Botany in Portuguese textbooks: Analysis of seven Biology books for High School students

Fernando Santiago dos Santos & Fernando Guimarães
Federal Institute of Education, Science and Technology of Sao Paulo, Brazil & Institute of Education, CIEC - University of Minho, Portugal
fernandoss@ifsp.edu.br & fernandoguimaraes@ie.uminho.pt

Abstract

Botany has traditionally been considered one of the most neglected areas in Biology, although it is of high importance for the environment, daily life, economy and so forth. This paper analysed how botanical contents are displayed in high-school textbooks used in Portugal for 10th, 11th and 12th grades. The methodological procedures are based on content analysis with *a posteriori* nine categories and sub-categories: i) Figures, ii) Additional information boxes, iii) Language, iv) Concepts, v) Contextualization, vi) Activities, vii) History of Science and Technology, viii) Teacher's guidebook, and ix) Transversal topics. An overview of our analysis has evidenced that the Portuguese textbooks studied lack contextualization and perhaps deeper relations with other areas of knowledge, despite language is used correctly and appropriately in all books, and teachers' guide books are precise and adequate. Textbook analyses are important tools to track the way Science is dealt with by students and teachers.

Keywords: botanical content; secondary level; textbooks.

Introduction

Botany has been usually addressed as an uninteresting and boring subject, perhaps the toughest area within the biological sciences, despite of its importance (food, furniture, oxygen production, clothing, transportation, medicine etc.); such view is intensified with the teaching and learning of excessive scientific names and nomenclature without cultural, social, economic, and historical contexts, as stated by Wandersee and Schlussler (1999).

Studies on aspects of vegetal groups and plants have been reported since immemorial times (Ferri, 1983; Low, Rodd & Beresford, 1994). Botany is a consolidated area with various specializations, such as anatomy, physiology, ecology, biochemistry and so forth (Mish, 2003). Joly (1987) and some other authors refer to Botany as the *Scientia Amabilis*, although it might be easy to "(...) transform Botany in the most boring blabber talk of names and characteristics, with no connection with the plant world, which is beautiful and diversified, as well as interesting to study" (p. xv-xvi).

Botanical information extracted from nature has given humankind the basis of initial investigations about the surrounding environment, as plants of common occurrence have supplied men with clothes, food, transportation, shelter, medicines, incenses and a myriad of other uses (Thomas, 2010). Up to now, Botany and Zoology have been recognized as the 'central, building blocks' of biological studies, despite many other areas, such as biotechnology, genetics and ecology (Krasilchik & Marandino, 2004).

Several investigators (Cavadas & Guimarães, 2010; Guimarães, 2008; Guimarães & Santos, 2011) have pointed out that Botany teaching at the elementary school level is perhaps one of the most obliterated tasks within all biological contents, as teachers consider it difficult and out of stimuli; Caldeira (2009), Kinoshita, Torres, Tamashiro and Forni-Martins (2006) and Santos (2006) mention that teachers might have a better and more solid background in Botany so that they could enhance more satisfying educational practices.

In the past fifteen years, we have been investigating how botany is presented in textbooks in Brazil and Portugal by considering the unquestionable use and credibility such materials are usually given. Textbook use is unquestionable and credible, as teachers usually regard them as important tools to teach (Astolfi & Develay, 1990; Baganha, 2010; Bittencourt, 2007; Issitt, 2005). Moreover, they are a social construction, thus embedded

with ideologies, and cultural and historical drivers. They convey transpositions of the academic knowledge and, thus, omissions, simplifications, complexifications and errors are commonly found (Chevallard, 1991; Fracalanza & Megid-Neto, 2003; Casper, 2014). There has been much research on the importance, use and applications of textbooks, as well as strong criticism regarding their adoption (Bizzo, 2000; Massabni & Arruda, 2010). The Education Bureau (2016) states that textbooks play an important role in supporting learning and teaching in schools, and they ought to enable students to seek various ways of learning; thus, learners might have opportunities, in accordance to their own interests and needs, to enhance various skills of learning.

Guimarães (2019) has recently published a study investigating how Natural Sciences in Portugal are dealt with in primary school textbooks; this study is an extensive analysis of textbooks in the past hundred years. Regarding textbook selection and evaluation, Souza and Dionisio (2011) carried out an interesting study of how teachers assess didactic materials in Portugal, pointing out that the two most important features focused by teachers is quality and adequateness to students' ages.

As far as botany teaching is concerned, Hershey (1996), one of the first authors to deal with such topic, and more recently Uno (2009), have stressed the need for a more comprehensive, contextualized and effective methodology so that teachers can teach botanical contents and attract their students' attention.

The secondary school level (High School) in Portugal comprises a three-year period (10^{th}, 11^{th}, and 12^{th}); the curricular component 'Biology and Geology' is offered in the first two years, being part of the syllabus "Specific Formation" (there is another, "General Formation", with several other subjects, such as French, Physical Education, Portuguese and so forth). 'Biology' is offered in the 12^{th} year (Diário da República, 2018).

This paper presents the results from the first author's post doctorate program at the University of Minho (Braga, Portugal). There is no report on the analysis of secondary level textbooks in Portugal concerning Botany; thus, our results are unprecedented.

Our research focus relies on: a) To analyse how botanical contents are displayed in high-school textbooks used in Portugal for 10^{th} and 11^{th} (Biology-Geology) and 12^{th} (Biology) grades; b) To characterize the material analysed in terms of compliance with the Portuguese Guidance for the high-school curriculum.

Research methods

The methodological procedures are based on content analysis as proposed by Bardin (1994), and modified by Fonseca Jr. (2006), having in mind that such methodological approach is a useful tool to assess textbooks.

Content analysis is a set of techniques aiming at analysing communications and describing contents with systematic procedures. It supplies researchers with guidelines that allow inferences of knowledge regarding conditions of production and reception of such messages. This technique also deals with various forms of communication amongst men so that subjacent messages in a text are found. It is particularly suitable for printed materials, as it may be used as many times as needed; thus, for textbooks, it is a common practice. As Bardin states, "[content analysis] is the manipulation of messages [i.e., content and expression of such content] to evidence guidelines that might allow us to infer upon other realities other than the message itself (...)' (Bardin, 1994, p. 46).

Content analysis goes through three steps (or phases): a) previous analysis (during which researchers make a list of text features); b) inference (includes logical deduction, where we may emphasize causes and consequences relative to the first descriptions of messages); and, c) interpretation (the true meaning of described messages).

During the previous analysis, Fonseca Jr. (2006) mentions the importance of the categorization process, which is a method of selecting, counting, and classifying representative units of text into categories (and sub-categories). Bardin (1994, p. 117) says that "categorization is a classifying operation of the building elements out of a group or set of things, through differentiation, and, subsequently, through re-grouping with genre (analogies) by considering previously definied criteria".

In our study, nine *a posteriori* categories and sub-categories were created to analyse botanical contents (Table 1). Each of the categories and their sub-categories are explained and commented in detail in the section 'Results and discussion'.

Table 1. Categories and sub-categories created for the textbook analysis.

Category	Description	Sub-categories
Figures	Inclusion of any graphic material which might enhance students' perception of structures, physical appearance etc.	Pictures (photographs)
		Size scale
		Illustrations
		Graphs
Boxes	Side or bottom square or equivalent with information which is not present in the main text	Occurrence
		Curiosity
Language	Use of the Portuguese language in accordance with the New Orthography	Correct use
		Adequateness to age
		Glossary
Concepts	Terms of essential understanding of ideas, theories and alike	Updating and precision
		Conceptual problems
Contextualization	Insertion of botanical contents into culture, economy and so forth	Occurrence
		Interdisciplinary approach/pertinence to routine life
Activities	Exercises aimed at revising and/or enhancing further studies	Type
		Field/laboratory practice
History of Science and Technology	Naturalists/scientists and/or scientific episodes/events related to Botany	Occurrence
		Type of citation
Teacher's guidebook	Specific material designed for teachers	Didactic approach
		Assertive and direct language
Transversal topics	Occurrence of other areas of knowledge which are not normally related to Botany	Occurrence
		Relevance to students

Content analysis was applied to seven high-school textbooks, chosen in accordance with the nationwide textbook approval carried out by the Portuguese Ministry of Education (Direção-Geral da Educação, 2018), and effectively used in secondary level schools in Portugal (Table 2). Each material was scrutinized in details, looking for any botanical content, as part of the previous analysis.

Table 2. Textbooks used for the present work (YP = year of publication).

Authors	Title/Editorial company	YP
Amparo Dias da Silva *et al.*	Terra, Universo de Vida (10th year)/Porto Editora	2012
	Terra, Universo de Vida (12th year)/Porto Editora	2016
Osorio Matias and Pedro Martins	Biologia 10/Areal Editores	2018
	Biologia 11/ Areal Editores	
	Biologia 12/Areal Editores	
Joao Carlos Silva *et al.*	BioDesafios 12/ASA Editores	2011
	BioDesafios 12^{o} ano/ASA Editores	2014

Results and discussion

During the inference and interpretation steps of content analysis, we found that botanical contents were found in all of the materials analysed, in all grades (10th to 12th). Table 3 shows how information extracted from our analysis was condensed for a broader view of the material selected.

Table 3. Condensed information regarding the content analysis carried out with the seven textbooks (numbered in the first column, 1 through 7). **Fig** = Figures (Q = quantity; P = photograph/picture; S = size scale; IG = illustrations and/or graphs); **Box** = Additional information boxes (O = occurrence; C = curiosity); **Lang** = Language (U = correct use of Portuguese; A = adequateness to student's age; G = glossary or similar tool); **Conc** = Concepts (U = updating and precision; C = conceptual problems); **Cont** = Contextualization (O = occurrence; I = interdisciplinary relations; **Activ** = Activities (O = occurrence; Q = questionnaire-like; F = field/laboratory practice); **HCT** = History of Science and Technology (O = occurrence; T = type: B = information in a box; T = information in the main text; E = historical context of the evolution of a certain scientific concept); **TG** = Teacher's guidebook (D = didactic approach; A = direct and assertive language); **Trans** = Transversal topics (O = occurrence; R = relevance to students). In all cells: Y = yes/occurrence; Pr = partially present; N = no/absence.

	CATEGORIES																					
	Fig				Box		Lang			Conc		Cont		Activ			HCT		TG		Trans	
#	Q	P	S	IG	O	C	U	A	G	U	P	O	I	O	Q	C	O	T	D	A	O	R
1	39	Y	N	Y	N	N	Y	Pr	Y	Pr	Y	N	N	Y	Pr	Y	N	N	Y	Y	Pr	Pr
2	49	Y	N	Y	N	N	Y	Y	N	Y	Y	Pr	N	Y	Pr	Pr	Y	B/E	Y	Y	N	N
3	19	Pr	N	Y	N	N	Y	Pr	Y	Y	N	Y	Y	Y	Y	Pr	Y	T/E	Y	Y	Y	Y
4	35	Pr	N	Y	Y	Y	Y	Pr	N	Y	N	Y	Y	Y	Y	Y	Pr	T/E	N	N	Y	Y
5	42	Pr	N	Y	N	N	Y	Pr	N	Pr	Y	N	N	Y	Pr	N	N	N	N	N	N	N
6	47	Y	N	Y	N	N	Y	Y	N	Y	N	Y	Y	N	N	N	Pr	T/E	N	N	Y	Y
7	4	N	N	Y	N	N	Y	Pr	N	Y	N	Y	Y	Y	Pr	Y	N	N	N	N	Y	Y

Category 'Figures'

Figures are not shown with size references or scales in any material (0%), although all materials (100%) present figures, mostly photographs (Figure 1).

Illustrations and graphs are shown very occasionally: the first ones are present especially when complex mechanisms or phenomena (e.g., photosynthesis) would require a series of elaborate (and perhaps expensive) sets of photographs; graphs are evident mainly when presenting statistics and related subjects (e.g., number of seeds of a certain plant produced during a season).

The existence of pictorial material in a textbook is an important didactic trace, as students seem to be more interested in a certain subject when pictures and, mainly, photographs add colour, shape and three-dimensional perspectives (Santos, Costa & Santos, 2018; Vidal Junior & Kock, 2013).

The lack of size references or scales, on the other hand, might be an issue as students (and teachers) do not grasp the real magnitude of living beings and their structures; for instance, a sequoia (which may not be found in the neighbourhood) may be compared to a common pine tree, or a chloroplast may have no direct connection in the student's perception of microscopic bodies.

Category 'Boxes'

Additional information boxes with curiosities were found in only one material (14.3%). These boxes usually provide students and teachers with additional data which are not present in the main text (Pacheco, 1996).

Although suggestions on additional material may be present in the teacher's guidebook, textbooks with boxes might drive students into complimentary studies by reading such information. Moreover, bridges to other areas of knowledge may also be enhanced when boxes bring information with which teachers and students have the chance to work on other curricular topics: in Figure 2, for example, the numbers may be used to statistical and mathematical problems and situations.

Figure 1. Examples of photographs shown in one of the textbooks. Note that scales/size references are not present.

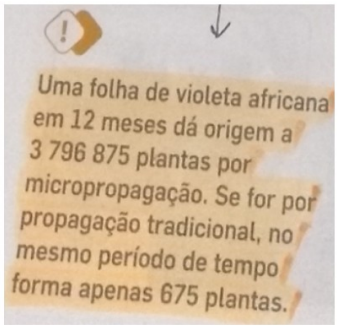


Figure 2. Example of a lateral box found in one of the books regarding vegetative propagation.

Category 'Language'

All materials use Portuguese appropriately (100%), but glossaries or term explanations were found in only two materials (28.6%). We noted that the Portuguese language seemed to be use appropriately towards students' ages at such schooling period in two materials (28.6%); in the remaining materials (71.4%), language was partially adequate, as it sometimes involves difficult concepts and even grammatical constructions, being appropriate, perhaps, to undergraduate students.

Caldeira (2009) discussed that biological and/or scientific terms are usually difficult to be grasped, especially when they are too specific or abstract (such as molecular, genetic

and biochemical structures); thus, the presence of glossaries might ease the understanding of such peculiar terms. Figure 3 brings an example of a concept defined in a side box of one of the textbooks.

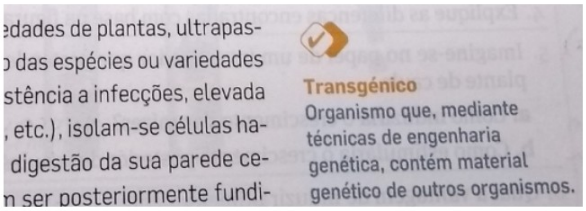


Figure 3. An example of a term defined in a glossary (in this case, the side box shows the definition of a transgenic organism).

Category 'Concepts'

Conceptual problems occurred in four materials (57.1%), mostly related to simplifications and omissions. An example of a simplification for a High School textbook is the extreme reduction of the photosynthetic process into a simple $6H_2O + 6CO_2 = C_6H_{12}O_6 + 6O_2$; an omission is, for instance, the suppression of information (as when one says that green algae are responsible for most of the ocean-producing oxygen that goes into the atmosphere – many other groups of microscopic, photosynthetic organisms also produce oxygen and release it into the atmosphere, such as cyanobacteria). As seen in Figure 4, books still present obsolete information; updating information may be an issue for textbook editors, as new discoveries and taxonomic placement (just to mention few examples) sometimes take years or decades to be added to more recent editions.

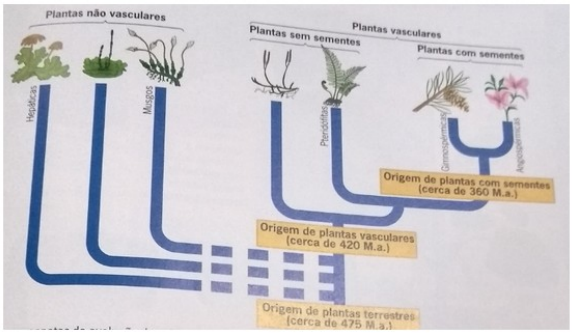


Figure 4. The above cladogram brings phylogenetic issues, such as the inappropriate terms 'pteridophyte' and 'gymnosperms', which are no longer valid (these are polyphyletic clades); moreover, the picture does not show the name of the second group (left to right, which is a hornwort, or Anthocerotophyta).

Category 'Contextualization'

Botanical contents were contextualized in five materials (71.4%), although very reduced or almost imperceptible in one material (14.3%).

Bostick, van Dyke and Stucky (2000) stated that by supplying students with contexts (economical, financial, ecological, social and so forth), botany teaching might be enhanced greatly because students tend to get more interested in a subject when it has commitments to their lives. Our world has changed rapidly, and menaces to our existence are the focus of international debates, such as global warming, famine, transgenic organisms, organic agriculture, just to name a few issues.

Figueiredo, Amaral and Coutinho (2012) point out that interdisciplinary approaches should be encouraged, especially those that are pertinent to routine life; Figure 5 brings an

example of how botanical contents might help students understanding his surrounding environment by visualizing its context.

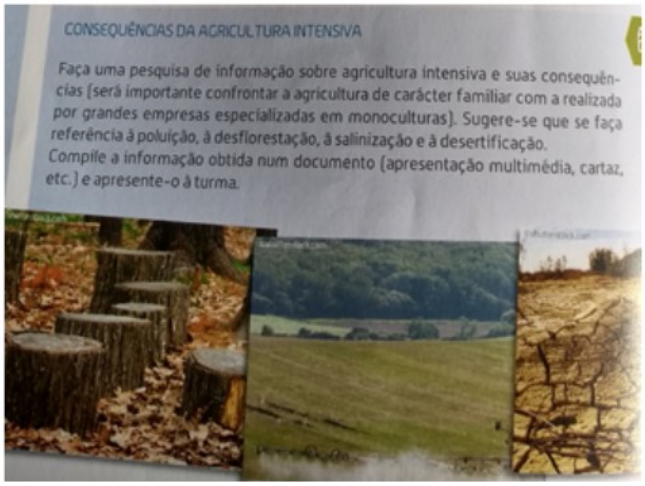


Figure 5. Example of contextualization: consequences of intensive agricultural practices.

Category 'Activities'

Activities were found in all but one material (85.7%), generally a mixture of questionnaire-like activities and laboratory/field work tasks. Moreno, Reis and Calefi (2016) discussed that students should be exposed to a diversified set of activities (home research, project development, data collection etc.), and not only (or almost exclusively) to questionnaire-like questions, which do not demand much of the student's curiosity and problem-solving skills, abilities to be enhanced and reinforced (UNESCO, 2003).

Even laboratory or field work may present some issues, as materials may not be easily found or reproduced: spirogyra filaments are not frequently found in freshwater bodies (Figure 6).

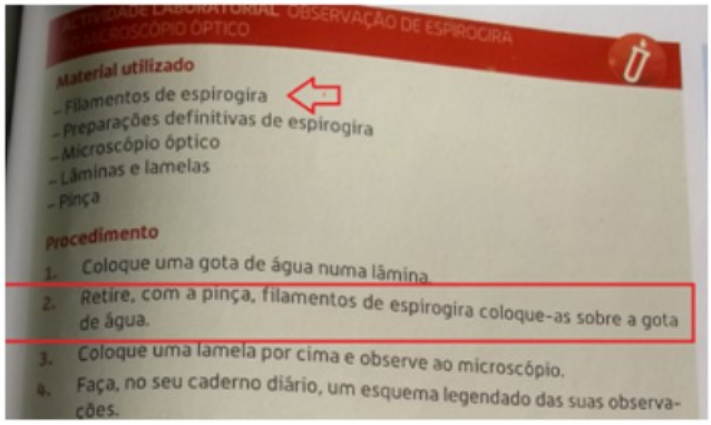


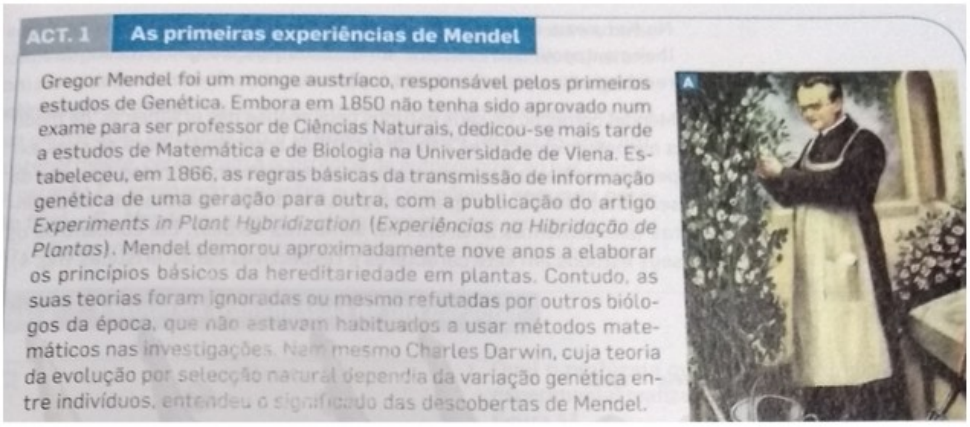
Figure 6. Excerpt of an activity aimed at visualising green algae (*Spirogyra*).

Category 'History of Science and Technology'

Botany in a historical approach is basically based on biographies of scientists and found in only two materials (28.6%); most of this information is presented in the main text, and in only one material (14.3%) it was shown in a side box.

When science and technology are presented in a linear and superficial way, students tend to misunderstand how scientific thought is actually built, thus leading students to have a shallow perspective of scientific endeavours (Vidal & Porto, 2012).

It is important to note that out of the seven books analysed, only two books mentioned something related to Botany in a historical perspective, even though in problematic ways (Figure 7).

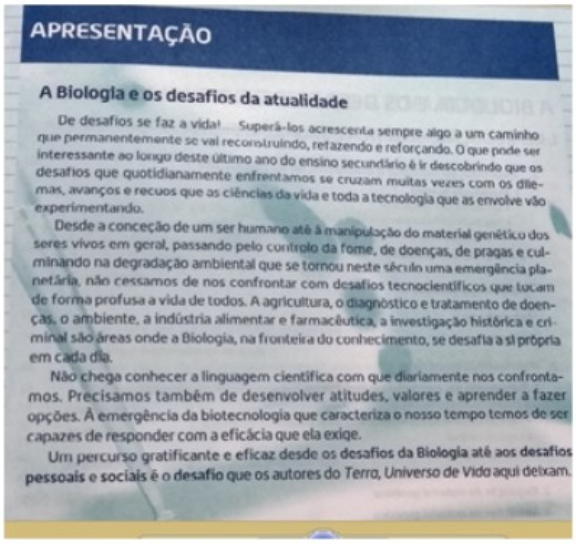

ACT. 1 As primeiras experiências de Mendel

Gregor Mendel foi um monge austríaco, responsável pelos primeiros estudos de Genética. Embora em 1850 não tenha sido aprovado num exame para ser professor de Ciências Naturais, dedicou-se mais tarde a estudos de Matemática e de Biologia na Universidade de Viena. Estabeleceu, em 1866, as regras básicas da transmissão de informação genética de uma geração para outra, com a publicação do artigo *Experiments in Plant Hybridization* (*Experiências na Hibridação de Plantas*). Mendel demorou aproximadamente nove anos a elaborar os princípios básicos da hereditariedade em plantas. Contudo, as suas teorias foram ignoradas ou mesmo refutadas por outros biólogos da época, que não estavam habituados a usar métodos matemáticos nas investigações. Nem mesmo Charles Darwin, cuja teoria da evolução por seleção natural dependia da variação genética entre indivíduos, entendeu o significado das descobertas de Mendel.

Figure 7. An example of a text concerning Gregor Mendel and his experiments with peas in the XIX century. Note that his dates of birth and death are not shown. Also, he did not establish the basic rules for genetic information transmission, as written in the text.

Category 'Teacher's Guidebook'

Teacher's guidebooks are precise and appropriate in three materials (42.9%%), with didactic approaches and direct, assertive language. These seem to bring relevant, objective and coherent information regarding the material to be used with students (Figure 8).


APRESENTAÇÃO

A Biologia e os desafios da atualidade

De desafios se faz a vida! Superá-los acrescenta sempre algo a um caminho que permanentemente se vai reconstruindo, refazendo e reforçando. O que pode ser interessante ao longo deste último ano do ensino secundário é ir descobrindo que os desafios que quotidianamente enfrentamos se cruzam muitas vezes com os dilemas, avanços e recuos que as ciências da vida e toda a tecnologia que as envolve vão experimentando.

Desde a conceção de um ser humano até à manipulação do material genético dos seres vivos em geral, passando pelo controlo da fome, de doenças, de pragas e culminando na degradação ambiental que se tornou neste século uma emergência planetária, não cessamos de nos confrontar com desafios tecnocientíficos que tocam de forma profusa a vida de todos. A agricultura, o diagnóstico e tratamento de doenças, o ambiente, a indústria alimentar e farmacêutica, a investigação histórica e criminal são áreas onde a Biologia, na fronteira do conhecimento, se desafia a si própria em cada dia.

Não chega conhecer a linguagem científica com que diariamente nos confrontamos. Precisamos também de desenvolver atitudes, valores e aprender a fazer opções. A emergência da biotecnologia que caracteriza o nosso tempo temos de ser capazes de responder com a eficácia que ela exige.

Um percurso gratificante e eficaz desde os desafios da Biologia até aos desafios pessoais e sociais é o desafio que os autores do *Terra, Universo de Vida* aqui deixam.

Figure 8. An example of a page introducing the book to the teacher.

In the case of the materials commented above, there is particular care in aligning pedagogical recommendations and directions with those suggested by the Portuguese Ministry of Education, which recommend that Science/Biology teachers should consider that "(...) the purposes of the Biology education ought to be addressed towards the

scientific education of all citizens...” (Aprendizagens Essenciais, 2018, p. 1); moreover, the same document says:

> (...) it is important that young people are prepared to face (...) both the scientific and the technological issues brought by societies (...) the study of conceptual, procedural and behavioural contents in Biology makes it possible to comprehend working methodologies used by specialists, analyses of crucial moments in the history of Biology and, also, the instrumental value of scientific and technological skills to grasp problems that may affect people’s lives (Aprendizagens Essenciais, 2018, p. 1-2).

The teacher’s guidebooks analysed bring information to teachers that cover basically the above recommendations.

Category ‘Transversal topics’

Transversal topics are generally centred in ecology, economy and agriculture, but also in medicine (Figure 9). They occur in five materials (71.4%).

Amorim (1998) and Güllich and Araujo (2003) suggested that textbooks contextualize subjects in a transversal way, so that students perceive the importance of science and, particularly, Botany in their own lives. Such trend is also shared by Auler, Dalmolin and Fenalti (2009).

The books analysed, in which it was possible to note the presence of transversal topics, brought relevant information, thus trying to make students ponder on their own lives and the importance of botanical contexts and contents in such realities.

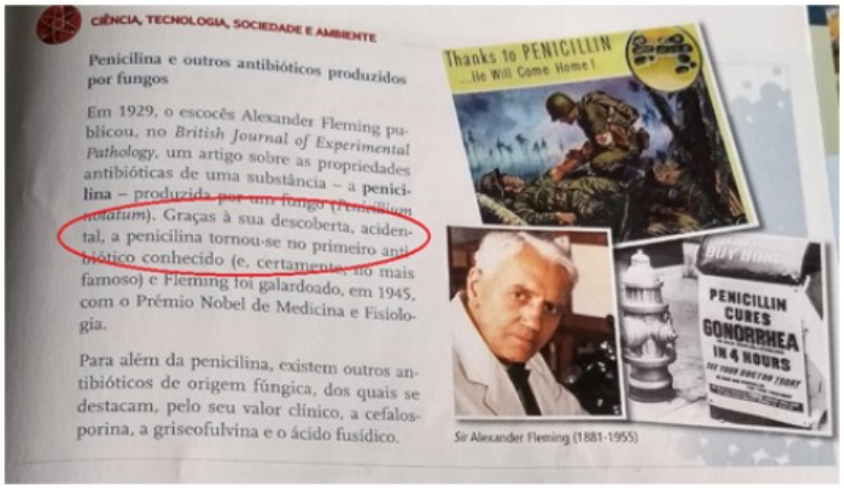


Figure 9. Example of how science positively interferes in our lives: in this case, the development of penicillin from Fleming’s studies with bacteria.

Final words

By considering the importance of textbooks during schooling (despite some critiques otherwise), and analysing them with our categories, we realized that the seven books considered in this paper are partially appropriate for teaching and learning Botany. Our assumption is based upon two statements: a) “(...) in our uncertainty regarding the future, where there is a myriad of new opportunities for the human development, it is necessary to have students develop competencies that might allow them to question established knowledge by integrating emerging skills, communicating effectively, and solving complex problems” (Diário da República, 2018, p. 2928-2929); b) every teacher

should be aware that textbooks are meant to present, in a didactically structured way, a certain knowledge that students should grasp, understand and make it somehow valid for his own life – the best book will depend upon the material conditions in which both teachers and students are immersed (Baganha, 2010).

Our nine *a posteriori* categories might not be fully sufficient for a straightforward observation that these textbooks may supply users with whole and appropriate materials.

Figures are not shown with size references or scales in any material analyzed; this fact may lead students to misunderstand the real size of beings and structures. By considering that living beings come in microscopic and gigantic sizes, it is important that scales or size indicators are presented in textbooks. Only one material brought such resource.

The boxes with additional data may bring students (and teachers) information regarding curiosities, complementation of texts, suggestions of home research and so forth. Although they are not mandatory items in a textbook, additional boxes are useful tools and should be present.

Major mistakes were not found in any of the books analysed, but glossaries of new concepts and/or more complex terms were very scarce. It is noteworthy to mention that botany is a very complex area and its nomenclature may be difficult to gasp, so the occurrence of glossaries in such few materials is something to ponder.

Conceptual mistakes were not common in the textbooks analysed; most issues found concerned simplifications and omissions. There should be no such problems in textbooks, but usually authors and/or publishers do not have appropriate updating of information and, therefore, commitment to avoid spreading over-simplified data.

The occurrence of botanical contents in only half of the materials shows us that textbooks should be more carefully devised, as contextualized topics might enhance curiosity, better understanding, and more meaningful relations with daily life.

There should be a variety of activities (home research, experimentation, projects, field work, laboratory practice etc.) so that students may grasp botanical skills more appropriately and effectively. The activities of the analysed textbooks were questionnaire-like exercises mixed with scarce field and/or laboratory work (generally, experiments with known results, lacking creativity and more active practice).

Only two materials presented some texts with a historical background when dealing with botanical aspects. Even so, biographies of scientists were the most common approach. In general, textbooks lack a broad view of how concepts and ideas were historically built, as well as how technology has taken place in practically all aspects of our lives.

Most materials present botany in a transversal way, usually associated with agriculture, ecology and economy. Although these are important areas of our lives, there should be more transversal topics such as medicine (plants as medicinal drugs), biotechnology, arts and human welfare.

Regarding the general guidelines of the Portuguese Ministry of Education, which consider Biology and Geology as " (...) crucial scientific areas for the development of responsible citizenship" (Aprendizagens Essenciais, 10.º/11.º ano, 2018, p. 2), we see these textbooks as tools that may help students comprehend problems and make decisions upon questions that affect both societies and our earthly subsystems. Yet, we cannot see these materials as enhancers of democratic citizenship (as the Portuguese Government suggests), but as a way of realizing how Science – and, particularly, Botany – is brought to perspective in a society which is gradually welcoming new technologies and skills for the demands of the XXI century.

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