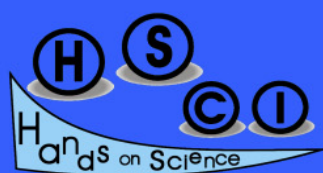


# Hands-on Science

## Brightening our Future

Edited by  
Manuel Filipe P. C. Martins Costa  
José Benito Vázquez Dorrió



The Hands-on Science Network



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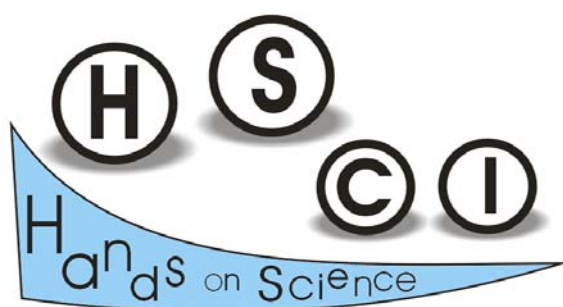


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## The Scientific Concepts in Biology Textbooks

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**Abstract.** Learning a science requires the understanding of its language, and the textbook as an educational resource, stands out in the whole teaching process, particularly in the years before the national tests. To what extent, do biology textbooks represent a strategic instrument for teaching and learning and a vehicle of the curricular message? All biology concepts covered and defined in the two biology 10<sup>th</sup> grade textbooks that are most adopted in Portugal, were quantified using a comparative study. The results showed that these textbooks covered more than 90% of the concepts recommended in the curriculum guidelines, although the total number of concepts was 6.5 to 7.5 times bigger than suggested.

**Keywords.** Biology, Concepts, Secondary school, Teaching and learning, Textbook.

### 1. Introduction

The key to learning any science lies in understanding its language [1]. Biology is a science that gathers knowledge, facts, theories and principles and, as such, many concepts. However, not all are equally relevant in order to profoundly structure a biological way of thinking. Given this, some authors suggest that biology teaching should be based on a justified selection of the most important concepts [2], [3]. Regarding this, the Ministry of Education (ME) in the Curriculum Guidelines for Secondary Education, identifies the most relevant concepts as well as the appropriate teaching methods for fulfilling the curricular programme [4].

The curricular programme of this subject aims to promote meaningful learning in the youth in order for them to achieve scientific literacy, which is fundamental for assuming a proactive attitude on scientific issues or matters relating to their life and to the life of others [4], [5]. Knowing that knowledge is constructed and reconstructed from the selection of different information acquired throughout life, it is expected that as a privileged educational

resource, the textbook should be in perfect coordination with the goals and overall objectives of the Curricular Programme. The textbook should contribute to the construction of a solid body of knowledge and to the development of various skills [6], [7] promoting in the student, an autonomous learning, particularly in school years prior, and that prepare for, exams that give access to Higher Education.

The importance of language, vocabulary and concepts used in school textbooks has been studied for different purposes. Some studies address the importance of language in the construction and communication of scientific ideas [1], [8]. Others check to what extent the concepts explored in the Science and Biology textbooks approximate or differ to the knowledge of reference, in other words, to the knowledge that is the object of study of the teacher in training [9]. There are others that identify the most important biology concepts that student must know, demonstrating the existence of a discrepancy between the number of concepts that students are able to learn and the time available for such learning [2]. Some textbook studies have also evaluated the key contents that enhance scientific literacy in students [10], and created a list of the most important concepts in Biology [3].

In Portugal, very few studies have been made involving biology textbooks. Some of these studies compare the message of the Natural Science textbooks of the 3rd cycle of basic education with the recontextualization processes that take place in the curriculum message during the elaboration of the textbooks [11], [12]. However, none focused to what extent the 10<sup>th</sup> grade Biology and Geology textbooks represent a strategic instrument for teaching and learning and a vehicle of the curricular message proposed by the Ministry of Education, particularly regarding the recommended biology concepts.

The aim of this study is the quantification of the number of biology concepts referred to in the Curriculum Guidelines of the Ministry of Education that are presented and defined in the two selected textbooks as well as evaluate whether these number of definitions allow the student an overall understanding of the content and an autonomous study during the years prior to the exams that give access to higher education.

## 1.1. Selection of the textbooks

The textbooks selected for analysis were the two most adopted 10<sup>th</sup> grade Biology and Geology textbooks of the secondary schools in Portugal during the school year 2012/2013, one from Areal Editores [13] and the other from Porto Editora [14], according to data confirmed by the publishers. These textbooks were also the most used in the secondary schools of the Autonomous Region of Madeira (ARM).

Each textbook consists of two volumes, one of biology and another of geology. In this study, only the Biology volumes were analyzed.

## 2. Methodology

Direct research and the descriptive method were used to develop a descriptive/ comparison type of study [15], [16]. Based on this method an inventory was made of all biology concepts present in both analyzed textbooks.

The textbook analysis was performed by two investigators. Each one fulfilled a complete analysis of one of the textbooks, quantifying all the biology concepts present in the text, illustrations, text boxes and activities, except for the ones present in headers and titles, in theme presentation pages of the unit or chapter and in the questions of the consolidation activities along each chapter or at the end of it. Each concept was checked in order to verify if it had a definition in the text, in illustrations, in text boxes and in the glossary (if any), and if the concepts were considered by the Curricular Programme of the subject, as mandatory concepts to be covered [2]. Each concept was counted once, regardless of the number of times it appeared in the textbook. Given the high number of synonyms of some concepts, all terms for the same concept were considered as a single one.

In order to standardize criteria and avoid ambiguities in data collection, definitions were created for concepts such as *Text*, *Illustration*, *Text box* and *Activity* (Table 1). The textbooks were analyzed gradually, page by page, marking and quantifying all the concepts and respective information regarding the definition. During the data collection process, all doubts and questions raised were marked and discussed weekly between the two researchers, in order to minimize the margin of error. Once the analysis was carried out, the

same researcher performed a second reading in order to detect possible omissions. A data matrix was created in an Excel spreadsheet with the gathered information.

Analysis Criteria	Definition
<b>Text</b>	Any set of linked words or sentences contained in a particular chapter, except for the information highlighted in text boxes, in illustrations or in activities.
<b>Illustration</b>	Figure, graph, table, diagram, concept map, photograph, geographic map or chart contained in each chapter.
<b>Text Box</b>	Any set of linked words or sentences highlighted outside an illustration or activity in order to complement or add new information regarding the contents already presented in the body text, illustrations or activities.
<b>Activity</b>	Any proposed exercise in a chapter whether it is practical or experimental in nature, formative, informative or associated to Science, Technology, Society and Environment (STSE).

Table 1. Definition of the analysis criteria for data collection

### 2.1. Study variables

The variables selected were four dichotomous qualitative variables recorded in nominal scale: Term of the concept, Textbook, Definition and Reference of the concept in the Biology and Geology Curricular Programme.

These variables were summarized numerically in order to enable their comparison in absolute terms.

The variables were defined as follows:

*Term* – The presence (1) or absence (0) of the term was checked and its designation was registered.

*Textbook* – The analyzed textbook was identified (Areal Editores and Porto Editora).

*Definition* – The presence (1) or absence

(0) of a definition was checked for every concept found. Its location in the textbook was not taken into account, and neither was a qualitative evaluation of the definitions performed.

*Reference in the Curricular Programme of the ME* – The presence (1) or absence (0) of the term in the Curricular Programme was checked in each chapter of the textbook. When the concepts proposed by the ME in the textbook were referred to by synonymous terms, they were also considered present (e.g. *Facilitated transport* in the curricular programme versus *facilitated diffusion* in the textbook). When the concepts proposed by the ME were inserted in chapters that were not suggested by the curricular programme, its presence was not registered.

## 2.2. Data analysis

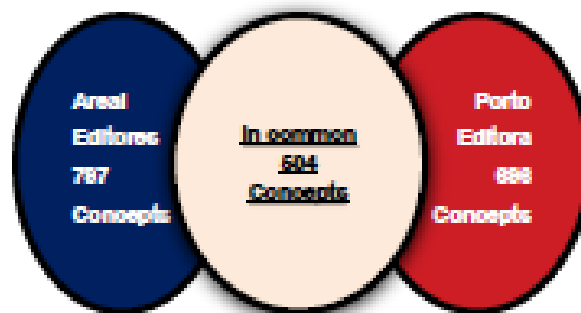
The process of analyzing and processing information went through three distinct phases: the description and reduction of information; the presentation and organization of the most relevant information and the interpretation and verification of data.

In the reduction information process, all terms considered common sense in the English language, although related to biology, were eliminated from the final data matrix, (e.g. air, grass, man, life, wind, thirst, and others), as well as some examples of living beings known in general by the students and that in the textbooks were not explained or addressed as explicit examples of concepts (e.g. bush, tree, camel, grass, mushroom, grasshopper, pig, etc.). All concepts considered of little relevance to answer the proposed research questions were also excluded from the data matrix, such as, those associated with laboratory activities, chemistry concepts, concepts associated with technology or with agricultural activities or with the nature of science, political and administrative concepts and concepts relative to other scientific areas.

## 3. Results

The number of biology concepts in both analyzed textbooks was considered very high, reaching a total of 2178 concepts. Each of the textbooks mentioned only half of these concepts, that is, 1161 concepts (53.3%) in the

Areal Editores and 1017 (46.7%) in the Porto Editora textbook. After excluding all synonymous terms and repeated concepts, 797 concepts prevailed in the Areal textbook (68.6%) and 696 (68.4%) in the Porto Editora textbook. Of these, only 504 (33.8%) were common to the two textbooks, while the remaining were addressed only in one of the two textbooks (293 concepts in the Areal Editores textbook and 192 concepts in the Porto Editora textbook) (Fig. 1).



**Figure 1. The number of biology concepts in both textbooks**

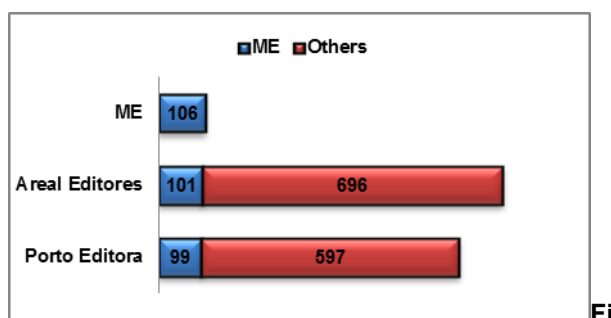
The curricular programme of the Ministry of Education suggests the study of 106 scientific concepts of biology in the 10<sup>th</sup> grade. Any one of the two analyzed textbooks covered more than 90% of the biology concepts proposed by the ME. The Areal textbook explored 101 (95.3%) concepts and the Porto Editora textbook 99 (93.4%) concepts (Fig. 2).

In percentage terms, the biology concepts proposed by the ME accounted for only 12.7% of the total Biology concepts covered in the Areal Editores textbook and 14.2% in the Porto Editora textbook. The number of other biology concepts not suggested by the ME was about 6.9 times bigger in the Areal textbook and about 6 times bigger in the Porto Editora textbook, than the one suggested by the Curriculum Guidelines (Fig. 2).

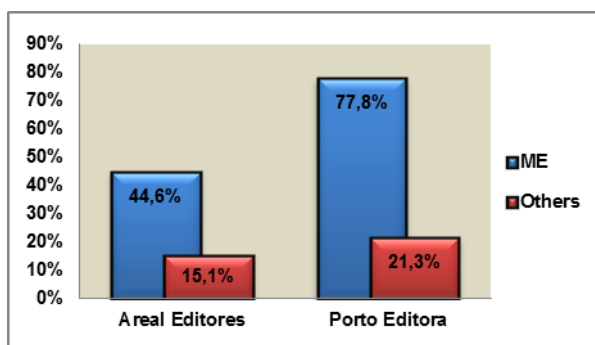
None of the textbooks covered or defined all of the biology concepts proposed by the ME.

The Porto Editora textbook defined three quarters of the covered concepts (77 concepts - 77.8%). On the other hand the Areal Editores textbook defined less than half of the referred concepts (45 Concepts - 44.5%) (Fig. 3). If we consider that all the concepts proposed by the ME are considered fundamental for the understanding of the subject addressed and the progression of student's knowledge in other

related subject, we find that the number of defined concepts is clearly not enough to help the student learn Biology, particularly in the Areal Editores textbook.



**Figure 2. The number of biology concepts suggested by the ME Curriculum Guidelines in the two textbooks and the number of other Biology concepts not suggested by the ME**



**Figure 3. The percentage of biology concepts suggested by the ME that present definition in both textbooks in comparison to the percentage of other concepts defined but not suggested by the ME**

Of all the concepts of the ME that each textbook covered, only 39 (86.6%) are defined in the two textbooks. The rest of the concepts were defined only in one of the textbooks. The Areal Editores textbook defined exclusively 6 concepts (13.3%) while the Porto Editora textbook defined 38 (49.4%). When comparing the number of concepts suggested by the ME that have definition in the Areal textbook (44.5%) and in the Porto Editora textbook (77.8%), with the number of other defined concepts not suggested by the curricular programme (Areal Editors - 15.1% and Porto Editora - 21.3%), we found that the biology concepts suggested by the ME were always the most defined in any of the textbooks (Fig. 3).

#### 4. Discussion

Today more than ever, great importance is given to the way the selection, organization and presentation of what we want students to learn

is made [17]. It is fundamental to find the best way to relate all concepts with the previous knowledge of the student. In this sense, the organization of the information, the amount of concepts and the way these are defined in the textbooks play an important role in student learning.

The textbook should not be a copy of the curriculum proposed by the Ministry of Education, however it should reflect its message. The biology concepts proposed by the ME in the analyzed textbooks were always the most defined, in relation to other biological concepts that were not suggested in the Curriculum Guidelines. However, only a third of the concepts of biology proposed by the ME (36.8%) were defined in both textbooks. When the meaning of unfamiliar concepts is not presented, the student needs the teacher's help in interpreting the scientific contents much more, which reduces his autonomy in the learning process [18]. If we consider that all biology concepts proposed in the Curriculum Guidelines represent those that the student needs to know in order to understand 10<sup>th</sup> grade Biology contents, we find that the number of defined terms in common in the two analyzed textbooks is clearly lower to what the student really needs to know.

In this sense, in secondary education the textbook assumes a crucial role during the preparation for exams that give access to higher education. The gaps found in the two textbooks indicate that the student should use more than one textbook during the study of the concepts recommended in the Curriculum Guidelines. In this way, the teacher's role is even more crucial to the understanding of the proposed concepts. It is up to the teacher and the school to make a critical evaluation of the textbooks to be chosen, so that the students get a good preparation and understanding of the subject [4], [11], [12].

The total number of concepts covered in each textbook is also relevant. This study showed that the total number of concepts covered in the textbooks of Porto Editora and Areal Editores was respectively 6.5 and 7.5 times bigger than the one suggested by the guidelines. In addition to the concepts of the ME, the number of other biological concepts not suggested, was 6.9 times bigger in the Areal Editores textbook and approximately 6 times bigger in the Porto Editora textbook than

suggested in the curriculum guidelines. These results are very similar to those found in the analysis of Biology textbooks of grade 7 and 10 in Germany [2]. The same authors found that taking into account the lesson time available, students had to learn a new concept every minute (1.4 minutes) in order to know all the concepts that the textbook presented [2]. However, since the number of concepts covered must be adequate to the time available for teaching and to the learning capabilities of students, these authors consider that only of two or four new concepts per lesson are possible to be learnt by students [2].

In Portugal, if we consider the 10<sup>th</sup> grade and relate the total number of biology concepts initially recorded in the textbooks (2178 concepts) with the time available per lesson throughout the school year (108 periods of 45 minutes or 4860 lesson minutes), and if we assume that the teacher teaches the whole textbook contents, we understand that students have to learn a new biology concept every 2.2 minutes, which is considerably exaggerated. The inclusion of a large number of concepts will only hinder the cognitive organization of the student and complicate the understanding of a particular matter. In this way, it becomes necessary to select the most important concepts and focus teaching on the essential concepts. It is important that a critical assessment of the most important concepts and of the most appropriate teaching strategies given the available time of the lesson is done, in order to promote meaningful learning.

## 5. Acknowledgements

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