually carry out): (1) generating research questions; (2) designing studies which involves several subprocesses as selecting variables, planning procedures, controlling variables, and planning measures; (3) making observations, (4) explaining results which includes several important aspects as transforming observations, finding flaws, indirect reasoning, and generalizations;

¹ The ESSA Group – Sociological Studies of the Classroom – is a research group of the Institute of Education of the University of Lisbon.

(5) developing theories; and (6) studying others' research reports. These authors analysed inquiry tasks in nine middle school textbooks, and they concluded that the inquiry activities in most textbooks developed few of the cognitive process of authentic science. In addition, Hofstein and Lunetta (2004) in their review reported that several studies have verified that very often teachers involve students principally in low level and routine practical activities and there is a divergence between the goals of the activities and what students do.

More recently, Ma, Wang, Wang, Chen and Yan (2019) analysed the quality of scientific inquiry in 24 high school Chinese science textbooks, related to the relevance to daily life, the explicit teaching guidance, the complete inquiry process and the openness of inquiry. The results showed that most inquiry activities included close connections to daily life, however, few textbooks provided explicit teaching guidance, most of the activities lacked the process of scientific inquiry, especially the opportunity for proposing questions, and most textbooks lack open-ended inquiries. Those results are consistent with the results of Andersen's (2020) study: the analysis of German and Luxembourgish primary science textbooks open-ended tasks showed that those curriculum resources contain mainly implicit forms of that tasks. The analysis of four high school Turkish biology textbooks (Dogan, 2020) also showed that activities in textbooks were insufficiently designed to prepare students to do inquiry. However, as Hofstein (2017) defends, inquiry-type practical activities "*are central to learning science, since students are involved in the process of conceiving problems and scientific questions, formulating hypotheses, designing experiments, gathering and analysing data, and drawing conclusions about scientific problems or phenomena*" (p. 359).

Some studies also considered the level of complexity of practical work in science education. The complexity of practical work can be appreciated by its level of conceptual demand. In the context of the research that has been carried out within Bernstein's theory (1990, 2000), conceptual demand is defined as the level of complexity of science education as given by the complexity of scientific knowledge and of the strength of intra-disciplinary relations between distinct knowledges and also by the complexity of cognitive skills (Morais & Neves, 2016). Ferreira and Morais (2014) studied high school Biology and Geology curriculum, external assessment, and pedagogical practices. The results showed that practical work is poorly represented in both texts and that recontextualising processes have occurred within the curriculum and between the curriculum and external assessment, in the direction of lowering the level of conceptual demand of practical work. Furthermore, the teachers' practices studied also showed a relatively low level of conceptual demand and tended to follow the message expressed in the external assessment.

TEXTBOOKS IN SCIENCE EDUCATION

Curriculum materials, in particular textbooks and their accompanying teacher's guides, are only one of the resources available to teachers. However, they have a major role in teaching and learning. Many teachers depend on them to provide some or all of their content knowledge and pedagogical content knowledge. Textbooks provide the subject matter content for a great deal of what is taught in science classrooms, and to some degree how the content is taught (Andersen, 2020; Kesidou & Roseman, 2002).

The research focused on science textbooks has been increasing in recent years. The results of the review of Vojříř and Rusek (2019) "*show that science textbook research represents a very wide and still evolving area*" (p. 1510). The authors also stated that the research is mostly centred on high school textbooks (58% of the analysed papers) and increasing attention has been given to all levels of education. However, empirical research on primary science textbooks is less frequent (e.g., only 12% of the papers were exclusively centred on primary level). The three main topics of research are related to learning content, learning concepts, namely the concepts of the nature of science and scientific literacy, and non-textual explanations in textbooks. Topics related, for instance, with students' active learning, the relation between the textbook and the curriculum, possible problems and errors, and textbook evaluation by teachers and students, are less frequent in the research analysed between 2000 and 2018.

As referred before, the results of several studies seem to show that the practical work in textbooks rarely engage pupils in authentic investigations and most activities failed to provide the pupils with opportunities to establish an understanding about scientific inquiry (e.g., Andersen, 2020; Chin & Malhotra, 2002; Ma *et al.*, 2019). In addition, Kahveci (2010) concluded that the Turkish middle and high school science chemistry textbooks failed to provide sufficient empirical evidence to be considered as gender equitable and inquiry-based. From the analyses it appeared that gender representations were not fair enough, higher level cognitive questions were not adequate, and science vocabulary readability level were not sufficient enough for these textbooks to be considered as reform-oriented.

Science textbooks research in Portugal, namely focused on primary education, follows the international tendency and it seems to have a low expression in science education publications. Rola, Pereira and Gomes (2013) analysed the rocks and soils theme in Portuguese primary textbooks and pupils' learning after a practical activity with rocks samples. The textbooks revealed some inconsistencies with the concepts of rock, mineral and texture. Mafra and Lima (2007) studied microorganisms thematic in sixteen textbooks of Environment Study of primary school and the findings showed that the microorganisms only appear in textbooks indirectly, related with health/hygiene, food and environment contents. Similarly and related to the same subject, Camargo, Silva and Santos (2018) analysed a Brazilian collection of middle school Natural Sciences textbooks and the predominant microbiology content focus is on health and biodiversity and suggestions for practical activities are scarce. At the level of Portuguese middle school, Silva, Duarte and Durães (2019) identified 22 laboratory investigations in eight textbooks of Physics and Chemistry. The results showed that those investigations are mainly focused on the scientific knowledge and do not seem to value the science process skills. Likewise, Kupske, Hermel and Güllich (2014) verified that mostly 225 practical activities of 12 Brazilian Natural Sciences textbooks present a low level of complexity and give a traditional view of experimentation, based on observations, repetition of procedures and proof of theories.

METHODS

The analysis of the primary science textbooks was focused on 3rd and 4th grades (children aged approximately between 8 and 10 years old). The choice of those years of schooling was related to the fact that certain thematic units included in the Environment Study national curriculum included scientific knowledge and provide conditions that make possible to carry out practical activities, namely laboratory activities driven by investigative process such as predicting and testing variables, which was the focus of the investigation. For that reason, the textbook analysis was also centred in two curricular themes 'Discovering the natural environment' and 'Discovering materials and objects'.

For this study were selected the three textbooks to 3rd grade (A, B and C) and 4th grade (D, E and F) which had been more widely selected across the whole country (mainland and islands) by the Portuguese teachers/schools (public and private), in the academic year 2019/2020 (DGE, 2019)². The books analysed were Textbook A (selected in 1192 schools – 34%), Textbook B (774 schools – 22%) and Textbook C (726 schools – 20%) for 3rd grade and Textbook D (1380 schools – 40%), Textbook E (548 schools – 16%) and Textbook F (732 schools – 21%) for 4th grade. That analysis included both the part that was directed to the students (corpus of the textbook) and, when present, their accompanying teacher's guides. Only the practical activities associated with Natural Sciences, comprising biology, geology, chemistry, and physics, were considered. The textbooks activities mentioned in the article have been translated from Portuguese to English by the authors.

Data analysis

The practical activities related to the two curricular themes were selected in the six textbooks. Each activity was considered a unit of analysis. The activity, as a whole, contains indications and questions for pupils and orientations for the teachers that allowed the characterization of the practical work context. We also selected the evaluation questions related to the practical activities presented in the textbooks. In this case, each question corresponded to a unit of analysis. In total, 176 units of analysis were evaluated (121 practical activities and 55 evaluation questions) – Table 1. The study followed an approach that combines quantitative and qualitative methods of analysis and made use of a mixed methodology (Creswell & Clark, 2011; Morais & Neves, 2010). The study contains a referential theoretical framework which directed the construction of instruments for collecting data (a characteristic of quantitative approaches) and, on the other hand, the analysis was made through a constant dialectics between the theoretical and the empirical data (a characteristic of qualitative approaches).

Following previous studies carried out by the ESSA Group (e.g., Ferreira & Morais, 2014), the level of conceptual demand of the science textbooks, with respect to practical work in primary education, was appreciated through the analysis of the type of practical work, the complexity of scientific knowledge and the complexity of cognitive skills (*the what* is taught) and also the analysis of the intra-disciplinary relations between theory and practice (*the how* is taught). The explicitness of practical work (a dimension of *the how* is

² In Portugal, textbooks are evaluated by teams of specialists and certified by the Ministry of Education. Schools and teachers select the textbooks from that set of certified textbooks.

taught) was also analysed, to appreciate the extent to which the textbooks authors make explicit to teachers the message relative to the scientific knowledge and cognitive skills of practical work contexts.

Table 1 – Number of units of analysis selected and analysed in the primary science textbooks.

Textbook	Number of practical activities selected and analysed	Number of evaluation questions selected and analysed
3 rd grade	A	23
	B	20
	C	19
4 th grade	D	23
	E	20
	F	16

Instruments of analysis

In order to characterise the message underlying each one of the units of analysis, four instruments were constructed, piloted and applied. They were based on instruments constructed in former studies for the analysis of science curricula and pedagogical materials (e.g., Calado, Neves, & Morais, 2013; Ferreira & Morais, 2014). The instruments were organized to contain two sections: practical activity and evaluation. Each unit of analysis was associated with one of these two sections and analysed by using the instruments constructed.

After constructing the first version of each one of the instruments, the authors carried out a preliminary study in order to validate those instruments and to introduce the necessary changes, in a dialectical relation between the theoretical and the empirical, therefore following a procedure recommended by several authors (e.g., Teddlie & Tashakkori, 2009). A comparison of the analyses highlighted inconsistencies in some descriptors of the instruments. These descriptors were clarified further, and the structure of the instruments was adapted.

The analysis of the *type of practical work* did not require the construction of a specific instrument and was based on the conceptualization followed in the Experimental Science Teaching Training Program for primary teachers that was developed in Portugal over four academic years, between 2006 and 2010. In this training program several pedagogical materials were produced, related to practical work in primary science education, and are still available online to support teachers in the experimental science teaching (Martins *et al.*, 2007). The classification of the type of practical work followed Caamaño's typology (1992), adapted from Woolnough and Allsop (1985), and considers four types of practical work: (a) sensorial experiences, practical activities that aimed to obtain a perceptual familiarization with the phenomena; (b) illustrative experiences, practical activities to exemplify principles or improve understanding of certain concepts; (c) practical exercises, practical activities to develop practical and technical skills; and (d) investigations, practical activities that involve pupils in problem solving.

The instrument for the analysis of the *complexity of scientific knowledge* considered the distinction between facts, simple concepts, and complex concepts. A fact corresponds to a very specific type of informational content, with a relatively low level of abstraction (Anderson *et al.*, 2001; Marzano & Kendall, 2007). Conceptual knowledge corresponds to more complex and organized knowledge forms and represents an idea that arises from the combination of several facts or other concepts. The categorization of concepts results from a hierarchy between levels of abstraction and complexity. The simple concepts are those that have a low level of abstraction, defining attributes and examples that are observable and the complex concepts "*are those that do not have perceptible instances or have relevant or defining attributes that are not perceptible*" (Cantu & Herron, 1978, p. 135). Considering that the study is focused on practical work in primary education, we made the methodological option to not include in the instrument a higher degree of complexity,

corresponding to the most abstract formulations, the knowledge of theories. Table 2 presents an excerpt of this instrument, for the 'practical activity' section, and examples of units of analysis which illustrate different degrees of complexity.

The analysis of the *complexity of cognitive skills* was based on the taxonomy created by Marzano and Kendall (2007, 2008). The instrument considered the four levels for the cognitive system that have a hierarchic structure. Retrieval, the first level of the cognitive system, involves the activation and transfer of knowledge from permanent memory to working memory. Comprehension, the second level, is responsible for translating knowledge into a form appropriate for storage in permanent memory. The third level, analysis, involves the production of new information that the individual can elaborate on the basis of the knowledge s/he has comprehended. The fourth and more complex level of the cognitive system implies the knowledge utilization in concrete situations. In the analysis of a specific activity, for classification, we considered the cognitive skill of higher complexity mobilized in the activity. Table 3 presents an excerpt of this instrument, and examples of units of analysis which illustrate different degrees of complexity.

Table 2 – Excerpt of the instrument to characterize the complexity of scientific knowledge of practical work in primary science textbooks (adapted from Ferreira & Morais, 2014, p. 63).

Section	Degree 1	Degree 2	Degree 3
Practical activity	Scientific knowledge mobilized in practical activity refers to facts.	Scientific knowledge mobilized in practical activity refers to simple concepts.	Scientific knowledge mobilized in practical activity refers to complex concepts.
<i>Units of analysis:</i>			
Degree 1: “[...] In a gear, two cogwheels against each other rotate in ___ directions. In a gear, a ___ sprocket rotates faster than a ___ sprocket, because it has fewer teeth.” (Textbook A, 3 rd grade)			
Degree 2: “[...] Problem: Is the air necessary for combustion? [...] Conclusion: Why did the candle on which the cup was placed went out first?” (Textbook D, 4 th grade)			
Degree 3: No units of analysis were found.			

Table 3 – Excerpt of the instrument to characterize the complexity of cognitive skills of practical work in primary science textbooks (adapted from Ferreira & Morais, 2014, p. 64).

Section	Degree 1	Degree 2	Degree 3	Degree 4
Practical activity	Cognitive skills mobilized in practical activity involve cognitive processes of retrieval (e.g., describe; observe).	Cognitive skills mobilized in practical activity involve cognitive processes of comprehension (e.g., compare; data interpretation).	Cognitive skills mobilized in practical activity involve cognitive processes of analysis (e.g., prediction; control of variables).	Cognitive skills mobilized in practical activity involve cognitive processes of knowledge utilization (e.g., formulation of problems; planning).
<i>Units of analysis:</i>				
Degree 1: “Question: What is the function of levers? [...] In which of the situations, 2, 3 or 4, did you find the lower effort needed to lift the books [with different positions of two pencils]?” (Textbook C, 3 rd grade)				
Degree 2: “How do plants reproduce? [...] Observe and records what happens every two days [in the germinators of different seeds]. [...] After two weeks, observe the two species of plants and points out the similarities and differences between them. [...]” (Textbook B, 3 rd grade)				
Degree 3: “Communicating vessels [...] My prediction: What do you think will happen to the water level in each bottle when you raise one of them? [...]” (Textbook E, 4 th grade)				

Degree 4: “Does the amount of irrigation water influence the development of a plant? [...] Plan, in group, an experiment to investigate the influence of another environmental factor. [...]” (Textbook B, 3rd grade)

The instrument constructed to analyse the *relation between theory and practice* considered the relation between scientific knowledge and science processes skills (Table 4). This instrument contained a two-degree scale of classification (C⁻, C⁺), based on Bernstein’s concept of classification (1990, 2000), to indicate the strength of boundaries between various types of knowledge. The weak classification (C⁻) corresponds to an integration of theory and practice, i.e., a relation between scientific knowledge and science processes skills, and the strong classification (C⁺) corresponds to a separation between theory and practice.

Table 4 – Excerpt of the instrument to characterize the relation between theory and practice of practical work in primary science textbooks.

Section	C ⁺	C ⁻
Practical activity	The practical activity focuses on scientific knowledge and/or on science processes skills but does not focus the relation between them.	The practical activity focuses on the relation between scientific knowledge and science processes skills.

Units of analysis:

C+: “Look at the image and, with the help of your colleagues, choose the materials [hose, ball of yarn, spoon, cup] that you would use to pass all the water from one jug to the other without touching them. Give it a try.” (Textbook D, 4th grade)

C-: “Rubber band car racing. You are going to build a rubber band car. [...] Do a search [...] Define the materials you will use in its construction. [...] After you build your car, present it to the class. [...] At the end of the races, talk to your colleagues about the characteristics of the winning cars. [...]” (Textbook A, 3rd grade)

The *explicitness* of practical work in the textbooks was characterised through Bernstein’s concepts of evaluation criteria and framing (1990, 2000). The aim of this analysis was to appreciate the extent to which the textbooks authors make explicit to teachers the message relative to the scientific knowledge and cognitive skills to be involved in the teaching-learning and evaluation contexts of practical work. This is a control relation that is characterised the concept of framing in a two-degree scale (Table 5). The lowest framing (F⁻) indicates a situation where the textbook authors leave criteria implicit, and the highest framing (F⁺) indicates that the textbook authors make criteria explicit to teachers.

Table 5 – Excerpt of the instrument to characterize the explicitness of practical work in primary science textbooks.

Section	F ⁺	F ⁻
Practical activity	The scientific knowledge and/or the cognitive skills to be explored in the practical activity are explicitly mentioned.	The scientific knowledge and the cognitive skills to be explored in the practical activity are generically mentioned. Or The indications of practical activity can be confusing or contain inaccuracies.

Units of analysis:

F+: Teachers’ guide – Suggestions of exploration: “[...] Guide the answers to the problems and the conclusions of the activity: in the freezer, the water solidifies and went from a liquid to a solid state; at room temperature, the ice melted into liquid water; [...]” (Textbook E, 4th grade)

F-: “Question: What happens to the water absorbed by the roots? What we need: potted plant, plastic bags; sticky tape. [...] We concluded that: Part of the water absorbed by the roots is released into the ____ through the leaves. Plants contribute to air ____.” (Textbook C, 3rd grade)

In order to clarify how the same unit of analysis was classified in the study in terms of the dimensions related to the what and the how of practical work, two illustrative examples of the analysis that was made are presented. These examples, one from Textbook C (3rd grade) and other from Textbook F (4th grade), highlight the interpretative content analysis carried out when doing the textbooks analysis (Tables 6 and 7).

Table 6 – Practical activity presented in Textbook C (3rd grade).

Discover earthworm preferences	
Question: What environmental factors influence the earthworms' behaviour?	
We need: Earthworms Newspaper sheets Vaporizer with water	We need: Earthworms Cardboard box with cover Scissors Vaporizer with water
How are we going to do it? 1. Wet half the newspaper sheets, keeping the other half dry. 2. Put the earthworms in the dry part of the newspaper.	How are we going to do it? 1. Vaporize the bottom of the cardboard box with water (must be homogeneous). 2. Cut half the cover. 3. Put the earthworms on one border of the box. 4. Put the cover on the other border. 5. Put the box in a light place.
In your notebook:	
What do you think will happen? 1. Observe the earthworms' behaviour for 10 min. 2. Repeat two more times the procedure 2.	What do you think will happen? 1. Observe the earthworms' behaviour for 10 min.
Describe what you observed.	Describe what you observed.
We concluded that: Earthworms' behaviour is influenced by _____ and by _____.	

The practical activity exemplified in Table 6 corresponds to an illustrative experience, which mobilize simple concepts, related to the influence of water and light in earthworms' behaviour (degree 2), and to cognitive skills involving the cognitive process of analysis, since it mobilizes the science process skill of predicting (degree 3). In this unit of analysis, the textbook authors generically present both scientific knowledge and cognitive skills, leaving implicit to teachers what will be the object of learning in this specific practical work (F⁻). This activity involves scientific knowledge and science processes skills, but does not make an explicit relation between them, namely in the questions for the pupils and in the incomplete conclusion (C⁺), failing to describe the earthworms' behaviour in relation whit each one and both environmental conditions.

The practical activity exemplified in Table 7 corresponds to a practical exercise, which mobilize simple concepts, related to the materials which may conduct electricity or not (degree 2), and to cognitive skills involving the cognitive process of analysis, since it mobilizes the science process skill of predicting (degree 3). The textbook authors explicitly mention to the teachers the scientific knowledge that is to be the object of learning in this specific practical work (F⁺). This activity involves the relation between scientific knowledge and science processes skills (C⁻).

To estimate the reliability of the coding, a 20% random sample of units of analysis was analysed independently by three researchers familiarized with the theoretical framework (the two authors and a third researcher). The three coders achieved 84,55% agreement (percent agreement). The researchers discussed

the differences encountered in the classification of units of analysis and reached a consensus. The remaining units of analysis were classified by both authors, with 91,25% intercoder agreement in the analysis.

Table 7 – Practical activity presented in Textbook F (4th grade).

Conductors and non-conductors of electricity

Question: What objects are conductors and non-conductors of electricity?

We need:

- One battery 4,5 V
- One bulb 3,5 V-4,5 V, with socket
- One bulb holder
- Three coated copper wires (25 cm each)
- Scissors; ruler
- Several objects: clip, paper, plastic lid, metal lid, rubber...



How are we going to do it?

- 1- Cut 3 cm of the coat of each wire in both ends, with the scissors.
- 2- Wrap the copper wires around the battery poles and the bulb holder.

In your notebook:

1. What do you think will happen if you try to close the circuit putting different objects in A? Record your ideas in the table below.
2. Now try it and complete the table.

Objects	I think that the bulb		I observed that the bulb		Good conductor	Bad conductor
	Light up	Does not light	Lit	Did not lit		

3. Why the bulb lit with some objects and did not lit whit the others?
4. Describe one characteristic common to all the objects that allowed the bulb to light up.

We concluded that:

Good conductor objects are made of _____. Other objects, made of _____ do not conduct electricity.

RESULTS

The primary science textbooks analysis related to the level of conceptual demand of practical work considered the type of practical work, the complexity of scientific knowledge, the complexity of cognitive skills and also the intra-disciplinary relations between theory and practice. The results to practical activities and to the related evaluation questions are presented in the Figures 1, 2, 3 and 4, respectively.

Figure 1 shows the relative frequency of the various *types of practical work* in the six primary science textbooks analysed (textbooks A, B and C for 3rd grade and textbooks D, E and F for 4th grade). The type of practical work proposed in both 3rd and 4th grade textbooks is, mainly, focused on practical exercises and illustrative experiences. The 3rd grade textbooks were more focused in practical exercises (the relative frequency ranges between 70-78%, depending on the textbook). Illustrative experiences prevail in the 4th grade textbooks (39-50%), when compared with the 3rd grade textbooks (13-26%). The other types of practical work, investigations, and sensorial experiences have almost no expression in the textbooks. Only textbooks B, D and F included one investigation and textbook A proposed two sensorial experiences. Thus, the practical activities in those textbooks rarely engage pupils in authentic investigations.

Figure 2 shows the results of the analysis of the *complexity of scientific knowledge*. The practical activities in the six textbooks show a prevalence of simple concepts (degree 2) over scientific facts (degree 1) and a total absence of complex concepts (degree 3). In the evaluation questions, facts tend to have a greater

expression. This absence of scientific knowledge of high level of complexity puts at stake the understanding of the hierarchical structure of scientific knowledge by the pupils, whenever they are doing practical activities.

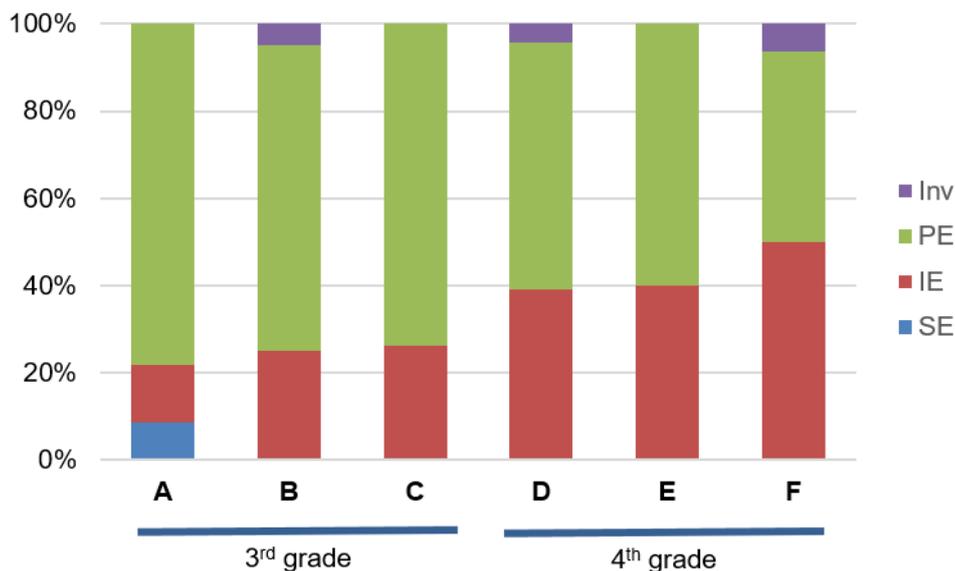


Figure 1 – Types of practical work in six primary science textbooks (SE- sensorial experiences; IE- illustrative experiences; PE- practical exercises; Inv- investigations).

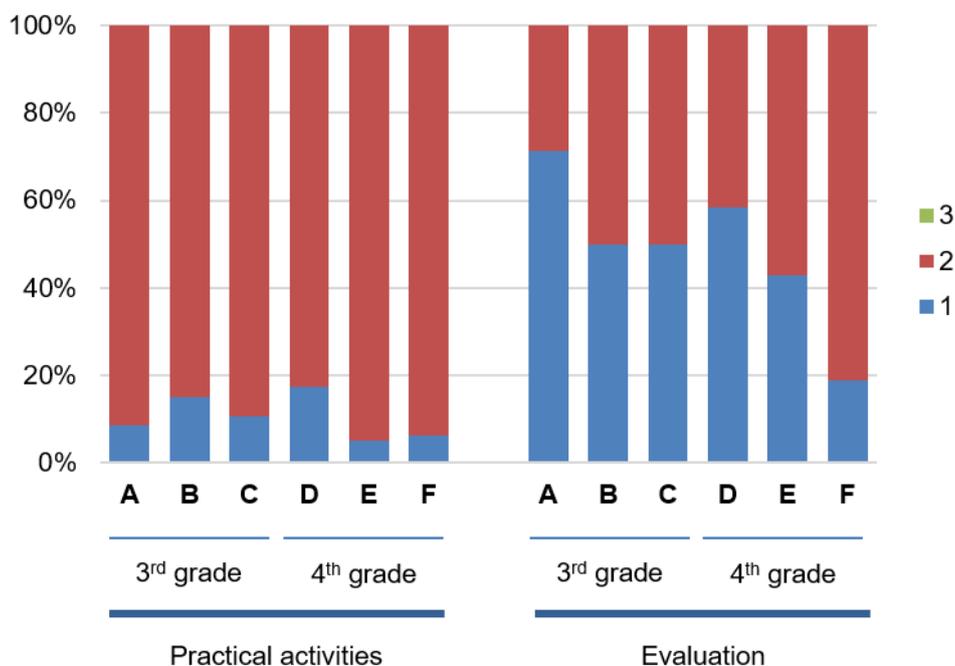


Figure 2 – Complexity of scientific knowledge of practical work in six primary science textbooks.

When the focus of the analysis is the *complexity of cognitive skills*, it turns out some variability between 3rd and 4th grade textbooks (Figure 3). In textbooks A, B, D and E, the four cognitive skills degrees of complexity are represented. Textbooks E and F place greater emphasis on cognitive skills of a high degree (cognitive

process of analysis and/or of knowledge utilization), while textbooks A, B C and D focus on cognitive skills of a low level of complexity (cognitive processes of retrieval and comprehension). The highest complexity of cognitive skills in textbooks E and F is particularly related to the formulation of predictions (degree 3 in both textbooks) and the construction of a model and planification of a practical activity (degree 4 in textbook E). The absence of other complex cognitive skills, such as questioning and controlling variables, puts at stake the implementation of practical activities that reflect the work carried out by scientists.

The cognitive processes of retrieval prevail in the evaluation questions, whit a greater expression in the 3rd grade textbooks, achieving 100% in textbooks A and B. As for textbooks C, D, E and F, evaluation questions include some items at the level of comprehension, but only in textbook F the units of analysis classified in this degree of complexity exceed half of the cases (56%).

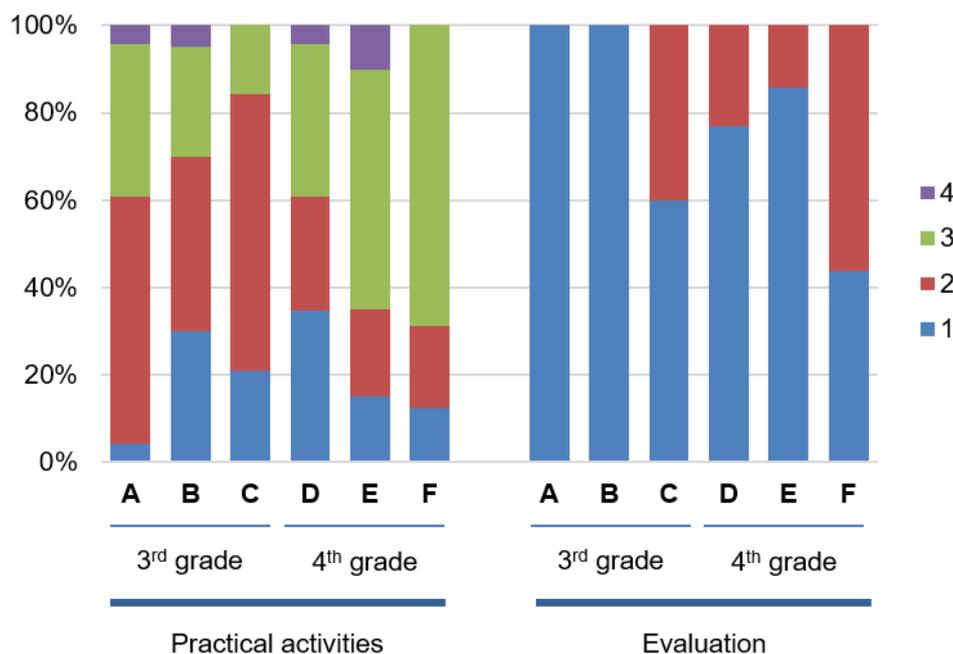


Figure 3 – Complexity of cognitive skills of practical work in six primary science textbooks.

Figure 4 shows the results of *intra-disciplinary relations between theory and practice*. The data show that both 3rd and 4th grades textbooks messages of the practical activities seem to value the relation between scientific knowledge and science processes skills (degree C⁻), except for the textbook C. On the contrary, the evaluation questions related to the practical activities tend to assess only scientific knowledge (degree C⁺). The excerpt that follows, related to the example presented above in table 7, illustrate this situation:

*“Indicates the name of two materials:
a) conductors of electricity;
b) non-conductors of electricity.”* (Textbook F, 4th grade).

In the analysis of the six primary science textbooks, we have also considered the extent to which the messages associated to the practical work are made explicit to the teachers. The results of this analysis are presented in the Figure 5.

The results of the *explicitness of practical work*, with regard to the relation between the textbooks authors and the teacher, mainly shows a weak concern with the explicitness of the scientific knowledge and cognitive skills that are supposed to be the subject of learning in the practical work. The data of Figure 5 show that, on the whole, most practical activities units were classified with F⁻. However, in the case of the textbooks B and E more emphasis is given to the explicitness of practical work (50% and 60% of the units classified with F⁺, respectively). The teachers' guides of these two manuals support the explicitness of the scientific knowledge and/or the cognitive skills to be explored in the practical activity, giving didactic suggestions for the teacher. The excerpt that follows, associated to a practical activity about soil permeability, illustrate this situation:

Teachers' guide – Suggestions of exploration:

“- Request the definition of the problem-question: How water moves through different soil samples?

- Request the presentation of predictions, justifying it.

- Draw students' attention to put the water into the three containers at the same time. Request records of what they observe.

- Request registration of the conclusions: water moves very easily through sandy soils; water moves very slowly through clay soils and may not even move through it; different soils have different permeabilities.” (Textbook B, 3rd grade).

In the case of the evaluation questions, most units explicitly assess the scientific knowledge of low level of complexity related to practical work (except for the textbook A).

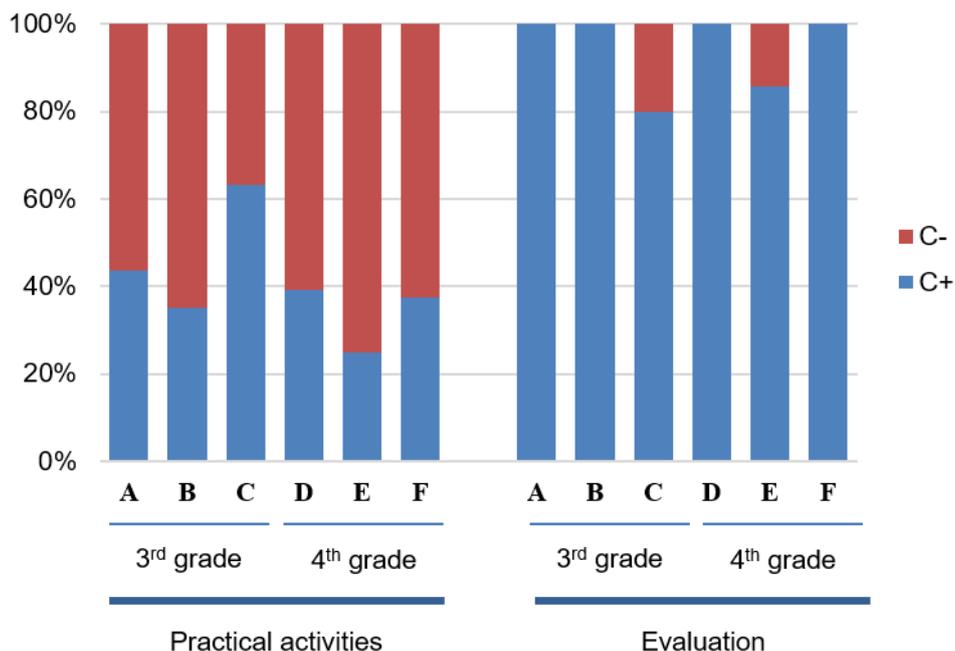


Figure 4 – Relation between theory and practice of practical work in six primary science textbooks.

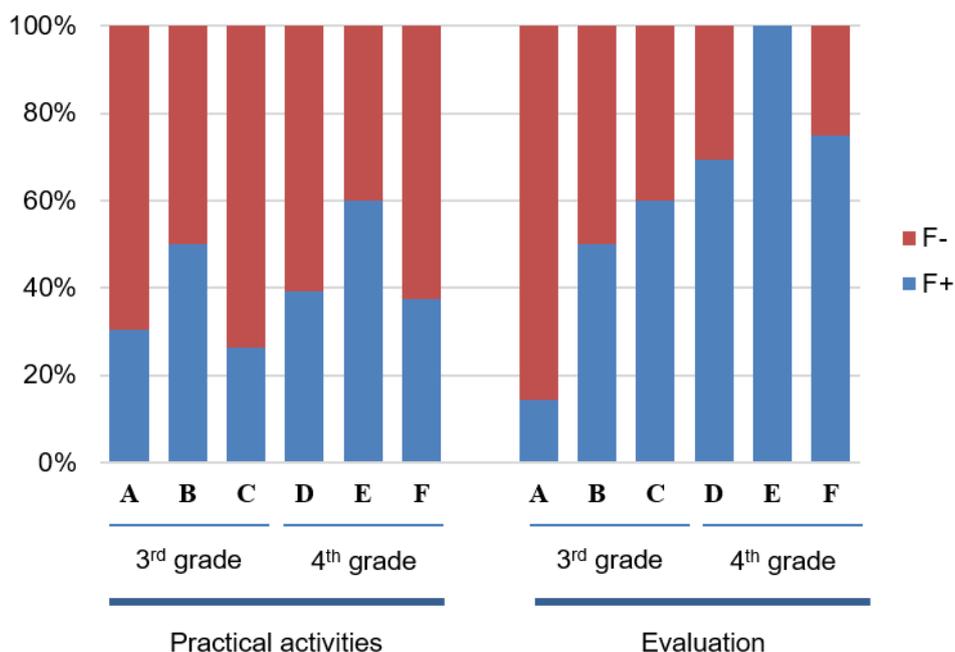


Figure 5 – Explicitness of practical work in six primary science textbooks.

DISCUSSION AND CONCLUSION

This study intended to investigate the level of conceptual demand of practical work and its explicitness in Portuguese primary science textbooks for 3rd and 4th grades. The methodological approach of this study can be used to appreciate the level of conceptual demand of practical work in other texts and in different educational contexts.

According to the results of the study, textbooks evidence a tendency towards a low level of conceptual demand of practical work, when analysed according to the proposals for practical activities and the related evaluation questions. This conclusion is based on the analysis of the type of practical work, the complexity of scientific knowledge and the complexity of cognitive skills (dimensions of *the what*) and also the analysis of the intra-disciplinary relations between theory and practice (dimension of *the how*) of practical work contexts presented in the textbooks we studied.

With regard to *the type of practical work*, activities that engage pupils in problem solving (investigations) are poorly represented in primary science textbooks, more specifically in the themes 'Discovering the natural environment' and 'Discovering materials and objects'. The illustrative experiences and the practical exercises predominate in those textbooks. Practical work is mainly used to exemplify principles or improve understanding of certain concepts and also to develop practical and technical skills. The prevalence of these types of practical work does not allow to enhance important learning skills as learning by inquiry and argumentation (Hofstein, 2017). In fact, inquiry experiments stimulate the construction of arguments, particularly in the hypotheses definition, analysis of the results and the drawing of conclusions (Katchevitch, Hofstein, & Mamlok-Naaman, 2013). Those results are in line with the literature stating that practical work in textbooks rarely engage pupils in authentic investigations and most activities do not allow an understanding about scientific inquiry (e.g., Andersen, 2020; Chin & Malhotra, 2002; Ma *et al.*, 2019).

When the focus is the *complexity of scientific knowledge* of practical work, the activities contain more abstract and complex knowledge when compared with evaluation questions. However, complex concepts are absent in the six textbooks. This absence of scientific knowledge of high level of complexity puts at stake the understanding of the hierarchical structure of scientific knowledge by pupils (Bernstein, 1999; Morais & Neves, 2016).

Cognitive skills of practical work in the primary science textbooks are more complex in practical activities than in evaluation questions. The highest *complexity of cognitive skills* in practical activities is particularly related to the formulation of predictions (cognitive process of analysis). However, other important science processes skills are not mobilised in those activities, as identifying, and posing scientifically oriented questions, designing scientific investigations, and drawing conclusions about scientific problems (Hofstein, 2017). Similarly, the results of Chakraborty and Kidman's (2021) study show that the integrated process skills of questioning and controlling variables have no expression in primary science textbooks of Bangladesh, only the simple process skills observing, recording data, and communicating results received the highest emphasis. Thus, it appears that textbook authors do not value either the learning of high-level cognitive skills or investigations in primary education. In evaluation questions, the textbooks authors seem to encourage memorisation of some scientific knowledge mobilised in practical activities rather than conceptual understanding, involving analysis and knowledge utilization. The assessment practice did not focus higher order thinking. In addition, it seems that the textbooks authors had been unable to formulate evaluation questions that really assessed scientific knowledge and cognitive skills about concrete situations of practical work.

The *intra-disciplinary relations between theory and practice* were the fourth dimension that was used to appreciate the level of conceptual demand of practical work in primary science textbooks. Contrary to evaluation questions, the practical activities seem to value the relation between scientific knowledge and science processes skills. The presence of this relation in the textbooks practical activities is particularly important since several studies (e.g., Abrahams & Millar, 2008) point out to the existence of a separation between theory and practice when teachers implement practical activities.

Considering our last research question, related to the *explicitness of practical work*, we intended to analyse the extent to which the textbooks authors make explicit to teachers the message relative to the scientific knowledge and cognitive skills of practical work contexts. The results show, in general, that the textbooks authors do not make the scientific knowledge and cognitive skills explicit at the level of practical activities presented in the textbooks. In this way, the teacher has a high degree of autonomy given by the textbooks authors when implementing the practical activities suggested, particularly in the case of the textbooks that do not have teachers' guides with didactic suggestions. This is of particular importance because the few studies carried out at the level of the Portuguese primary school (e.g., Correia & Freire, 2016) have

shown that practical work is poorly represented in the activities performed by pupils and that the practical work that is done mobilizes simple cognitive skills only. In this situation, if teachers are to promote a sound scientific learning with regard to the implementation and evaluation of practical work with a high level of conceptual demand, we consider that practical work should be explicit in the textbooks, at least with regard to scientific knowledge and cognitive skills. Like other authors (e.g., Kesidou & Roseman, 2002; Ma *et al.*, 2019) we view textbooks as tools that should allow teachers to implement their best practices with students. For that reason, they should provide a coherent science education for students based on the knowledge available in the field, and material that supports teachers about their own pupils' science learning.

The team of authors of each textbook does not seem to value science teaching that points to high-level learning, focused on a clear relationship between complex scientific knowledge and complex cognitive skills, namely associated with science processes. These results are of particular importance given the essential role textbooks play in guiding teacher planning, practice, and decision-making. Textbooks tend to influence the implementation of the curriculum and, thus, the pedagogical practices.

The conclusions of this study should not go in the direction of generalizing from practical work presented in six Portuguese primary science textbooks only, but instead should raise questions related to the complexity and the explicitness of practical work as proposed/suggested in science textbooks. This study can provide important information for different members of the science education community, as primary teachers, science textbooks' authors and policy makers in education areas. The results may support the teachers' selection of primary science textbooks, focusing their attention on how textbooks approach the complexity of practical work and give guidance to its implementation in the teaching of science. Textbooks' authors may also find support in the present study results when they write new or edit their existing textbooks. In particular, they may pay especial attention to the explicitness of practical work, namely scientific knowledge and science process skills that are supposed to be the subject of learning and assessment in the practical work.

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