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TO WHAT EXTENT DOES GENETIC CONTENT IN TEXTBOOKS CONTRIBUTE TO SCIENTIFIC LITERACY? ANALYSIS OF STSE ISSUES IN TEXTBOOKS

EM QUE MEDIDA O CONTEÚDO SOBRE GENÉTICA NOS MANUAIS ESCOLARES CONTRIBUI PARA A LITERACIA CIENTIFÍCA? ANÁLISE DOS TEMAS CIÊNCIA-TECNOLOGIA--SOCIEDADE-AMBIENTE EM MANUAIS ESCOLARES

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ABSTRACT: Our article analyses science-technology-society-environment (STSE) issues in the genetics-related chapters of Portuguese natural sciences and biology textbooks and considers how they contribute to students' scientific literacy. We inspected manner of imparting of the decontextualized and socially neutral view of science and technology (S&T) as an obstacle for achieving scientific literacy. Our sample comprised four textbooks, two for the 9th and two the 12th grades. We identified and content-analytically analyzed 1019 STSE statements with regard to their compliance with previously proposed criteria. We quantitatively analyzed the statements' frequencies. We noted an attempt to approach STSE issues, but we found important deficiencies in all the textbooks, as well as indicators of a distorted view of science. We discuss possible influences of the socio-cultural context in the selection of STSE contents, in the terms being applied, as well as in the S&T conceptions displayed by the textbooks.
KEYWORDS: textbook analysis; scientific literacy; STSE issues socio-cultural context.

RESUMO: O nosso artigo analisa o tema das relações entre a ciência, a tecnologia, a sociedade e o ambiente (conhecidos na língua inglesa como *STSE issues*), nos capítulos relacionados com a genética, em manuais de ciências naturais e de biologia, e considera em que medida eles contribuem para a literacia científica dos alunos. Adicionalmente, foi averiguada a transmissão da visão descontextualizada

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e socialmente neutra da ciência e da tecnologia, enquanto obstáculo à literacia científica. A amostra compreende quatro manuais portugueses de Biologia e de Ciências Naturais, nomeadamente, dois para o 9.º ano e dois para o 12.º. Identificámos e analisámos 1019 expressões com conteúdo STSE, conformes com critérios previamente propostos, e procedemos à análise de frequências. Verificou-se uma tentativa de abordagem de conteúdos STSE, tendo sido também detetadas deficiências importantes em todos os manuais, assim como indicadores daquela visão distorcida da ciência e da tecnologia. Discutem-se ainda possíveis influências do contexto sociocultural na seleção dos conteúdos STSE, nos termos utilizados, bem como na conceção sobre ciência e tecnologia refletidas nos manuais.
PALAVRAS-CHAVE: análise de manuais escolares, literacia científica, STSE issues, contexto sociocultural.

1. INTRODUCTION

1.1. Visions of science and perspectives of science education

A variety of arguments has been proposed for educating students towards scientific literacy (SL), including economic, utilitarian, cultural, democratic and moral (Millar, 2002; Osborne, 2000; Wellington, 2001) ones. These seem to derive from underlying visions of science. Roberts (2007) argued for the existence of two visions of science that generate different conceptions of SL, and therefore determine different curricular options. Vision I focuses on the internal perspective of science itself and sets as the goals of science education students' acquisition of knowledge and skills, leading them to think and act like a professional scientist would, with goals underpinned by traditional views of science education. Vision II is consonant with humanistic perspectives of science education (Aikenhead, 2006), viewing science both from the context in which scientific ideas and processes evolved, and from their role in society. In the educational context, this view seeks opportunities for students to integrate scientific ideas and scientific reasoning with moral reasoning and cultural considerations that underlie decision-making about socio-scientific issues (Roberts, 2007; Sadler & Zeidler, 2009; Lee et al., 2013). The present survey is guided by Robert's Vision II of science, & therefore, by the democratic argument. We here consider the interplay between Science, Technology, Society & Environment as a fundamental SL component (Calado, Scharfenberg & Bogner, 2015), conventionally labelled

as STSE issues (e.g., Kim & Roth, 2008; Pedretti & Nazir, 2011). According to this perspective, and in order to foster students' SL, educators need to promote understanding of the interactions between S&T and their influence in society and environment (Calado, Scharfenberg & Bogner, 2015).

Science textbooks have been suggested as a means to convey the notion of the "social context of science" (Green & Naidoo, 2008, p. 249). However, they may convey distorted views of S&T (Calado, Scharfenberg & Bogner, 2015) deriving from public and individual misconceptions. They are expected to follow the official syllabi and guidelines, but may also "contrast radically with the curricula and other steering documents" of a given country (Gericke, Hagberg, Santos, Joaquim, & El-Hani, 2014, p. 408). We decided to analyze the contribution of Portuguese natural sciences and biology textbooks to students' SL in the manner in which they approach STSE issues. In the positive sense, we seek ideas that help understanding STSE interactions. However, we also look for potential ideas or deficiencies indicating distorted views of S&T propagated by textbooks.

1.2. SL and STSE issues in genetics

Introducing STSE contents in classrooms has often been recommended as a method of confronting students with controversial socio-scientific issues, including those with moral and ethical implications (e.g., Gaskell, 1992; Kolstø, 2001). Particularly in such controversial aspects as human genetics & genetic engineering, decision-making may lead to moral dilemmas (e.g., gene therapy and cloning). Such issues therefore require complex reasoning and may allow students to engage in discussions and to make judgments, involving emotive considerations and personal values (Sadler & Zeidler, 2004). Genetics and gene technology are essential contents in biology curricula and affect important domains of human lives, such as reproduction, health and nourishment, as well as the environmental balance. However, they also include controversies concerning genetic processes and products (Bauer & Gaskell, 2002). For these reasons, we consider genetics to be an adequate field for surveying the approach to STSE issues of textbooks.

1.3.Textbooks: Support for teaching STSE or vehicles of mis(conceptions)?

Textbooks are considered to be powerful resources for science education, especially for approaching STSE issues (Calado, Scharfenberg & Bogner, 2015). However, even though the incorporation of STSE issues

into the curricula seems to be an international trend, most textbooks still fail to include perspectives from social science (Morris, 2014; Calado, Scharfenberg & Bogner, 2015).

Along with the promotion of STSE issues, distorted views of S&T deserve attention, as they may be conveyed to students through teaching practice in general and textbooks in particular. We specifically examine the distorted idea of a decontextualized and socially neutral view of science and technology (DSNVST; Fernández et al., 2003; Calado, Scharfenberg & Bogner, 2015): Science is either exalted as being the absolute source of progress in society or, alternatively, S&T (perceived as applied science) are presented as being solely responsible for environmental degradation, and therefore to be rejected. That is, DSNVST ignores the responsibility of other agents of decision (Fernández et al., 2003; Stinner, 1995) such as lawyers, politicians, entrepreneurs, and even citizens. DSNVST also disregards the efforts of S&T in solving problems that affect humanity and scientists' concerns with potential risks deriving from their own activity (Kolstø, 2001; Fernández et al., 2003). Approaching STSE issues in classrooms provides an opportunity for students to identify their own misconceptions and to replace them by correct ideas about the nature of science (NoS). On the other hand, simply including STSE content *per se* does not guarantee the conveyance of a fair image of the interactions involved. In previous work (Calado, Scharfenberg & Bogner, 2015), we recognized in German biology textbooks an orientation towards providing learning material concerning STSE issues in the context of genetics and gene technology. However, we also found deficiencies and detected some naive and inadequate ideas about S&T, which might contribute to the promotion of DSNVST. Our results suggested that some features of textbooks might be justified by the socio-cultural background in which they were conceived. Those conclusions led to the following research question: Does our set of criteria for analyzing STSE issues in textbooks reveal similar usefulness when applied to a different socio-cultural context?

1.4. Socio-cultural context and the science curriculum

Perceptions of the "impact of S&T on individuals and society" may vary substantially between different nations (Miller, 1998, p. 205). Local political decisions may be in conflict with educationally driven research findings concerning the inclusion of STSE issues into curricula (and learning materials). Which knowledge is of most value to a science curriculum is very

likely mostly oriented by economic criteria (Aikenhead, 2007), but might also be influenced to a certain extent by distorted S&T views of decision--makers. As Höttecke & Silva (2011) have argued, epistemological views are significant as they also seem to condition beliefs about science teaching. A community's perception of S&T might influence its expectations of science education. Both together may lead to particular STSE syllabi and, consequently, to particular science textbook profiles.

The final contents in the curriculum, and, ultimately, in textbooks, depend strongly on the arguments for promoting SL underlying the selection process (Calado, Scharfenberg & Bogner, 2015). Implementing STSE issues in school science curricula may be consonant with humanistic initiatives, as an alternative to traditional approaches, aiming to enable citizens to critically and rationally assess S&T (Aikenhead, 2007). However, science education is often intertwined with economic globalization; and is mainly concerned with generating scientists and technologists competent in developing mechanisms of production of goods and services (Bencze & Carter, 2011). Bencze & Carter (2011) found frequent statements in political documents urging school systems to prepare students to "compete in the global economy" (p. 651), thus contradicting the concerns of promoting a science education towards SL. This led to our second research question:

Are textbooks in an inclusive educational system, where diversity is privileged, independently of learners particular needs (Ainscow & César, 2006), conceived for targeting education for citizenship or are they more focused on preparing future scientists and technologists?

1.5. Transferring S&T views in science education

1.5.1 Public S&T views

Several studies have viewed science as a socio-cultural construct (Aikenhead, 1996; Hodson, 1998, Jenkins, 1992). As scientific knowledge has arisen from local contexts and in response to local needs, there might be as many sciences as there are contexts and cultures (Harding, 1998). On a smaller scale, science is seen as a system, reflecting the social position of individual groups and their role in society (Prpić , 2011), and resulting in a *cultural common sense notion of science* (Weinstein, 1998). Public S&T views seem therefore to derive from a combination of "cultural traditions, practical experiences, school learnings and mediatic messages" (Costa, Ávila & Mateus, 2002, p. 43).

Knowledge about science and understanding of the relationship between science and the other STSE spheres determine individual views, which, together with personal experiences and cultural values, might contribute to the development of a participative citizenship (Calado & Bogner, 2013). Gaskell (1992) has argued that both knowledge about and views of the object should be seen as influencing one's attitudinal judgements; and this perspective has guided debate in science education. Despite the necessary caution in avoiding simplistic cause-effect relations, knowing public attitudes in a particular context might help to interpret the S&T views displayed by textbooks.

Curriculum designers determine syllabus orientations by selecting and emphasizing some issues, while neglecting or excluding others. The language selected is affected by the prevailing ideology (Knain, 2001), since "the freedom to choose language resources... may differ immensely between cultures and individuals" (Liberg, Geijerstam & Folkeryd, 2007, p. 42). Either explicitly or implicitly, the narrative construction of S&T events is influenced by the corresponding socio-cultural context (Lakin & Wellington, 1994). One can therefore assume that science education, either by inclusion or by omission, reinforces a naive image of the scientific knowledge construction, which has been consolidated and become a socially accepted stereotype in a certain context. All these considerations led to our third research question:

Are prevailing public views of science reflected in textbooks?

1.5.2. Individual S&T views

Curriculum design teams might include scientists, science teachers, philosophers, sociologists of science, and science educators (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). The multidisciplinary character of these working groups may contribute to a balanced account in terms of S&T ideas, conveyed by the contents selected, the strategies proposed and by the discourse employed. Even so, some curricular documents display misconceptions about S&T (Calado, Scharfenberg & Bogner, 2015). Textbook writers are mostly teachers (Markert, 2013), who, as members of the general public with similar levels of education, are likely to hold similarly distorted views (Yates & Marek, 2013). Although textbook writing is supposed to follow the official pedagogical recommendations, both in terms of content selection and of didactical strategies, a re-contextualization that "creates space for changing" is intrinsic to the pedagogical discourse (Ferreira &

Morais, 2013, p. 5). Thus, one may expect textbook writers to transfer their own views to textbooks. Pre-service teachers may already hold a wide variety of views about NoS despite their Bachelor's degree in a science subject or in engineering (Aguirre, Haggerty, & Linder, 1990); and their views may diverge from recommended ones (Abd-El-Khalick & Lederman, 2000; Gil Pérez et al. 2005). Consequently, pre-service teachers may retain their own socially and culturally defined beliefs (Hollingsworth, 1989) as textbook writers later on.

Assuming that teachers' epistemological S&T views condition their beliefs about science teaching (Höttecke & Silva, 2011), one can assume from a constructivist view of teaching and learning that teachers as textbook writers will transfer their conceptions of teaching and of learning to the pedagogical orientation of textbooks (e.g., Aguirre et al., 1990; Carter, 2007). School textbooks are therefore, together with teachers, transmitters of social models, working as key agents that might contribute to the improvement of students' interests in, attitudes towards, and images of science (Christidou, 2011).

1.6. Textbooks as vehicles of misconceptions

Comparison of biology textbooks from eight countries has shown significant interactions between scientific knowledge and values (Selmaoui, Agorrama, Kzamia, Razoukia, Clément & Caravita, 2012). In this study, cultural, socio-economic and ethical dimensions were rarely found . Analyses of biology textbooks from sixteen countries have found implicit ideological messages, conveyed by representations of social conditions and beyond the messages of scientific content (Castéra, Sarapuu & Clément, 2013). These messages may have ethical, cultural and social implications (Clément & Castéra, 2013). Therefore, the integration of updated substantive S&T knowledge and of modern epistemological views about the STSE relationships are important requirements of SL.

Summarizing, school science textbooks might exert influence on students' views of science which "makes analysis of their content particularly important in order to determine their aspects or features negatively affecting youngsters' conceptions, interests and attitudes related to science, and formulate relevant suggestions for their design" (Christidou, 2011, p.151).

1.7. Objectives of the study

In order to answer to our first question we applied our criteria to Portuguese textbooks. First, seeking answers to our second research question, we examine the extent of STSE content in Portuguese natural sciences and biology textbooks for middle and secondary schools, Second, in order to answer our third research question, we examine the presence of inadequate S&T ideas, especially DSNVST as a barrier to the achievement of students' SL; and third, we examine syllabi and guidelines and include several social studies in order to isolate the view of S&T under study. Finally, we infer possible relationships between misconceptions displayed by textbooks and the constraints imposed by socio-cultural milieu, in terms of communication between S&T settings and the general public S&T, such as historical background, socio-economic development and values.

2. METHODOLOGY

2.1. The Portuguese socio-cultural context in terms of STSE issues

Differentiation among the European countries with respect to their attitudes towards S&T depends predominantly on stronger or weaker scientific and technological systems (Gonçalves & Castro, 2009). Portugal is a late-industrializing country (Fontes & Novais, 1998; Pepinsky, 2013), where scientific competencies at the level of public research, particularly in the field of biotechnology, have not been successfully transferred to industry (Fontes & Novais, 1998). Portuguese public opinion displays optimism towards biotechnology and a high acceptance of genetically modified organisms (GMO) (Kurzer & Cooper, 2007), with more supporters than opponents (Gaskell et al., 2006).

Several studies have pointed out that the greater scientific knowledge, the more positive the attitude to science (Sturgis & Allum, 2001), but there is also evidence that this linkage is weaker than supposed, in certain cases even negative with respect to specific technologies (Allum, Sturgis, Tabourazi, & Brunton-Smith, 2008). An ambivalent attitude is also observed where a relatively high scientific knowledge level coexists with positive attitudes, but also with readiness to criticism (Ávila, Gravito & Vala, 2000), frequently a precursor of public debate about socio-scientific issues. Costa, Ávila & Mateus (2002) pointed out that positive attitudes towards S&T are

strongly related to school attendance, in particular to the highest school grades. Portugal did not enact compulsory education effectively, and had a long period of only four-year compulsory education (Candeias, 1993), being among the countries where more than 50% of the population aged 25 to 64 had not completed upper secondary education (OECD, 2008). On the other hand, the Portuguese people have been subjected to long-term authoritarian politics, that disregarded public interests and discouraged capabilities in decision-making (Delicado & Gonçalves 2007), and is still experiencing an immature democracy (Menezes, 2003).These political constraints prevented the development of a strong and organized civil society (Roberts, 1995) where social movements and citizens' organizations could defend opinions and interests. The change of regime in 1974, despite brief experiences in popular mobilization during the revolutionary period, did not provide the platforms for public debate, and debate was confined to parliament (Santos & Nunes, 2004). Portugal has a short tradition of public communication of science (Gonçalves & Castro, 2009). Some controversies triggered by a more sensationalist than informative media have shaken Portuguese society; especially human cloning, which awakened emotional reactions, such as fear, anger and hysteria, and caused social tensions, thus moving public conceptions of science towards an unbalanced attitude on socio-scientific issues (Reis & Galvão, 2004).

2.2. The Portuguese educational context

Portuguese schools embrace a considerable diversity of students, for instance, children from immigrant families, from minority cultures, and students with special education needs. Following the inclusive education principles of the national policy (César & Santos, 2006), the educational system adopted the ideal of "Schools for all" (César, 2003, p. 3; Turner, 2008, p. 2), integrating all children in one school type and following one curriculum (Vislie, 2003). In 2012, twelve years compulsory education was enacted. Before, 9th grade was the last grade for many children, even disregarding the high Portuguese rates of early school leavers (Portdata, 2014).

The textbook market continuously adapts its products to student diversity, supplying teachers with versatile didactic material, but also with textbooks offering partly simplified options, in order to fit heterogeneous classes. Despite the legislative directives to form diverse classes, Portuguese schools have autonomy for homogenizing classes, for promoting educational success, and for combating student dropout (ME, 2007).

In 2001, Portugal reformed the lower secondary curricula, and upper secondary curricula in 2004. The reform integrated STSE issues into both natural sciences (9th grade) and biology (12th grade) syllabi. Implemented within the theme *To live better on the Earth*, 9th grade guidelines repeatedly refer to "*contributing to the development of students' scientific literacy*" (Galvão et al., 2001, p. 4). They suggest a multidisciplinary approach, relating contents to students' daily lives; and they extensively recommend STSE relationships through exploration of both events in the history of science, and analysis of contemporary controversial issues as presented by the media. The 12th grade guidelines (Mendes, Rebelo, & Pinheiro, 2004) address students' citizenship as well as the acquisition of basic biological knowledge and scientific skills. They also emphasize the role of substantive knowledge in individual decision-making, the importance of understanding science as a human endeavor, dependent on the context in which it develops, and the mutual influence of biology/biotechnology and society, including ethical dimensions. The guidelines suggest "exploring explicit and reciprocal relationships between Science, Technology and Society" (Mendes Rebelo & Pinheiro, 2004, p. 9), including the component *environment* with references to environmental risks. Concepts of gene technology in particular are presented in a problem solving context, starting from the identification of social problems, through the contents, to possible solutions. Nonetheless, limitations of S&T are scarcely referred while approaching genetics issues.

2.3. Characterization of the Textbooks Sample

We selected four Portuguese textbooks (student versions), two each for the 9th and 12th grades, as the textbooks most adopted in the school year 2013/2014 (data provided by DGE[1]) for our subjects and school grades. They represent two publishers. Pair One: 9th grade natural sciences textbook P9-1 (Antunes, Bispo & Guindeira, 2014) and 12th grade biology textbook (P12-1 (Matias & Martins, 2009); Pair Two: 9th grade natural sciences textbook P9-2 (Motta & Viana, 2014) and 12th grade biology textbook P12-2 (Silva et al, 2006).

Both 9th grade textbooks allocate genetics issues to two chapters. P9-1: *Fundamentals of Heredity* (17 pp.) include the contributions of genetic

[1] Direção-Geral da Educação [General Direction of Education], Portuguese Ministry of Education.

engineering towards the solution of contemporary problems; *Science and Technology in the Resolution of Individual and Social Health Problems* integrates previous genetics contents with non-genetic contents. P9-2: *Fundamentals of Heredity* (20 pp.) and *Science and Technology in the Resolution of Individual and Social Health Problems- Assessment and Management of Risks* (4 pp.). Our 12th grade textbooks differ in the number of chapters. P12-1: *Genetic Patrimony* (67 pp.), *Changes in Genetic Material* (38 pp.) including *Fundamentals of Genetic Engineering,* and *Food Production and Sustainability* (28 pp.) including genetics in sub-chapter *Exploration of the Potential of Biosphere*. In the latter, specific sections refer to STSE relationships. P12-2: *Genetic Patrimony* (84 pp.) comprises the sub-chapters *Genetic Heritage* and *Changes in Genetic Material*, the latter including *Fundamentals of Genetic Engineering;* and *Food Production and Sustainability* (104 pp.) including the sub-chapters *Food Obtained by Genetic Manipulation*, *Genetic Engineering and Plants Improvement*, *Genetic Engineering and Animal Breeding* and *Genetic Control*.

2.4. Qualitative Analysis

We based our study on Product Oriented Research (Cabral, 2005). Textbooks present interpretations beyond their content. Extracting their meaning and assumptions requires qualitatively deductive content analysis (Elo & Kyngäs, 2008; Pingel, 2010). We applied such an analysis using our previously proposed set of criteria and sub-criteria (Table 1). Those six criteria may be summarily explained as follows (for details, see Table 1 and Calado, Scharfenberg & Bogner, 2015).

i) Science and Technology Events and Their Social Contextualization: Scientists and educators agree that social and historical contexts have affected scientific ideas, especially, concerning the way in which science is executed, interpreted and accepted by society. Participative citizenship requires therefore, awareness of how scientific work is conditioned by the social, historical, moral and spiritual contexts.

ii) Interplay between Science and Technology: Science and technology are regarded as distinct entities, often explicitly distinguished by their different purposes. Pragmatic definitions of each entity offer two possible relationships: technology helps science or science helps

technology. For instance, technology often precedes science, while scientific knowledge may play an important role in technological processes. On the other hand, technology has often been seen as a by-product of applied science. This idea has been viewed as the simplest misconception of interplay between science and technology, and as to reinforce distorted views of science.

iii) Science and Technology as a Means to Solve Social Problems: For this criterion, two different perspectives may apply: One, where technology is naively portrayed as a mere product of science may tend to praise science. While science education tends to integrate technology elements, it may focus on applications of technology by promoting products and disregarding technological processes. A balanced compromise may shift away from the paradigm of technology as being applied science, towards a view of technology as an autonomous entity that seeks to overcome problems by invention. Another perspective is that, by highlighting problems that motivated research, may help students to appreciate science and technology as a human enterprise committed to satisfy societal needs and solve societal problems. However, students should also understand the limitations intrinsic to science and technology and that they are somehow socially constrained

iv) Risks and Impacts of Science and Technology: Many political and moral dilemmas originate in science and technology, requiring the need to balance reasons for potential and/or real risks and economic benefits. Students should appreciate the social impact of scientific and technological changes in their daily lives and also analyse risk minimisation and undesired side effects.

v) Controversial Issues: Controversial issues are frequently handled by mass media from a common sense perspective. Although the media constitute an important forum for discussing this issues, their messages often rely on limited or even one-sided information and ignore potential co-existing options. Citizens need to possess scepticism, open-mindedness, critical thinking, inquiry, ambiguity or even skills in the interpretation of data-driven knowledge.

vi) Decision-Making Process: Concerning STSE Issues, a curriculum should foster the ability to make decisions about science-related social and environmental issues. According to our view, five aspects may counteract a student's misunderstanding of the relationship

between science and technology in this context: specification of concrete legislation, awareness that decisions differ according to their social context, personification of decision agents, and awareness of the fact that common citizens may influence decisions. This misunderstanding may lead to the misconception that environmental degradation only is caused by science. Therefore, textbooks should also enable students to learn about making choices and participating in political decisions.

We analyzed STES statements by identifying the co-variation between text and context (Knain, 2001). We recorded all the statements matching our set of criteria and sub-criteria (Calado, Scharfenberg & Bogner, 2015). As recommended (Pingel, 2010), we combined the content analysis with a quantitative frequency analysis in order to identify deficits in the treatment of STSE issues, and to detect indicators of DSNVST (for details and representative examples, see Table 1). We randomly selected 12% of the textbook statements (127 of 1019 statements) for a second intra-rater and inter-rater categorization. We computed Cohen's Kappa coefficient (Cohen, 1968) and obtained Kappa values of 0.94 (intra-rater reliability) and of 0.77 (inter-rater reliability). The first is regarded as "almost perfect", the second as "substantial" (Landis & Koch, 1977, p. 165).

2.5. Quantitative Analysis

We valuated all statements equally and examined contingencies between criterion frequencies by computing Pearson's adjusted contingency coefficient *C* (Pearson, 1904). Applying cross-tabulations, we examined the observed versus the randomly to be expected statement frequencies. Due to multiple testing, we decreased the alpha level to .005 and treated only contingencies of *C*> .200 as relevant. To avoid bias, we compared the ratio between statement frequencies and number of pages. Both the 9th grade books and the 12th grade books did not differ pair-wise (P 9-1 and 9-2: Chi square 0.594; $df = 2$; $p = .640$; P 12-1 and 12-2 Chi square 0.297; $df = 2$; $p = .140$; ratio (statements/page number): P9-1 148/33 = 4.5; P9-2 131/22 = 6.0; P12-1 346/102 = 3.4; P12-2 387/124 = 3.1).

Table I
Definitions, textbook examples and textbook frequencies of all criteria and sub-criteria (sub-criteria headed by the criterion, keywords in textbook statements in *italics*)

Sub-criterion	*Definition*
	S&T (S&T) events and their social contextualization
	Mentioning and/or suggestion of
Event per se	*… a scientific or a technological event*
Event time	*… the time the event took place*
Event place	*… the place the event occurred*
Underlying problem	*… the social problem that motivated research regarding the event*
Favorable factors	*… factors favorable for the event*
Obstacles	*… factors representing obstacles*
	Interplay between S&T
Distinction	*S&T are distinguished.*
T towards S	*A T device or process is useful for achieving S knowledge.*
S towards T	*S knowledge is useful or even indispensable for T advancements.*
S & applied S	*T is seen as applied S*
	S&T as means to solve societal problems
	Mentioning and/or suggestion of
Potential applicability	*… potential applicability of S&T in the future*
Applicability	*… real benefits of S&T processes or devices*
Costs	*… costs of S&T processes or devices*

Textbook example	Textbook Frequencies			
	P9-1	P9-2	P12-1	P12-2
	49	36	166	126
Watson and Crick presented the tridimensional DNA model (P9-1, p. 78).	20	12	68	55
At the end of the 20th century (P9-1, p. 206)	18	11	63	43
An English crystallographer (P9-2, p. 66)	4	7	7	7
… infertility problems, hereditary diseases (P9-2, p. 76)	7	6	21	13
This disease is … well known since it has affected … European royal families (P12-1, p. 111)	0	0	5	3
Human genetic research faced great difficulties for several years (P12-2, p. 103)	0	0	2	5
	10	11	16	17
… genetic engineering, whose aim is the direct manipulation of genes with a practical goal (P12-1, p. 167)	6	8	7	6
In recent years, techniques of molecular genetics have triggered a veritable explosion of knowledge (P12-2, p. 103)	1	1	6	3
The success of biotechnology is certainly not irrelevant to the advancement of scientific areas (P12-1, p. 226p)	2	1	3	5
… to the citizens, whom the products of science target (P12-2, p. 56)	1	1	0	3
	41	22	96	109
While some scientists ensure that the future of human nutrition is in scientists' hands, other … (P9-2, p. 183)	7	3	19	38
A Portuguese scientist team developed a pioneer technique … for application in ... (P9-1, p. 86)	27	13	66	63
… managed to reduce production costs (P12-1, p. 169)	2	2	2	2

Sub-criterion	*Definition*
Limitations	*… limitations of S and/or T*
	Risks and impacts of S&T
	Mentioning and/or suggestion of
Risks	*… risks of S&T*
Social impact	*… potential and/or real S&T impact on society*
Local environmental impact	*… a local potential and/or real S&T environmental impact*
Global environmental impact	*… a global potential and/or real S&T environmental impact*
	Controversial issues
	Mentioning and/or suggestion of controversial issues
Different perspectives	*… given with different perspectives*
Conflict values	*… by referring to values interfering with decisions*
Involved interests	*… given with potentially involved interests (e.g., social, individual, political and/or economic ones).*
Different sources of information	*… presented with different information sources conveyed by media*
	Decision making process
	Mentioning and/or suggestion of
Legislation	*… legislation processes and/or results*
International comparison	*… decisions by comparing international realities concerning legislation*
Agents	*… the agents involved in decision making*
Citizen participation	*… the citizens as participants in decisions (e.g., as consumers, as voters, as informed human beings)*

Textbook example	Textbook Frequencies			
	P9-1	P9-2	P12-1	P12-2
It is possible within certain limits to improve agricultural production (P12- 2, p. 316)	5	4	9	6
	22	26	25	60
Currently the long-term effects of this practice are still unknown (P9-1, p. 215)	11	17	19	29
Society must be attentive ... and denounce any attempt to put human health at risk... (P9-2, p. 77)	7	5	4	20
... others consider [Bt corn], a threat to the ecological balance, compromising the entomofauna (P12-2, p. 298)	3	0	0	3
The extent to which GMOs ... can affect the balance of ecosystems? (P12-1, p. 46)	1	4	2	8
	22	26	15	40
The utilization of embryos for the extraction of stem cells is very controversial (P9-1, p. 86)	16	10	5	16
Is it right to modify or create new living beings? (P9-2, p. 77)	5	10	5	19
For doctors, ... means better prevention, … will dominate the debate between environmentalists and the interests of industry … (P12-2, p. 298)	1	1	3	4
Excerpt from the magazine Visão, 15th January 2009 (P12-1, p. 69)	0	5	2	1
	12	10	27	35
The establishment of norms and rules that ensure the continuity of research is required … (P9-1, p. 89)	7	1	16	9
The Food and Drug Administration ... commissioned the National Academy of Sciences to conduct a survey (P9-2, p. 80)	1	0	4	7
National Ethic Council (P12-1, p. 121)	3	3	2	3
As citizens ..., we cannot remain mere spectators) (P12-2, p. 56)	1	6	5	16

3. RESULTS

We identified 1019 STSE statements in all four textbooks (for examples, see Table I). They complied with all the six criteria and at least 26 sub-criteria in each textbook (see Table I).

9th grade textbooks did not differ at the level of either the criteria or the sub-criteria (*C* values with $p \geq .074$). Regarding the criterion *S&T events*, both textbooks lacked the sub-criteria *favorable factors* and *obstacles* (Table I). With respect to the criterion *risks and impacts of S&T*, P9-2 lacked the sub-criterion *local environmental impact*. Regarding criterion controversial issues, P 9-1 lacked *different sources of information*. Finally, P9-2 lacked the sub-criterion *international comparisons* in *decision -making processes*.

12th grade textbooks differed at the level of the criteria and of the sub-criteria ($C = .248$ and $C = .328$; in both cases: $p < .001$, $n = 732$), revealing two different statement patterns. For criterion *S&T events and their social contextualization*, P12-1 showed a higher statement frequency than randomly to be expected (166 observed [o.] vs. 138 randomly to be expected [e.] statements), in comparison to P12-2 showing a lower frequency (126 o. vs. 154 e.); especially in the sub-criterion *event time* (P 12-1: 63 o. vs. 50 e.; P 12-2: 43 o. vs. 56 e.). In contrast, P12-2 provided more statements in the criterion *risks and impacts of S&T* (P 12-1: 25 o. vs. 40 e.; P 12-2: 60 o. vs. 45 e.). In particular, P 12-2 provided more statements related to *social impacts* (P 12-1: 4 o. vs. 11 e.; P 12-2: 20 o. vs. 13 e.) and to *environmental impacts* (P 12-1: 2 o. vs. 6 e.; P 12-2: 11 o. vs. 7 e.). Similarly, P 12-2 scored higher with respect to the criterion *controversial issues* (P 12-1: 15 o. vs. 26 e.; P 12-2: 40 o. vs. 29 e.). Especially P 12-2 out-performed P 12-1 in the sub-criteria *different perspectives* (P 12-1: 5 o. vs. 10 e.; P 12-2: 16 o. vs. 11 e.) and *conflicting values* (P 12-1: 5 o. vs. 11 e.; P 12-2: 19 o. vs. 13 e.). In the criterion *decisionmaking process*, P 12-2 stood out in the sub-criterion *citizen participation* (P 12-1: 5 o. vs. 10 e.; P 12-2: 16 o. vs. 11 e.). Regarding the DSNVST, P12-1 made no reference to the distorted idea *technology as applied science*, contrasting to P 12-1 that offered three indicators of this inadequate idea.

We generally found about two and a half times as many statements within the 12th grade books compared to the 9th grade books (P 9: $n = 287$; P 12: $n = 732$). When relating these differences to the given page numbers (see above), both book pairs also differed ($\chi^2 = 8.387$; $df = 2$; $p = .01$). Analyzing the ratios *statements/number of pages* between the four textbooks (P9-1 4.5; P9-2 6.0; P12-1 3.4; P12-2 3.1; for details, see above) showed higher ratios for the 9th grade books.

9th and 12th grade textbooks differed both at the level of the criteria and of the sub-criteria ($C = .220$ and $C = .301$; in both cases: $p < .001$, $N = 1019$), showing different statement patterns. Regarding the criteria *S&T events and their social contextualization* and *S&T as means to solve societal problems*, P12 textbooks contained more statements (292 o. vs. 271 e. and 205 o. vs. 193 e.), in contrast to P9, whose texts contained fewer statements (85 o. vs. 106 e. and 63 o. vs. 76 e.). P12 textbooks outperformed P 9 textbooks in the sub-criteria *events per se* (123 o. vs. 111 e. and 32 o. vs. 44 e.) and *favorable factors,* neither of which were mentioned in theP9 books. On the other hand, P9 textbooks contained more statements regarding the criterion *controversial issues* (48 o. vs. 29 e.), compared to P12 textbooks with slightly more statements, but fewer statements than randomly be expected (55 o. vs. 74 e.). In particular, we found this in the sub-criterion *different perspectives* (P 9: 26 o. vs. 13 e.; P 12: 21 o. vs. 34 e.). Regarding the DSNVST, P 9 and p12 texts contain only few statements referring to the distorted idea *technology as applied science* (in total, 2 vs. 3 statements).

4. CONCLUSIONS

We first discuss STSE approach in textbooks according to their criteria and sub-criteria frequency profiles. Second, we discuss the detected indicators of DSNVS. Third, we look for relationships of our findings in the Portuguese context, both in terms of educational system, and of socio-cultural context. Finally, we consider implications for students' SL.

4.1. Comparison of textbooks

Despite stemming from the same nation and, therefore, being subject to the same official guidelines, the textbooks analyzed revealed somewhat different profiles, but also some similarities. We discuss the main differences and/or similarities vertically between P9 and P12 as well as horizontally between P9-1/-2 and P12-1/-2 ; the first to draw inferences about the differential investment in students' SL in the middle school and in the high school.

4.1.1. Approach to STSE

Regarding the vertical comparison, we identified two remarkable results. Quantitatively, the 12th grade textbooks provided about two and a half times more statements concerning STSE issues than the 9th grade textbooks. That might derive from the decision to treat more superficially both substantive

knowledge (genetics) and technological aspects (gene technology) in the earlier grade, while deepening them in the later one. However, the comparison of the ratios *statements/number of pages* between the different grades suggests that P9 books, in comparison with P12 ones, privileged frequency rather than depth (see below). Qualitatively, examination of statements confirmed that 9th grade textbooks very often provided superficial references instead of detailed reasoning (e.g., regarding transgenic plants; P9-2, p. 183; P12-2, p. 296-298); that is, we found a superficial STSE approach in P9 books, in dissonance with Portuguese 9th grade guidelines.

Turning to the horizontal comparisons, the quantitative analysis showed that 9th grade textbooks yielded similar profiles, while the 12th grade ones displayed two different patterns. This variability might be caused by adding or omitting fundamental information when discussing complex issues. Subsequently, we discuss compliance with our criteria and sub-criteria in detail. Considering *S&T events and their social contextualization*, P12 books quantitatively out-performed P9 ones, especially in regard to *event per se* and *favorable factors*. However, all the textbooks mostly referred to *events per se* and the *event times* as the mode of social contextualization. The *underlying problem* (that motivated research) was approached by the textbooks in less than a half of the *events per se* (see Table I). That is, most events were not presented as having been motivated by a social problem. Focusing on scientific and technological achievements without describing the processes that underlie them may lead to the simplistic view that scientific and/or technological problems have been overcome without difficulties (Gardner, 1990). We therefore argue for our sub-criteria *obstacles* (as social constraints) and *favourable factors* as indicators that scientific advancements did not occur by chance, but have been influenced by the socio-scientific situation (Calado, Scharfenberg & Bogner, 2015). Factors positively or negatively influencing events were poorly approached by P12 books and completely disregarded by P9 ones. However, we found attempts to connect S&T events to their social milieu.

We considered both historical and contemporary events, though without distinguishing them. Nevertheless, despite the presentation of the historical development of concepts, none of the textbooks provided an adequate contextualization of S&T events. Our results confirm that the history of science as presented does not display an adequate picture of science (Leite, 2002). We previously found a similar pattern in German biology textbooks (Calado, Scharfenberg & Bogner, 2015).

We considered *costs* as economic constraints and *limitations* as technical constraints of S&T that have to be surmounted (Calado, Scharfenberg & Bogner, 2015). Here, all the textbooks scored quite modestly, when compared with the emphasis given to the positive aspects, such as *potential* and the current *applicability* of products. However, awareness of the benefits of those enterprises, of their constraints, and of their potentially negative implications is required for critically analyzing controversial issues and for objectively judging related economic interests and political decisions (Calado & Bogner, 2013).

When comparing textbooks vertically, P12 books provided a wider contextualization of events, particularly in terms of the social problems underlying research. The relative relevance they gave to the inputs of society into S&T seems to rest on the curricular option of approaching socio-scientific issues in the context of *Food production and sustainability*, where S&T advancements are explicitly approached as solutions for social problems. P12 textbooks therefore reflect the orientations of Portuguese science education policy enacted during the last decade.

In respect *risks* and *impacts*, all the textbooks approached *risks* frequently, while references to *social impacts* and to *environmental impacts* are seldom, with the exception of P12-2, which provided nearly half of all such statements and more than half of all *social impact* statements (Table 1). P12-2 especially used the term (social) "impact", and reinforced its meaning using dramatic and emotion-laden expressions; for instance, "Today the markets are invaded by transgenic [organisms]" (p. 141). All the books failed to adequately refer to the environmental dimension, with P9-2 and P12-1 completely neglecting the *local environment*, (Table 1). P12-2 discussed the potential disruption of ecological balance from a biocentric perspective, without connecting threats to human health. That is, potential environmental impacts of gene technology are worthy of improvement. This tendency was also found in other studies (Aivelo & Uitto, 2015; Clément & Castéra, 2013) as "in many cases they don't take environmental effects into consideration" (Kohring & Matthes, 2002, p. 148). A case study approach to "experimental releases of genetically modified (GM) insects" (Reeves, Denton, Santucci, Bryk & Reed, 2012, p. 1) or transgenic plants resistant to pesticides (Calado, Scharfenberg & Bogner, 2015) is recommended in order to awaken awareness about environmental impacts of GM organisms.

Regarding *controversial issues*, we again observed great variability both at the level of the criterion and of its sub-criteria. P9 books and P12-2 gave

high prominence to *different perspectives* while judging socio-scientific issues, as well as to *conflicting values* involved. However, *involved interests* were seldom mentioned in P9 and only touched upon in P12 books; the confrontation with *different sources of information* was absent in P9-1, rare in P12 books, and considerable in P9-2 (with 5 records; Table 1). Qualitatively, we found that Portuguese textbooks explicitly referred to the importance of values in judging genetics issues, what seems to result from an attempt to comply with guidelines, but scarcely connected them with values. However, the controversial character of STSE issues might have been emphasized by textbooks through providing *different sources of information*, thus conveying different points of view. Textbook P9-2, though scoring higher, mostly referred to simple titles of newspaper articles as a starting point for discussion, but lacked potential excerpts of documents illustrating diverse perspectives, interests, and values (e.g., Calado, Scharfenberg & Bogner, 2015).

Regarding the criterion *decision-making process,* there is no clear tendency, despite the descriptive differences displayed at the level of the sub-criteria. P12-2 stood out in referring to or suggesting *citizen participation,* while P9-2 lacked *international comparisons* of decision-making processes. Both P12 textbooks showed better compliance with this criterion than P9, particularly P12-2 with the sub-criterion *citizen participation*. However, P12-1 qualitatively outlined better the genetics issues in legislation terms, with references to American, European and Portuguese realities. Following the syllabus, P12-1 provided three references to "bio-ethics councils" (e.g., p. 121), but no reference dealt with local reality, remaining therefore abstract to students. All the textbooks scored low regarding *agents* involved in the decision-making process, which appears to reflect the lack of Portuguese regulation as well as the unfamiliarity of the Portuguese public with decision- making in these domains. Similarly, references to *citizen participation* were rare, with the exception of P12-2. No textbook presented a balanced picture of the regulation of scientific and technological activities in the context of genetic issues.

In summary, all four textbooks revealed similarities regarding references to *events* and information, but 12th grade textbooks complied better with the criteria than 9th grade ones and provided a more complete image of S&T. P9 books disregarded some aspects, like social factors and individual interests, that might have influenced events, while P12 books focused on them. Nonetheless, all the textbooks, though following some

of the guidelines, do not follow the corresponding holistic pedagogical principles.

In our qualitative analysis of syllabi and guidelines, we limited our scope to approaching STSE issues in the context of genetics. However, other authors (Calado, Neves, & Morais, 2013) have analyzed the broad guidelines to the middle school, corresponding to the 7th, 8th and 9th school grades (Galvão et al., 2001). On the one hand, they found a relatively high level of conceptual demands (in terms of the complexity of cognitive skills, of scientific knowledge and of inter-disciplinary relations between distinct subjects within biology). On the other hand, they argued that this level has decreased when transposed into the guidelines for teachers and textbooks writers. Moreover, this tendency towards a decreasing level of conceptual demand is even more evident in the re-contextualization in textbooks. In our view, superficial approaches might lack the empirical evidence required for discussing the impact of S&T achievements on society and the environment, representing therefore a limitation for adequately approaching STSE issues. A reductionist representation of phenomena, besides representing a limitation itself, might lack the prerequisites for introducing the context, in which S&T achievements developed.

Our analysis revealed a visible discrepancy between the textbooks' profile and some critical aspects expressed in both syllabi. We suggest that other factors might have intervened in the didactic transposition into textbooks. That might result from an attempt of publishers to address teachers' anticipations (as they are the textbook users) while providing them with learning materials adaptable to their didactical needs, preferences, and constraints. Indeed, some teachers showed that they experience reluctance or difficulty in approaching controversial issues (Chikoko, Gilmour, Harber, & Serf, 2011; Dawson & Venville, 2010); thus, confirming the often claimed urgency in preparing them for performing this task. However, the simplification of contents as observed (Calado, Neves, & Morais, 2013) requires further interpretations. We suggest a strategy to target weaker students or to fit homogenized weaker classes as a way to adapt to inclusion principles. We see this in the fact that 9th grade students did not reach an introductory stage; that is, they are not prepared for university education. In our sample, the abrupt transition from the 9th grade to 12th grade textbooks in terms of page numbers supports such explanations. Similarly, the different depth of approaching STSE issues made clear that final compulsory school grades and final secondary school grades set diverging goals and deal with

different student profiles. One might consider the lacks of STSE contents justifiable, since 9th grade students are considered still immature for understanding ethical and epistemological considerations.

4.1.2.2 Indicators of DSNVST

The absence or frequency of certain ideas might help to recognize indicators of DSNVST in a textbook (Gil-Pérez et al., 2005; Calado, Scharfenberg & Bogner, 2015). For potentially detecting the inadequate idea *T is seen as applied science,* we considered the criterion *interplay between S&T.* Concerning the sub-criterion *distinction*, all the textbooks more or less explicitly tended to distinguish S&T. However, we found some doubtful statements, mainly in P9-2, for instance, "Science and technology have been able to manipulate genes of living beings" (p. 74). The P12 textbooks showed increased accuracy, for instance, in P12-2, "Biotechnology is an interdisciplinary area, where knowledge and practices coming from several subjects … encounter each other" (p. 199). Especially, we found the DSNVST indicator *T as applied science* in three textbooks, except for P12-1. This absence is consistent with the explicit distinction of both entities interacting with each other "Biotechnology ... can be considered as resulting from the re-union between engineering and life sciences" (p. 226). Despite considering both entities distinctly, rare statements of this DSNVST indicator persist and the mutual support of S&T is under-represented, particularly in P9 textbooks (see Table 1). P12 books adequately contextualized events (see above), P9 books insufficiently; this is one more indicator of DSNVST.

Considering the sub-criteria *potential applicability* and current *applicability* together, we verified that P12 books placed the emphasis in positive aspects of *S&T as means to solve problems*, in detriment of the negative ones, perhaps based on the explicit emphasis given to this aspect in the syllabus. Specifically, P12-2 contains enthusiastic messages, such as "It seems not to have limits" (p. 132), "Has the genius come out of the lamp?" (p. 132), "sophisticated and amazing techniques" (p. 132), as well as expressions such as "to stop the hunger in the world" (appearing three times; pp. 225, 270 and 300). Together, the emphasis placed in S&T products and the high enthusiasm indicate the presence of DSNVST, probably a reflex of the current industrial stage of Portugal, where positive attitudes towards S&T are dominant and controversies lacking (Inglehart, 1990). This emotional approach might also result from an attempt to trigger emotions, in

order to increase motivation (Spitzer, 2007). On the other hand, it seems to mimic the Portuguese sensationalist media discourse, which frequently uses metaphors (Reis & Galvão, 2004), in order to convey (either positively or negatively) powerful messages (Liakopoulos, 2002). Consonant with that enthusiasm, all the textbooks practically disregard the constraints associated with S&T, such as costs of research, of development, and of production, as well as the limitations of S&T, thus once again re-inforcing DSNVST.

As referred to above, all the textbooks stressed risks inherent in using genetic information or applying gene technology. Both P9 books and P12-1 explicitly or implicitly considered the importance of *risks*, but often without providing empirical evidence or referring to the domain of impact; that is, messages remained incomplete. Risks for human health were dominant, but the books provided few links to empirical evidence of social and environmental impacts. Consequently, we recognized a tendency to a socially neutral approach of *risks* and *impacts*, and therefore to DSNVST. Perhaps for the same reasons, the books exclude the opposite view that blames S&T for environmental degradation. Regarding *controversial issues*, P12-1 almost failed to present the human dimension of S&T, pointing out once more its socially neutral approach.

The criterion *decision-making process* provided some variation. The sparse clarification of *agents of decision*, displayed by all textbooks, as well as disregarding *citizens' participation* as their right and duty, displayed by P9 books and P12-1, might implicitly indicate that scientists alone are responsible for the negative implications of S&T, representing also an indicator of DSNVST.

In summary, although introducing the social component, all the textbooks provided a quite incomplete picture in terms of both inputs and outputs of S&T and, therefore, tended to the naive DNSVST. On the other hand, the lack of environmental impact derived from the opposite view of DSNVST. Even P12-2, which scored comparatively high in referring to environmental impact, discharged scientists and technologists to a certain extent from the responsibility of alone deciding socio-scientific issues, while discussing *legislation*, *agents of decision*, and emphasizing *citizen participation*. Results of qualitative analysis of statements referring to environmental impact also excluded the distorted opposite view of DSNVST in P12-2. P9 textbooks in particular presented several indicators of DSNVST, since some social aspects of science were hardly approached and significant

ideas were lacking. The simplification of contents referred to above might confirm this assumption, perhaps resulting from the dominance of market dynamics over syllabus. P12 books were much centered on the S&T products and revealed both high expectations, and great enthusiasm towards them. Despite a trace of the DSNVST, P12-2 made an attempt to show the relationship of S&T with the social sphere and the environment. In contrast, P12-1 displayed a different profile, while contextualizing fairly the inputs of society into science and portraying the interplay between S&T in a balanced way, lacking however, or approaching insufficiently, important aspects related to the outputs of science in society and in the environment.

4.1.3. Views of S&T and socio-cultural context

Within P9 textbooks, we found no the reflection of positive attitudes towards S&T, which correlate with public knowledge about science in a country at an industrial stage (Inglehart, 1990). The ratio between positive aspects (*potential applicability* and *applicability*) and negative ones (*risks* and *impacts*) is quite balanced. Indeed, our results seem to reflect more distrust in respect of science (and technology; see Prpić, 2011) than indifference (see Gaskell et al., 2006). Positive attitudes seem to be mirrored in P12-1, where they clearly outnumber the negative ones. In this respect, P12-2 revealed high enthusiasm and expectations towards the achievements of S&T, though having fairly observed the negative aspects in quantitative terms.

Regarding *controversial issues*, P12-1, interestingly, referred explicitly to the "ethic and religious implications [of genetic issues]" (p. 177), "the phantom of eugenics" (p. 69) and the suspicion about eventual "eugenic and discriminatory policies" (p. 177) among the five references alluding to values. Nonetheless, P12-1 lacked concrete and contextualized examples, pointing to a superficial and sensationalist exploration of controversies, devoid of local context. We perceived an attempt to follow the guidelines, mainly by referring explicitly to ethical considerations, but barely presenting cases where such considerations should be applied. Assuming that enthusiastic or sensationalistic messages have the purpose of raising students' interest for S&T, they might reveal commitment to the economical argument for SL, justified by a society struggling for scientific and technological development. The re-incidence of these emotional and explicit statements, lacking evidential support, seems to mirror public inexperience in genetics and in gene technology as well as in legislation of genetics issues. Similarly,

the timid references to *different sources of information* might reflect the unfamiliarity with controversies in these domains as well as with media" specialized in genetic issues. Therefore, assuming that textbooks to some extent reflect the predominant public views, our results suggest the prevalence of a naive perception of S&T of the Portuguese public.

The co-existence of ideas that can be argued as DSNVST indicators and of ideas indicating non-DSNVST views might be explained as follows: First, STSE issues might have been acquired from different sources (e.g., literature) to textbooks; second, some confusion concerning the recent incorporation of the concept SL and its components (e.g., NoS) in educational systems; and third, inconsistency of the teachers' education programs, as textbook writers are frequently teachers.

4.2. Implications for students' SL and recommendations

First, STSE approach in Portuguese 9th grade requires particular consideration. The ninth grade provides a first contact with genetic issues. One may assume that students exposed to learning materials would have the chance of filling remaining gaps and of reconstructing persistent alternative conceptions in the 12th grade. However, the observed gaps in our textbooks are a matter of concern, since at the time of their publication, the 9th grade was the final year of compulsory education. For many students, who dropped out at the end of the middle school, it was the last chance to acquire the knowledge and engage in this kind of reasoning in an academic context. Therefore, if the inclusive system pursues the ideal of "Schools for all" (César, 2003), aligned with the goals of a civic SL (Miller, 1998), that simplification "contributes to increasing the gap between students with different socio-economic backgrounds" (Calado, Neves & Morais, 2013, p. 20). That is, it moves away from the goal of science for all, and endangers the public's SL.

Second, regarding STSE content, textbook writers may overcome these hindrances by judiciously selecting events in view of their potential for representing the interactions between S&T and between S&T and society and environment. Textbook content and language should elucidate how a certain final concept or product has been achieved, both from the internal (scientific community) and from the external (society and environment) perspectives of the scientific and technological enterprises (Leach, Millar, Ryder & Séré, 2000; Rudolph, 2003). Simple disconnected details should be replaced by complete, structured and diverse case studies, thus

providing a more realistic development. A classic example is the Human Genome Project as it provides an overview of those interactions (Calado, Scharfenberg & Bogner, 2015). Additionally, links to environmental (local and global) concerns should be considered. Being scientifically literate requires awareness of the global implications of genetics and gene technology events, based on textbook approaches being suitable for the target population.

Third, introduction of STSE issues, despite following an international trend, still represents a challenge to both curriculum developers and teachers (Morris, 2014). The addition of STSE material into textbooks and in science lessons must be accompanied by the awareness that textbook writers' and teachers' views of S&T might influence students' views (Calado, Scharfenberg & Bogner, 2015). Moreover, the awareness that one's S&T views have likely been influenced by one's socio-cultural milieu may increase the probability of detection of inadequate views and their replacement by correct views of those human enterprises.

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LIST OF ACRONYMS

DSNVST	Decontextualized and socially neutral view of science and technology
GMO	genetically modified organisms
NoS	Nature of science
SL	Scientific literacy
STSE	Science-Technology-Society-Environment
S&T	Science and technology

Bibliographic references

Ainscow, M., César, M. (2006). Inclusive education ten years after Salamanca: Setting the agenda. *European Journal of Psychology of Education*, *21*(3), 231-238.

Abd-El-Khalick, F., Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education*, *22*(7), 665-701.

Aguirre, J. M., Haggerty, S. M., Linder, J., C. (1990). Student-Teachers' Conceptions of Science, Teaching and Learning: a Case Study in Preservice Science Education. *International Journal of Science Education*, *12*(4), 381–390.

Aikenhead, G. S. (1996). Science Education: Border Crossing into the Subculture of Science. *Studies in Science Education*, *27*(1), 1–52.

Aikenhead, G. S. (2006). *Science Education for Everyday Life: Evidence-based Practice*. New York, NY: Teachers College Press.

Aikenhead, G. S. (2007). Humanistic perspectives in the science curriculum. In S. K. Abell, N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 881-910). Mahwah, N J: Lawrence Erlbaum Associates, Publishers.

Aivelo, T., Uitto, A. (2015). Genetic determinism in the Finnish upper secondary school biology textbooks. *Nordic Studies in Science Education*, *11*(2), 139-152.

Allum, N., Sturgis, P., Tabourazi, D., Brunton-Smith, I. (2008). Science knowledge and attitudes across cultures. *Public Understanding of Science*, *17*(1), 35–54.

Antunes, C., Bispo, M., Guindeira, P. (2014). *Novo Descobrir a Terra 9*. Porto: Areal Editores.

Ávila, P., Gravito, A. P., Vala, J. (2000), Cultura científica e crenças sobre ciência [Scientific culture and believes about science]. In M. E. Gonçalves (org.). *Cultura Científica e Participação Pública* [Scientific culture and public participation] (pp. 19-31), Oeiras: Celta Editora.

Bauer, M.W. Gaskell, G. (2002). Researching the public sphere of biotechnology. In M. Bauer, G. Gaskell, (Eds.), *Biotechnology -The Making of A Global Controversy* (pp. 1–17). Cambridge, UK: Cambridge University Press.

Bencze, L.,Carter, L. (2011). Globalizing students acting for the common good. *Journal of Research in Science Teaching*, *48*(6), 648–669.

Cabral, M. (2005). *Como Analisar Manuais Escolares* [How to Analyse Textbooks]. Lisboa: Texto Editores.

Calado, F., Bogner, F. (2013). A Reflection on Distorted Views of Science and Technology in Science Textbooks as Obstacles to the Improvement of Students' Scientific Literacy. *European Journal of Educational Research*, *2*(2), 51–68.

Calado, F., Scharfenberg, F., Bogner, F. (2015). To What Extent do Biology Textbooks Contribute to Scientific Literacy? Criteria for Analysing Science-Technology-Society-Environment Issues. Education Sciences, 5, 255–280.

Calado, S., Neves, I. P.,Morais, A. M. (2013). Conceptual demand of science curricula: a study at the middle school level. *Pedagogies: An International Journal*, *8*(3), 255–277.

Candeias, A. (1993). Políticas educativas contemporâneas: Críticas e alternativas. [Contemporary educational policy: criticism and alternatives] Faculdade de Psicologia e Ciências da Educação, Universidade do Porto. Retrieved from http://repositorio.ispa.pt/handle/10400.12/1619.

Carter, L. (2007). Sociocultural influences on science education: Innovation for contemporary times. *Science Education*, *92*(1), 165–181.

Castéra, J., Sarapuu, T., Clément, P. (2013). Comparison of French and Estonian students' conceptions in genetic determinism of human behaviours. *Journal of Biological Education*, *47*(1), 12–20.

César, M., Santos, N. (2006). From exclusion to inclusion: Collaborative work contributions to more inclusive learning settings. *European Journal of Psychology of Education*, *21*(3), 333–346.

César, M. (2003). A escola inclusiva enquanto espaço-tempo de diálogo de todos e para todos [Inclusive schooling as a dialogical space-and-time of all and for all]. In D. Rodrigues (Ed.), *Perspectivas sobre a inclusão: Da educação à sociedade* (pp. 119-151). Lisboa: Porto Editora.

Chikoko, V., Gilmour, J. D., Harber, C., Serf, J. (2011). Teaching controversial issues and teacher education in England and South Africa. *Journal of Education for Teaching*, *37*(2), 5-19.

Christidou, V. (2011). Interest, attitudes and images related to science: Combining students' voices with the voices of school science, teachers, and popular science. *International Journal of Environmental Science Education*, *6*(2), 141–159.

Clément, P., Castéra, J. (2013). Multiple Representations of Human Genetics in Biology Textbooks. In D. Treagust, C. Tsui (Eds.), *Models and Modeling in Science Education*, vol. 7, (pp. 147-163). Springer Netherlands.

Cohen, J. (1968). Weighted Kappa: nominal scale agreement with provision for scaled disagreement or partial credit. Psychological Bulletin, 70, 213–220.

Costa, A. F., Ávila, P. D., Mateus, S. (2002). *Públicos da ciência em Portugal* [Publics of science in Portugal]. Lisboa: Gradiva.

Dawson, V. M., Venville, G. (2010). Teaching Strategies for Developing Students' Argumentation Skills About Socio-scientific Issues in High School Genetics. *Research in Science Education*, *40*(2), 133–148.

Delicado, A. & Gonçalves, M. (2007). Os portugueses e os novos riscos: resultados de um inquérito. *Análise Social*, 687-718.

Elo, S., Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*(1), 107–15.

Fernández, I., Gil, D., Vilches, A., Valdés, P., Cachapuz A., Praia, J., Salinas, J. (2003). El olvido de la tecnología como refuerzo de las visiones deformadas de la ciencia [Disregard of technology as an endorsement of the distorted views of science]. *Revista Electrónica de Enseñanza de las Ciencias*, *2*(3).

Ferreira, S., Morais, A. M. (2013). The Nature of Science in Science Curricula: Methods and concepts of analysis. *International Journal of Science Education*, *35*(16), 1–22.

Fontes, M., Novais, A. Q. (1998). The conditions for the development of a biotechnology industry in Portugal: The impact of country specific factors. *Technology Analysis & Strategic Management*, *10*(4), 497–509.

Galvão, C. , Neves, A, Freire, A. M., Lopes, A. M., Santos, M. C., Vilela, M. C., Oliveira, M. T., Pereira, M. (2001). Orientações curriculares para o 3.º Ciclo do Ensino Básico: Ciências Físicas e Naturais [Curricular guidelines for the 3rd. circle of basic education]. Ministério da Educação – Departamento da Educação Básica. Retrieved from http://www.dge.mec.pt/sites/default/files/ficheiros/eb_cfn_orient_curriculares_3c_0.pdf.

Gardner, P. L. (1990). The technology-science relationship: Some curriculum implications. *Research in Science Education*, *20*(1), 124–133.

Gaskell, P. J. (1992). Authentic Science and School Science. *International Journal of Science Education*, *14*(3), 265–272.

Gaskell, G., Stares, S., Allansdottir, A., Allum, N., Corchero, C., Jackson, J. (2006). *Europeans and biotechnology in 2005: patterns and trends: final report on Eurobarometer 64.3*. Retrieved from: https://ec.europa.eu/research/biosociety/pdf/eb_64_3_final_report_second_edition_july_06.pdf.

Gericke, N. M., Hagberg, M., Santos, V. C., Joaquim, L. M., El-Hani, C. N. (2014). Conceptual Variation or Incoherence? Textbook Discourse on Genes in Six Countries. *Science & Education*, *23*(2), 381-416.

Gil-Pérez, D., Vilches, A., Fernández, I., Cachapuz, A., Praia, J., Valdés, P., Salinas, J. (2005). Technology as 'Applied Science'. *Science & Education*,*14*(3-5), 309-320.

Gonçalves, M. E., Castro, P. (2009). Local is beautiful? Governing science-society relations in Europe. *Portugese Journal of Social Sciences*, *8*(2), 191–207.

Green, W., Naidoo, D. (2008). Science Textbooks in the Context of Political Reform in South Africa: Implications for Access to Science. *Science Education International*, *19*(2), 235–250.

Harding, S. (1998). Multiculturalism, postcolonialism, feminism: Do they require new research epistemologies? *The Australian Educational Researcher*, *25*(1), 37–51.

Hodson, D. (1998) Science fiction: The continuing misrepresentation of science in the science school curriculum. *Journal of Curriculum Studies*, *28*(2), 115–135.

Hollingsworth, S. (1989). Prior Beliefs and Cognitive Change in Learning to Teach. *American Educational Research Journal*, *26*(2), 160–189.

Höttecke, D., Silva, C. C. (2011) Why Implementing History and Philosophy in School Science Education is a Challenge: An Analysis of Obstacles. *Science & Education*, *20*(3-4), 293–316.

Inglehart, R. (1990). *Culture shift in advanced industrial society*. Princeton University Press.

Jenkins, E. W. (1992). School science education: towards a reconstruction. *Journal of Curriculum Studies*, *24*(3), 229–246.

Kim, M., Roth, W. M. (2008). Rethinking the ethics of scientific knowledge: A case study of teaching the environment in science classrooms. *Asia Pacific Education Review*, *9*(4), 516–528.

Knain, E. (2001). Ideologies in school science textbooks. *International Journal of Science Education*, *23*(3), 319–329.

Kohring, M., Matthes, J. (2002). The face (t) s of biotech in the nineties: how the German press framed modern biotechnology. *Public understanding of Science*, *11*(2), 143-154.

Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*, *85*(3), 291–310.

Kurzer, P., Cooper, A. (2007). What's for dinner? European farming and food traditions confront American biotechnology. *Comparative Political Studies*, *40*(9), 1035-1058.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *biometrics*, 159-174.

Lakin, S., Wellington, J. (1994). Who will teach the "nature of science"?: teachers' views of science and their implications for science education. *International Journal of Science Education*, *16*(2), 175–190.

Lee, H., Yoo, J., Choi, K., Kim, S.-W., Krajcik, J., Herman, B. C., & Zeidler, D. L. (2013). Socioscientific Issues as a Vehicle for Promoting Character and Values for Global Citizens. *International Journal of Science Education*, *35*(12), 2079–2113.

Leite, L. (2002). History of Science in Science Education: Development and Validation of a Checklist for Analysing the Historical Content of Science Textbooks. *Science & Education*, *11*(4), 333–359.

Liakopoulos, M. (2002). Pandora's Box or panacea? Using metaphors to create the public representations of biotechnology. *Public Understanding of Science*, *11*(1), 5-32.

Liberg, C., af Geijerstam, Å., & Folkeryd, J. (2007). A linguistic perspective on scientific literacy. In C. Linder, L. Östman & P. Wickman (Eds.), *Promoting Scientific Literacy: Science Education Research in Transaction* (pp. 42-46). Proceedings of the Linnaeus Tercentenary Symposium. Uppsala: Geotryckeriert. Retrieved from http://uu.diva-portal.org/smash/get/diva2:40649/FULLTEXT01.pdf#page=40

Markert, M. (2013). History of Science in School Biology Textbooks: Characteristics and Consequences. In P. Heering, S. Klassen, D. Metz, (Eds.), *Enabling Scientific Understanding through Historical Instruments and Experiments in Formal and Non-Formal Learning Environments* (pp. 313–322). Flensburg: Flensburg University Press.

Matias, O., Martins, P. (2009). *Biologia 12* (Vol. 1 and Vol. 2). Porto: Areal Editores.

Mendes, A. M. P., Rebelo, D. H. V., & Pinheiro, E. J. G. (2004). Programa Biologia 12º Ano. Retrieved from http://www.dgidc.min-edu.pt/data/ensinosecundario/Programas/biologia_12.pdf.

Menezes, I. (2003). Civic education in Portugal: curricular evolutions in basic education. *JSSE-Journal of Social Science Education*, *2*(2).

Miller, J. D. (1998). The measurement of civic scientific literacy. *Public Understanding of Science*, *7*(3), 203–223.

Ministério da Educação (ME). (2007). Diário da República, 1.ª série – N.º 136 – 17 de Julho de 2007. Retrived from http://www.dge.mec.pt/sites/default/files/ManuaisEscolares/2007_decretolei_261.pdf

Millar, R. (2002). Towards a science curriculum for public understanding. In S. Amos, R. Boohan (Eds.). Teaching science in secondary schools, pp. 113-128. London: Routlege/Falmer and The Open University.

Morris, H. (2014). Socioscientific Issues and Multidisciplinarity in School Science Textbooks. *International Journal of Science Education*, *36*(7), 1137–1158.

Motta, L., Viana, M. J. (2014). *Bioterra 9 – Viver melhor na Terra*. Porto: Porto Editora.

Oecd. (2008). Education at a Glance 2008: OECD Indicators. Retrieved from https://www.oecd.org/education/skills-beyond-school/41284038.pdf.

Osborne, J. (2000). Science for citizenship. In M. Monk, J. Osborne (Eds.), Good practice in science teaching (pp. 225-240). Buckingham: Open University Press.

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas--about-science" should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching*, *40*(7), 692–720.

Pearson, K. (1904). On the theory of contingency and its relation to association and normal correlation. In *On the General Theory of Skew Correlation and Non-Linear Regression*. Cambridge, UK: Cambridge University Press.

Pedretti, E., & Nazir, J. (2011). Currents in STSE education: Mapping a complex field, 40 years on. *Science Education*, *95*(4), 601–626.

Pepinsky, T. B. (2013). The Global Economic Crisis and the Politics of Non-Transitions. *Government and Opposition*, *47*(02), 135–161.

Pingel, F. (2010). *UNESCO Guidebook on Textbook Research and Textbook Revision*. Unesco. Retrieved from http://unesdoc.unesco.org/ulis/cgi-bin/ulis.pl?catno=117188&gp=1&mode=e&lin=0.

Portdata (2014). Taxa de abandono precoce de educação e formação: total e por sexo [Premature education and training drop out rate]. Retrieved from http://www.pordata.pt/Portugal/Taxa+de+abandono+precoce+de+educa%C3%A7%C3%A30+e+forma%C3%A7%C3%A30+total+e+por+sexo-433.

Prpić, K. (2011). Science, the public, and social elites: How the general public, scientists, top politicians and managers perceive science. *Public Understanding of Science*, *20*(6), 733–750.

Reeves, R. G., Denton, J. A., Santucci, F., Bryk, J., & Reed, F. A. (2012). Scientific standards and the regulation of genetically modified insects. *PLoS Neglected Tropical Diseases*, *6*(1), e1502. http://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0001502.

Reis, P. & Galvão, C. (2004). The impact of socio-scienctific controversies in Portuguese natural science teachers' conceptions and practices. *Research in Science Education*, *34*(2), 153–171.

Roberts, R. (1995). 'Public involvement: from consultation to participation'. In F. Vanclay & D.A. Bronstein (eds.), *Environmental and Social Impact Assessment* (pp. 221-46). New York: Wiley.

Roberts, D. A. (2007). Scientific literacy. In S. K. Abell, & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 729–780). Mahwah, NJ: Lawrence Erlbaum Associates.

Sadler, T. D. & Zeidler, D. L. (2004). The morality of socioscientific issues: Construal and resolution of genetic engineering dilemmas. *Science Education*, *88*(1), 4–27.

Sturgis, P.J. & Allum, N. C. (2001) "Gender Differences in Scientific Knowledge and Attitudes toward Science: Reply to Hayes and Tariq," *Public Understanding of Science*,*10*(4), 427–30.

Sadler, T. D. & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, *46*(8), 909–921.

Selmaoui, S., Agorram, B., Kzami, S., Razouki, A., Clément, P., Caravita, S. (2012). Cultural and Socioeconomical Dimensions of Human Reproduction and Sex Education in the Biology Textbooks of Eight Countries. *Sociology Study ISSN*, *2*(12), 963–968.

Stinner, A. (1995). Contextual settings, science stories, and large context problems: Toward a more humanistic science education. *Science Education*, *79*(5), 555–581.

Silva, A. D., Santos, M. E., Mesquita, A. F., Baldaia, L., Félix, J. M. (2006). *Terra, Universo de Vida – Biologia 12º ano*. Porto: Porto Editora.

Santos, B. D. S. & Nunes, J. (2004). Introduction: Democracy, Participation and Grassroots Movements in Contemporary Portugal. *South European Society and Politics*, *9*(2), 1–15.

Spitzer, M. (2002). Lernen. *Gehirnforschung und die Schule des Lebens. Heidelberg: Spektrum*.

Turner, S. (2008). School science and its controversies; or, whatever happened to scientific literacy? *Public Understanding of Science*, *17*(1), 55–72.

Vislie, L. (2003). From integration to inclusion: focusing global trends and changes in the Western European societies. *European journal of special needs education*, *18*(1), 17-35.

Weinstein, M. (1998). Playing the Paramecium: Science Education From the Stance of the Cultural Studies of Science. *Educational Policy*, *12*(5), 484–506.

Wellington, J. (1991). Newspaper science, school science: friends or enemies? *International Journal of Science Education*, *13*(4), 363-372.

Yates, T. B. & Marek, E. A. (2013). Is Oklahoma really OK? A regional study of the prevalence of biological evolution-related misconceptions held by introductory biology teachers. *Evolution: Education and Outreach*, *6*(1), 1-20.