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Article

To What Extent do Biology Textbooks Contribute to Scientific Literacy? Criteria for Analysing Science-Technology-Society-Environment Issues

Florbela M. Calado *, Franz-Josef Scharfenberg * and Franz X. Bogner *

Centre of Math & Science Education, Didactics of Biology, University of Bayreuth, NW I, Universitätsstr. 30, D-95447 Bayreuth, Germany

* Authors to whom correspondence should be addressed; E-Mails: florbela.calado@esmunich.de (F.M.C.); franz-josef.scharfenberg@uni-bayreuth.de (F.J.S.); franz.bogner@uni-bayreuth.de (F.X.B.); Tel.: +49-490-499-74; +49-921-55-3640; +49-921-55-2590.

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Abstract: Our article proposes a set of six criteria for analysing science-technology-society-environment (STSE) issues in regular textbooks as to how they are expected to contribute to students' scientific literacy. We chose genetics and gene technology as fields prolific in STSE issues. We derived our criteria (including 26 sub-criteria) from a literature review of the debate in science education on how to increase scientific literacy. We inspected the textbooks regarding the relationships between science, technology, society, and environment, and considered the presence of the decontextualized and socially neutral view of science as distorted view. We, qualitatively and quantitatively, applied our set of criteria to two German Biology textbooks and identified, in total, 718 STSE statements. Based on the frequencies of different criteria and sub-criteria in the textbooks, we drew conclusions concerning STSE issues and the underlying conceptions of science and technology, which might hinder the furtherance of scientific literacy. The applicability of our approach in other science education contexts is discussed.

Keywords: textbook analysis; scientific literacy; science; technology; society; environment; STSE issues; misconceptions

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1. Introduction

Scientific literacy (SL) has met with increased interest during the last decades, rooted mainly in two different arguments within science education: One argument arose from concerns about the decline of scientific and technological careers in Europe (e.g., Portugal, France, Germany, and The Netherlands: see [1]). The European Commission [2] held school science education responsible for failing to attract students' interest in scientific issues and put forth the challenge to innovate educational settings and adapt curriculum and practices, in order to make scientific and technological careers more popular [3]. On the other hand, educational organizations as well as science education research have pointed to the need for a more participative citizenship, as science and technology make a significant impact in our daily lives (e.g., from nourishment to health care; e.g., [4,5]. Educators need to promote an understanding of the interactions between science and technology interactions and their influence in socio-cultural and environmental contexts. Besides possessing knowledge of science and understanding its concepts, scientifically literate citizens need to, at least superficially, understand scientific and technological activities and how they relate to society and environment [6], conventionally labelled as Science, Technology, Society, and Environment issues (STSE; e.g., [7–9]. Science textbooks have been suggested as a means to convey the notion of "the social context of science" [10] (p. 249). However, they may also "contrast radically with the curricula and other steering documents" of a given country [11] (p. 408). We analyse the contribution of textbooks to the understanding of the scientific enterprise; that is, how science interacts with technology, with society and the environment. We first present an overview of SL and STSE issues. We then proceed to examine the ideas about STSE issues that scholars have suggested should be taught. Finally, we summarize research on STSE issues in textbooks and present the objectives of our study.

2. Scientific Literacy and Science-Technology-Society-Environment Issues

The term SL (meaning: the personal fit to read science) encompasses many educational themes that have shifted over time [12], such as Public Understanding of Science (with the intent to increase confidence in science and support for the scientific enterprise) and Science for All (with its focus on the needs of those not choosing scientific or technological careers [13]). There are currently two major labels that prevail: the epistemological view of Nature of Science (NOS) and the relationships within STSE, converging with the concept of Civic SL [13], where scientifically literate citizens are thought to understand scientific and technological advancements and their interplay with society and the environment. Besides the knowledge domain, other aspects are thought to contribute, such as scientific skills and attitudes towards the role of science within societies [14,15]. However, nowadays, the cornerstone of SL is regarded as the understanding of the scientific enterprise in a broad sense [1,13]. Therefore, beside knowledge about science, we also consider understanding the interplay between Science, Technology, Society and Environment as a fundamental SL component [6].

In line with Pedretti & Nazir [8], we acknowledge that STSE issues began as science, technology, and society issues (e.g., [16]); that is, they are rooted in the interplay of these three issues, and "then later evolved to include the environment" [8] (p. 602). Some authors (e.g., [17,18]) have argued that STSE education has to approach the impact of science on both society and environment, together with

NOS in broad sense, in order to obtain SL. The perception that scientific knowledge is merely tentative, despite the fact that it is the best we have [19], lays down two naive views of science: an extreme confidence in science and technology or an extreme skepticism. Only the awareness of their benefits and of their negative implications enables critical analysis of controversial issues, as well as more objective judgements of the related economic interests and political decisions [6].

Introducing STSE issues in classrooms has often been recommended as a method of confronting students with controversial socio-scientific issues, including moral and ethical implications (e.g., [20,21]). Such strategies are regarded as valuable for preparing students for multi-angled controversies (e.g., [22,23]), including links with morality [24]. Dilemmas related to biotechnology products, environmental problems, and human genetics are potential sources of STSE content. For instance, STSE issues arising from controversial subjects, such as genetic diagnostics and human genetic engineering, raise students' understanding of NOS and promote their SL [25]. We therefore focus on genetics as part of biology education.

Since it affects important domains of human lives, such as reproduction, health and nourishment, as well as the environmental balance, genetics is a field of notable social importance, and therefore, constitutes essential curriculum. Decision making in genetic issues frequently involves social dilemmas and requires complex reasoning. Apart from illustrating the merits of scientific evidence, such issues potentially allow students to make judgements involving emotive considerations and personal values [24]. In particular, controversial aspects of genetic engineering lead to moral dilemmas (e.g., gene therapy and cloning), thus engaging students in discussions. Controversies around genetic issues were particularly significant in the "great European biotechnology debate", involving gene technology and its commercial applications in food production, pharmacy and medicine [26] (p. 3). Triggered by the shipping of Round-up Ready Soya to Europe and by the cloning of the sheep Dolly, they led to a massive media coverage and to concerns about the possibility of human cloning. The multinational Human Genome Research also activated the debate, although the reception and the global discourse varied according to national dynamics [27]. Earlier studies have shown that Germany is quite peculiar regarding civic participation in this debate about societal aspects of genetic issues, attitudes towards biotechnologies, and media communication concerning science and technology (e.g., [28]). Perhaps, based on experiences in Hitler's Third Reich [17], collective memory of eugenic programs and the consequent mistrust in science and technology led to a particularly stringent legislation concerning genetic manipulation, which, in turn, imposes restrictions on research, technological production and applications [29,30]. In summary, discussing genetic issues in this context might help students to understand how science, technology, science and environment interact and how complex is the process of decision making, thus contributing to students' SL.

3. Which Ideas about STSE Issues Should Be Taught?

Implementing STSE issues represents for many authors a shift from the positivist view of science to "a post-positivist vision for science education" that considers science within its "social, technological, cultural, ethical, political, [and] environmental" contexts [8] (p. 602). However, despite the agreement on considering STSE issues when addressing SL, the kind of ideas about interactions between STSE are not well defined [6]: "There is no single, widely accepted view of STSE education" as Pedretti &

Nazir summarized in their review of four decades of STSE education [8] (p. 602). They stated that differing discourses on STSE education lead to several distinct pedagogical approaches, programs, and methods. Osborne and colleagues reported a consensus, among scientists, science teachers, philosophers, sociologists of science, and science educators (see Table 1, right column) on which ideas about science (IAS) "students should encounter by the end of compulsory schooling" [31] (p. 712). Their ideas largely concurred with the ideas found by McComas & Olson [19] (Table 1, left column) in the analysis of international curriculum documents (from England, Wales, USA, Australia, Canada, and New Zealand. However, in our view, some of these ideas indicate distorted views about science and technology, for instance, the idea that *Science has played an important role in technology* is too simplistic, as it disregards the role of technology in the construction of scientific knowledge [32] (for details, see below). Despite the existence of considerable consensus, reported in the Delphi study [31], conflicting science views may still persist among educators, the scientific community, and epistemologists. In particular, constructivist science educators' views may diverge from the scientists' views [33,34]. Additionally, some scientists used a language associated with the traditionalist view of science, for instance, the description of a rigid step-by-step scientific method based on controlled processes and absolute truths [35]. Both sets of ideas (Table 1) represent a meaningful and referential basis. However, an additional literature review for building up an instrument serving our purpose was required.

Table 1. Parallelism concerning ideas about science (IAS) between international curriculum documents [19] and ideas of experts [31] (adapted from [31]).

Ideas about Science	
Most referred in curriculum documents (McComas & Olson, 1998)	Found in experts' *Delphi* Study (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003)
Scientific knowledge is tentative despite the fact that it is the best we have	Tentative nature of scientific knowledge
Science relies on empirical evidence	Science needs analysis and interpretation of data
Scientists require replicability and truthful reporting	Science needs experimental methods and critical testing
Science is an attempt to explain phenomena	Scientists develop hypotheses and predictions
Scientists are creative	Science involves creativity and continual questioning
Science is part of social tradition	Science needs cooperation and collaboration in the development of scientific knowledge
Science has played an important role in technology	Science and technology are different entities
Scientific ideas have been affected by their social and historical milieu	Scientific knowledge has historically been developed
	Science needs diversity of scientific thinking
Changes in science occur gradually	
Science has global implications	

4. STSE Issues in Textbooks

Many authors have pointed to textbooks as powerful resources for science education (e.g., [36,37]). Textbooks may support independent learning and promote parental participation [38]. From the teacher's point of view, textbooks transpose the official curriculum into the enacted curriculum [39]. In addition to the mere presentation of the achievements of science and technology, textbooks show how these achievements were realized, for instance, by contextualizing scientific and technological events [40,41]. Textbooks may emphasize meaningful aspects or explore historical reports of representative events. They may reference case studies or include stories and anecdotes about scientists, illustrating scientific and technological progress as a human enterprise [37]. The account, found in German textbooks [42], of the contribution of Robert Hooke to the development of microscopy is an example. Textbooks may also emphasize the positive and negative implications of science and technology in society and in environment; for example, an account of the Acquired Immune Deficiency Syndrome pandemic in European and African textbooks [43], and "the interaction between the genome and its environment" within French textbooks [44] (p. 58).

"To teach about science and consider its social implications", teachers are "reliant on the textbook" and, consequently, "good quality textbook[s]" are "considered essential" [45] (p. 9 and 13). In certain STSE aspects like historical contextualisation, "teachers rely heavily on textbooks" [37] (p. 334). However, curricular materials referencing STSE issues are often missing [46]. Due to their complexity and their controversial and value-laden nature, STSE issues are frequently avoided or treated superficially in science teaching [11,47]. Therefore, we summarized research on how biology textbooks address STSE issues and how they convey views of science and technology to students.

First, several studies have focussed on how *knowledge about science* is conveyed by textbooks. Chiappetta and colleagues [36] and Lumpe and Beck [48] analysed secondary school chemistry and biology textbooks in terms of the balance between four aspects: knowledge of science, investigative NOS, science as a way of thinking, and the interaction between science, technology, and society. The authors concluded that the textbooks focused on scientific content and its vocabulary, thus representing an unbalanced account for SL. Leite [37] examined the historical content included in physics textbooks: They did not provide students an adequate image of science. Regarding scientific inquiry in biology textbooks, most new science textbooks include technology issues as part of their science content [49].

Second, with respect to the interactions of science and technology with society, physics textbooks mostly emphasized the usefulness of science and/or technology, but often neglected to discuss societal issues and potentially negative aspects of science and technology [50]. More generally, the interaction of science and technology with society received poor coverage, a tendency that worsened as students progressed through the school system [51]. German science textbooks seem to completely neglect STSE issues [52]. However, the German National Standards of Competencies in Science [53] require students to be encouraged to reflect on ethical aspects in science education, especially in environmental, health, and gene technology education. Beside others issues (e.g., ecological content), genetics offers a promising way of promoting STSE issues. For instance, 9th graders should be aware of the effects of gene technology in the social and ecological spheres, of the *pro and contra* arguments, and of the fact that such issues imply ethical and moral considerations [54]. These demands seem to have been effective: Chemistry textbooks (secondary education) pointed both to the aspects of chemistry contextualization and to the socio-critical chemistry education [55]. The introduction of STSE issues into the curricula seems to be an international trend, although most textbooks still fail to include perspectives from social science [55].

Third, the "hidden curriculum" [56] (p. 372) might hinder the discussion of STSE issues. Hidden curricula are determined by several elements, such as the decisions of publishers caused by market dynamics, the conceptions of textbook authors, and the interpretations of teachers who have their own conceptions about science [57]. These considerations led to our first two specific research questions:

- Do biology textbooks explicitly and/or implicitly provide teachers and students with suitable information about the interplay between science and technology, their relationship to society, and their implications for the environment?
- Do textbooks stemming from the same socio-cultural context and based on the same guidelines differ essentially in the STSE issues discussed?

Along with the promotion of STSE issues, the above-mentioned distorted ideas of science deserve attention, as they may be conveyed to students through teaching practice in general and textbooks in particular. They may contribute to the construction of students' distorted views of science and technology, thus representing filters or even barriers to the realization of the SL requirements [6]. Fernández and colleagues [58] identified some distorted ideas widely referred to in the literature (e.g., the cumulative conception of scientific development). We specifically examine the distorted idea of *decontextualized and socially neutral view of science* (DSNVS). This simplistic conception of the complex relationship between science and technology regards technology as a mere product of science and disregards its role in the construction of scientific knowledge [32,58]. We have argued for an integrated treatment of DSNVS and STSE issues [6] because this distorted view may represent an obstacle to a balanced approach of the relationships between science, technology, society and environment. From the DSNVS view, science is exalted as being the absolute factor of progress in society. Alternatively, science and technology (perceived as science's application) presented as being alone responsible for the environmental degradation, and, therefore, are to be rejected. This simplistic exaltation or rejection of science portraits it as an activity carried out by isolated geniuses and separate from ordinary life. People possessing such a distorted view simply ignore the social context and the implications of science and technology in society and in the environment [32,59]. While science is seen as a mean of creating products, the social context in which scientific and technological events take place is disregarded. As mentioned above, DSNVS may encourage the opposite misconception; this less frequent conception considers science and technology alone as responsible for environmental degradation, and therefore ignores the responsibility of other agents [32,58] such as lawyers, politicians, entrepreneurs, and even citizens. In parallel, DSNVS neglects efforts of science and technology in solving problems that affect humanity, and ignores also scientists' concerns with potential risks deriving from their own activity [21,58]. DSNVS is then in conflict with the humanistic perspectives of science education and the Roberts Visions of SL [60]. In the educational context, the Roberts Vision I seeks opportunities for students to integrate scientific ideas and scientific reasoning with moral reasoning and cultural considerations that underlie the decision-making in socio-scientific issues. Roberts Vision II views science from an external perspective on science, that is, views the context in which scientific ideas and processes are involved, as well as the role of science in society [60,61]. Our third specific research question is therefore:

- DSNVS, explicitly and/or implicitly, is conveyed by textbooks?

We hypothesize that biology textbooks (mostly written by teachers [42,62]) may convey a more or less DSNVS-distorted view of science and so may convey some misconceptions regarding the STSE issues related to genetics and gene technology.

5. Objectives of the Study

Following our previous work [6], our general objective was to propose criteria for textbook analysis, in order to to enable the identification of weaknesses and strengths of science-technology-society-environment issues and to detect misconceptions of science and technology that might enable the identification of hinder a fair approach to these issues.

Our specific objectives were twofold:

(i) to develop a set of criteria for textbook analyses in order to examine how two German textbooks address science-technology-society-environment issues in the context of genetics and to detect indicators for confirming or disproving the presence of the decontextualized and socially neutral view of science;

(ii) to apply, qualitatively and quantitatively, these criteria to genetics and gene technology contents within two German biology textbooks and to identify differences regarding these issues.

6. Methodology

Our study fits in with the Product Oriented Research, with emphasis on the textbook as a product [63]. We first describe our textbook sample, then explain the development of our criteria, and finally apply the analysing process to the textbooks.

6.1. The Textbook Sample

In Bavaria, all textbooks require state-certification. We randomly selected two 11th grade biology textbooks from two different publishers: textbook A [64] and textbook B [65]. We focussed on the chapters of genetics and gene technology as appropriate for approaching STSE issues involving divergence of opinions and values. Additionally, we are convinced that these issues provide an exploration not only of ethical and moral aspects, but also of evolutional and procedural aspects that underlie the achievement of scientific knowledge.

Both textbooks are similar in layout (e.g., allocation of pictures), but they present different strategies towards both the organization of contents and the type and the sources of non-compulsory information. Textbook A includes 71 pages in one chapter on *Genetics*. Two motivational pages provide an introduction, presenting the title and sub-titles for five sub-domains: *Classic*, *Cyto-*, *Human*, *Molecular Genetics*, and *Gene Technology*. Small text boxes describe the sub-domains and differentiate their goals and fields of action. Sub-domain-specific pictures and representative scientists are given in these texts. Five sub-domain-chapters follow, concluded by evaluation tests, mostly comprising conceptual knowledge, but two questions involve ethical considerations (foetal genetic diagnosis, and the advantages and disadvantages of gene therapy). The human genetics and gene technology chapter presents further ethical considerations, including the *Contribution to a Discussion of Ethical Questions* and the *Impulses* dedicated to controversial issues. Students are confronted with societal problems and challenged to research on their own how society handles socio-scientific questions. Textbook B has a chapter entitled *Genetics and Gene Technology* (83 pages) and organizes the contents into four sub-chapters: *Molecular Fundamentals of Heredity*, *Cyto- and Classic Genetics*, *Human Genetics,* and *Gene Technology*. The chapter lacks an introduction and starts with defining the title terms. Every sub-chapter finishes with a summary and an evaluation test, including ethical considerations (e.g., abortion, traditional and modern methods of cystic fibrosis treatment, and implications of germ cells therapy). However, this textbook does not provide suggestions for students' research. Regarding non-compulsory information, textbook A approaches controversial issues related to both genetic diagnostics and genetic interventions. For instance, the euthanasia and pre-implantation diagnostics are discussed from an ethical perspective based on excerpts from legislative and constitutional documents as well as press notifications. In textbook B, non-compulsory information also involves controversial issues: Science and technology events are framed by concepts and principles that one should be aware of (e.g., the concept of risk or the human dignity principle). Thereby, textbook B follows a deductive approach by explicitly mentioning *a priori* principles and regularities that underlie the relationship of science and technology with the societal sphere and the environment.

6.2. Criteria Development

In developing our criteria, we alternated between deductive and inductive methods [66], according to their appropriateness. The sets of ideas about science [19,31] displayed in Table 1, though not representing a suitable framework for our textbook analysis, provided ideas that oriented our criteria development: science is part of the social tradition; science has played an important role in technology [19]; science needs cooperation and collaboration in the development of scientific knowledge; and science and technology are different entities [31] (see Table 1). In order to define our criteria, we carried out a bibliographic revision, which consisted of analyzing documents, mostly derived from epistemological debate and from research in science education. We then extracted from this bibliography the ideas that we assumed to be likely observable in textbooks. We only excluded ideas that are unlikely to be included in textbooks. For instance, despite the evidence of a positive relationship between reading newspapers and science magazines and the readers' substantive scientific knowledge [67], we could only partially incorporate the idea that students should be prepared for a critical interpretation of the news conveyed by the media [68]. Indeed, one cannot expect textbooks to provide up-to-date news, though they may present some examples of media-based STSE exploration in order to raise understanding of both the controversial character of socio-scientific issues and the corresponding multiple perspectives. In the following sections, we first describe the procedure for developing criteria, by taking the first criterion as an example (see Table 2). We then derive and present the remaining five criteria, each representing one sub-domain of the STSE relationships (Table 2). Finally, we divide each criterion into sub-criteria (26, altogether; summarized in Table 2), which were, where needed (some are self-explanatory), justified by arguments either found in the literature or formulated by ourselves.

Table 2. Definitions, textbook examples and textbook frequencies of all sub-criteria (sub-criteria headed by the criterion, keywords in textbook statements in *italics*).

Sub-Criterion	Definition	Textbook Example	Textbook	Frequencies
	Science and technology events and their social contextualization		A [a]	B [b]
	Mentioning and/or suggesting			
Event per se	a scientific or a technological event	*chromosome theory of inheritance* of Boveri and Sutton (A, p. 98)	78	40

Table 2. *Cont.*

Sub-Criterion	Definition	Textbook Example	Textbook	Frequencies
Event time	the time the event took place	*during the National Socialist regime* (A, p. 111)	70	20
Event place	the place the event occurred	Johann G. Mendel was a science teacher *in Brünn* (B, p. 98)	6	2
Underlying problem	the social problem that motivated research regarding the event	The *aim* is to *develop new possibilities for diagnoses and therapies for genetic diseases or cancer.* (A, p. 83)	11	7
Favourable factors	factors favourable for the event	The reason for that [advancement] were other *improvements in microscopes and staining techniques* (B, p. 102)	1	3
Obstacles	factors representing obstacles	had to fight, *as a woman*, against strong *prejudices of their colleagues* (A, p. 62)	1	1
	Interplay between science and technology			
Distinction	Science and technology are distinguished.	*Genetics* is *defined* as and *gene technology* is *defined* as (B, p. 58)	6	6
Technology towards science	A technology device or process is useful for achieving scientific knowledge.	These *enzymes* are *used* to *determine which genes are active* in a tissue (B, p. 131)	19	26
Science towards technology	Scientific knowledge is useful or even indispensable for technology advancements.	The *discovery* of enzymes was the *decisive condition for* the development of modern genetic *methods* (B, p. 128)	9	6
Science and applied science	Technology is seen as applied science	the *development of therapeutic possibilities*. In addition, *this branch of genetics* is (B, p. 112)	1	1
	Science and Technology as means to solve societal problems			
	Mentioning and/or suggesting of			
Potential applicability	potential applicability of science and technology in the future	In cancer patients, we *attempted* to *make* cancer genes *ineffective*." (A, p. 121)	19	7
Applicability	real benefits of science and technology processes or devices	Bacteria *can* now *produce* the *desired* *insulin* (A, p. 113)	42	63
Costs	costs of science and technology processes or devices	The *1 million-Dollar*, two-month *project* (A, pg. 83)	6	3
Limitations	limitations of science and/or technology	Nevertheless, it *isn't possible* to gain every desired medicament from bacteria cells (B, p. 135)	13	9
	Risks and impacts of Science and Technology			
	Mentioning and/or suggesting of			
Risks	risks of science and technology	The development of Bt-toxin resistant corn borers represents a *further risk* (B, p. 138)	22	19
Social impact	an potential and/or real science and technology impact on society	The introduction of pre-implantation diagnostics *might lead to a dam crack in the direction* of Brave New World (A, p. 111)	13	6
Local environmental impact	a local potential and/or real science and technology environmental impact	*Protection* of the *environment* remains primary *objective* of the [German] *gene technology law* (A, p. 125)	1	1

Table 2. *Cont.*

Sub-Criterion	Definition	Textbook Example	Textbook	Frequencies
Global environmental impact	a global potential and/or real science and technology environmental impact	Once accepted, Bt-maize would *in the future worldwide* and *almost exclusively* grow and the dimension of *damages* would be *enormous* (B, p. 138)	0	7
	Controversial issues			
	Mentioning and/or suggesting of controversial issues			
Different perspectives	given with different perspectives	Nevertheless, the *pros and cons* of cultivating [genetically modified plants] are still hotly debated in society (B, p. 138)	17	8
Conflict values	by referring to values interfering with decisions	The *human dignity* is inviolable (A, p. 111)	25	14
Involved interests	given with potentially involved interests (e.g., social, individual, political and/or economic ones).	Discuss *reasons* why *private companies invest millions of Dollars* to sequence human genes (A, p. 83)	10	4
Different sources of information	presented with different information sources conveyed by media	This year's 50th anniversary of the discovery of the structure of DNA has kindled many debates (*Guardian, 2003*) (A, p. 124)	11	0
	Decision making process			
	Mentioning and/or suggesting of			
Legislation	legislation processes and/or results	According to an *EU directive of 1998*, DNA sequences can be patented (A, p. 83)	26	7
International comparison	decisions by comparing international realities concerning legislation	but it is *not forbidden in other countries*, such as U.S.A. (B, p. 137)	4	1
Agents	the agents involved in decision making	In Germany, every treatment requires the *approval* of the *Ethics Committee* and of the *German Medical Association* (A, p. 121)	18	3
Citizen participation	the citizens as participants in decisions (e.g., as consumers, as voters, as informed human beings)	To the question "Would you eat genetically modified food?" *answer* 70% of *respondents* with "no" (A, p. 125)	23	2

6.2.1. Science and Technology Events and Their Social Contextualisation

Within science teaching, science and technology advances are frequently presented as occurring by chance, detached from their historical and socio-cultural context [32,59]. However, participative citizenship requires awareness of how scientific work is conditioned by the contexts (e.g., social, historical, moral and spiritual; see [69]). Scientists and educators agree that social and historical contexts have affected scientific ideas [19,31] (see Table 1); especially, concerning the way in which science is executed, interpreted and accepted by society. Assessing "the historical current" as one of the recently identified "six currents in STSE education" [8] (p. 610 and p. 601) lead us to assume that this idea is presented in textbooks. Based on a review of literature, we inductively dissected this idea into sub-ideas. For instance, Abd-El-Khalik and Lederman [70] (p. 1087) recommended "explicitly addressing certain aspects" of history of science. In a textbook, such aspects might be the spatial and temporal locations of scientific events as "concrete examples [as to] how the scientific enterprise operates" [71] (p. 1). That is, we identified a level of event contextualization (the event level). Additionally, Hackett [72] (p. 288) recommended a process level for "discovery and invention in science textbooks" in order to avoid students being "mislead into thinking of science as an activity conducted apart from society by lone heroes for unknown reasons". Hence, the circumstances (e.g., positive influencing factors) surrounding the event should also be mentioned in a textbook. At the process level, socially neutral perspectives may lead to misconceptions, especially when scientific research is expected to provide solutions to societal problems based on technological solutions [32]. Attention also needs to be given to the social fabric, to world views, power structures, and philosophical, religious, political, and economical factors [72]. In order to realistically assess embedding science and technology into society, Gardner [73] suggested the incorporation of historical case studies as blue prints for understanding how social factors may foster or hinder technological development. This reasoning underlies the definition of our first criteria and corresponding sub-criteria.

The first author initially applied these first-round sub-criteria definitions to randomly selected parts of textbook A. The definitions of the sub-criteria were iteratively applied and refined in order to reduce subjectivity and to increase accuracy. In the case of the first criterion and its sub-criteria, the event level was differentiated into *mentioning and/or suggesting of* the *event per se*, of the *event time*, and of the *event place* (see Table 2), while the process level was differentiated into *the underlying problem*, *favourable factors* and/or *obstacles*. Finally, a reviewer, a biology in-service teacher and non-participant in this survey, completed the validation test (interpersonal comparison). First, he received training in the context and the goals of the survey and to create familiarity with the criteria and sub-criteria. Second, he was invited to match the given definitions of criteria and sub-criteria with selected textbook statements as examples. In case of lack of clarity or ambiguousness, the first author and the reviewer cooperatively incorporated his feedback into refining the definitions. For instance, in a first sub-criteria version, we had included the assessment of risks as part of this sub-criteria definition. However, we ended up deleting the assessment aspect (see Table 2) because it was not clearly identifiable in textbook statements.

Due to the German language of the textbooks, we did all the analyses in German. After finishing the work, we translated the anchor examples (see Table 2) from German into English; for instance, "die Chromosomentheorie der Vererbung von Boveri und Sutton" into "chromosome theory of inheritance of Boveri and Sutton [65] (p. 98); "Zeit des Nationalsozialismus" into "during the National socialist regime" [65] (p. 111), or "hatte damals als Frau stark gegen Vorurteile ihrer Kollegen zu kämpfen" into "had to fight, as a woman, against strong prejudices of their colleagues" [65] (p. 62). We validated all the translations by a native speaker.

6.2.2. Interplay between Science and Technology

Science and technology are regarded as distinct entities, often explicitly distinguished by their different purposes [31,74]. Pragmatic definitions of each entity offer two possible relationships: technology helps science or science helps technology [75,76]. For instance, technology often precedes science, while scientific knowledge may play an important role in technological processes [73]. On the other hand, technology has often been seen as a by-product of applied science [77]. This idea has been viewed as the simplest misconception of interplay between science and technology, and as to reinforce distorted views of science [32]. We looked for statements referring to gene technology processes portrayed as being applied genetics. In contrast, we consider statements illustrating the usefulness of scientific advancements in transforming resources into goods and services as positive indicators of the role of science. Similarly, we marked statements mentioning a certain technological device or process as necessary for the fulfilment of a certain scientific advancement as indicators of the catalyst role of technology in science.

6.2.3. Science and Technology as a Means to Solve Social Problems

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 [32], towards a view of technology as an autonomous entity that seeks to overcome problems by invention [73]. 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 understand both the strengths and the limitations intrinsic to science and technology [1]. Additionally, mentioning financial costs associated with technologies may convey the message that such processes are somehow socially constrained [69].

6.2.4. Risks and Impacts of Science and Technology and Controversial Issues

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 [1]. Students should appreciate the social impact of scientific and technological changes in their daily lives and also analyse risk minimisation and undesired side effects [22]. 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 [47]. Citizens need to possess scepticism, open-mindedness, critical thinking, inquiry, ambiguity or even skills in the interpretation of data-driven knowledge [78]. Science education is an excellent basis to train such skills that synthesize scientific knowledge and social needs by instilling different ranges of options [21]. Exposing students to scientific controversies may not only raise their interest in techno-scientific issues, but also contribute to scientific and technological literacy, along with higher order thinking skills [79]. Such strategies may force re-evaluation of prior understandings and restructure conceptual understanding of subject matter through personal experiences and social discourse [80]. In particular, since controversial issues around genetic manipulation tend to be framed by socio-philosophic positions instead of scientific positions, their discussion requires the consideration of values, interests, needs, and beliefs as essential factors [81]. Given teacher's reliance on textbooks, the presentation of controversial issues in textbooks should reflect diverse perspectives, especially by highlighting the interests potentially involved. Scientific knowledge may serve opposite and sometimes conflicting interests [21]. While formal science education is centred in conventional non-controversial science, and while the media may tend to emphasize a controversial, superficial, and sensationalist science, textbooks may incorporate both to show controversial issues.

6.2.5. Decision-Making Process Concerning STSE Issues

A STSE curriculum should foster the ability to make decisions about science-related social and environmental issues [12]. 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 [60]. Therefore, textbooks should also enable students to learn about making choices and participating in political decisions.

6.3. Textbook Analyses

Textbook discourse contains interpretations beyond the content coverage. Such interpretations require qualitatively deductive content analysis [82] to extract meaning and assumptions [57]. Following Knain [83], we analysed textbooks' statements in the contexts genetics and gene technology. By identifying the co-variation between text and context, we inferred the ideas about science and technology that matched our criteria and we recorded them. That is, by applying our criteria and sub-criteria to our textbook sample, we gathered data that helped to infer the views about science and technology. With regard to the reliability of our statement categorization, we randomly selected 23% of textbook statements for a second intra-rater categorization (163 of 718 statements) and 36% of textbook statements for an inter-rater categorization (258 of 718 statements). We computed Cohen's Kappa coefficient [84] and obtained reliability scores for the intra-rater reliability of Kappa as 0.93 and for the inter-rater reliability of Kappa as 0.76. The first is regarded as "almost perfect", the second as "substantial" [85] (p. 165).

As recommended [57], we continued with quantitative analysis and combined our content analysis with a quantitative frequency analysis. In line with other researchers [37,50], we used our anchor examples (Table 2) for determining the extent of compliance of the textbook statements with the sub-criteria. The content analysis allows differentiation between explicit and implicit statements. We took also eloquence into account: A very expressive, although implicit, statement might convey messages more effectively than an explicit statement; for instance: (i) "However, besides this advantage, Bt-corn has also risks" [66] (p. 136); (ii) "Markers with antibiotic resistance are a necessary technical aid in the laboratory, however, in public debate they are also a cause for concern" [65] (p. 113). The first statement explicitly conveys the idea that a specific genetically modified cultivation also involves risks; using a different discourse strategy, the second statement merely supposes a potential risk implicitly, but, unlike the previous one, is emotionally charged. However, this differentiation was only taken into account as a qualitative qualifier and not as a quantitative one. In summary, we scored all statements equally. We examined potential contingencies between criterion frequencies and the analysed textbooks by computing adjusted Pearson's contingency coefficients C [86]. Due to multiple testing, we reduced our Alpha level to 0.01.

7. Results

We applied our sub-criteria framework to textbooks A and B and identified 718 STSE statements within the genetics and gene technology chapters (for examples, see Table 2). Textbook A supplied significantly more statements than textbook B (ratio A: 452/71 pages = 6.4; ratio B: 266/83 pages = 3.2; $\chi^2(1, N = 872) = 14.99$, $p<0.001$). In both textbooks, we found statements for at least 25 sub-criteria. Textbook A lacked the sub-criterion global environmental impact and textbook B the sub-criterion different sources of information (Table 2). Generally, criteria and sub-criteria frequencies significantly differed between the two books (adjusted Pearson's contingency coefficients: $C = 0.308$ and $C = 0.399$; in both cases: $p<0.001$; $N = 718$), pointing to different textbook profiles (Table 2).

Textbook A focussed on the criteria *science and technology events and their contextualization* (167 statements *vs.* 151 randomly expected ones; B: 73 *vs.* 89) as well as *decision-making processes* (71 statements *vs.* 53 randomly expected ones; B: 13 *vs.* 31). In contrast, textbook B focussed on the criteria *interplay between science and technology* (39 statements *vs.* 27 randomly expected ones; A: 35 *vs.* 47) *and science and technology as means to solve societal problems* (82 statements *vs.* 60 randomly expected ones; A: 80 *vs.* 102). At the level of sub-criteria, we only found differences for the criterion *science and technology as a means to solve societal problems* ($C = 0.326$; $p = 0.001$; $n = 162$). Textbook B exceeded textbook A regarding the sub-criterion (current) *applicability* of science and technology (Table 2) and provided more statements than randomly to be expected (63 *vs.* 53; A: 42 *vs.* 52). However, textbook A provided more statements on the sub-criterion *potential applicability* (19 *vs.* 13; B: 7 *vs.* 13). That is, both textbooks showed and explained social applications of science and technology and stressed their potential for solving problems in the future, but treated these sub-criteria differently. Generally, *costs* and *limitations*, both in scientific research and technological solutions, were cited less frequently in both textbooks.

With respect to the remaining criteria, the textbooks displayed a similar degree of agreement with sub-criteria (insignificant C values: $0.688 > p > 0.021$): Both textbooks made an effort to frame substantive contents within the realm of real life. They provided numerous references to historical and contemporary events that one might see as an attempt to convey the correct idea that science and technology achievements are a progressive human construction. However, the science and technology events were not completely contextualized: Beyond the references to *time* (when) and *place* (where), only a few and mostly implicit references occurred with regard to underlying social problems that triggered research. The contextual factors that, either positively or negatively, influenced research were rarely mentioned (Table 2). Regarding the interplay between science and technology, both entities were explicitly distinguished in both textbooks, though coexisting with one indicator per book with the incorrect idea that technology is considered applied science. However, the interplay was demonstrated and the mutually positive influence in their achievements was clearly marked (Table 2). Both textbooks primarily focussed on risks rather than negative impacts. Explicitly, textbook B pointed to a scientists' ethical code: "Scientists have the responsibility to assess risks as accurately as possible" [66] (p. 138).

With respect to the social and environmental impacts, the textbooks differ substantially (Table 2): While textbook A gave emphasis to the social dimension, textbook B emphasized the environmental dimension, so that no textbook provided a complete account. The textbooks differed in the character of the statements about controversial issues. Textbook A provided numerous examples, thus illustrating how and why solutions for societal problems may in certain cases be controversial, or even challenged students to investigate the reasons for controversy. It consistently demonstrated the existence of different perspectives by evaluating the genetic issues, the interference of values in these judgements, and the influence of particular, private, or social interests in the decisions by providing excerpts of media articles and other documents (e.g., official legislation document concerning abortion; § 218a StGB, 1992; a newspaper excerpt about the pre-implantation diagnostics; Washington Post, 1.10.2001; all [65] (p. 111)). Textbook B opted for stating explicitly the reasons for controversy (e.g., ethical values involved). It categorized the principles that underlie decisions in socio-scientific issues, such as the *principle of usefulness*, in opposition to the *principle of human dignity*. For instance, statements like "Genetic counselling may be associated with ethical problems" [66] (p. 123) or "On these ethical questions, there are no right answers" [66] (p. 124) stress the controversial nature. The textbooks also handled differently the aspects of *decision-making processes*. Textbook B formally presented principles that underlie decisions, such as the *precautionary principle* that might help students to understand the framework in which socio-scientific issues interact with society. Having based its strategy on portraying real situations (see above), textbook A provided a more contextualized overview of the regulation process and of the agents involved, therefore facilitating students' perception that science and technology are regulated by society through financing, legislation, and control, and that decision making depends upon socio-cultural contexts.

In summary, both textbooks supplied teachers and students with a considerable basis for generally raising understanding of the complex STSE relationships, although lacking relevant information. On the other hand, despite being compliant with the same state guidelines, they seem to follow considerably different orientations.

8. Discussion

We first present methodological aspects. We then discuss the specific criteria and sub-criteria frequency profiles we found in our textbook sample. Third, we take DSNVS into account and discuss the indicators of both extremes of this distorted view that we identified in textbooks. Finally, we discuss the implications of our findings for students' SL.

8.1. Methodological Aspects

With respect to our methodology, four aspects should be considered: First, concisely defined and reliable sub-criteria, covering the issues mentioned in the theoretical framework, helped to identify lack of information, correct and incorrect statements, and more complex ideas. They guided data analyses and reduced subjectivity, as they facilitated the distinction between similar, though different, statements and clarified dubious interpretations; Second, qualitative analysis of every meaningful statement provided an impression of the textbook author's STSE views [83], while the sub-criteria frequencies provided an overview of the general text compliance with STSE issues, representing additional and complementary information [57]. Third, though we analysed the sub-criteria frequencies, we did not define thresholds for determining the presence or the absence of a certain science and technology view, which prevents a classification of textbooks in absolute terms. Fourth, our selection of two related textbook chapters is a limitation of our study. Other chapters and contents may lead to different conclusions.

8.2. Comparison of the Textbooks

Despite the same provenance (in terms of nationality and state) and, therefore, compliance with the same guidelines and the same guidelines, our analyses revealed somewhat different textbook profiles. Indeed, while the statistical analysis (adjusted Pearson's contingency coefficients) pointed to considerable similarities regarding the compliance with most of our STSE criteria, it also showed differing approaches to some sub-criteria. Similarly, our qualitative analysis recognized differences in terms of style of message conveyance, as exemplified below. The main differences and/or similarities identified between textbooks A and B are outlined below.

First, considering the relationships between science, technology, society, and environment, both textbooks referred mostly to science and technology events *per se* and the event times as a mode of social contextualization. These aspects might already provide a basis for contextualization both for teachers and students well versed in history of science [37], or at least in history, but otherwise might be of little help. Similarly, Markert [42] concluded, based on his analyses of treatments of history of science in German biology textbooks. They "simply state historical events and actors in a serial way, never or only seldom mentioning disciplinary, social, political, or cultural contexts [42] (p. 317); that is, "contextual aspects of science are dramatically disregarded" [42] (p. 317). To increase understanding. We argue for a more embracing contextualization, especially for providing information about the underlying problem and the circumstantial factors that influenced both research and establishment of new knowledge. However, our textbooks scored quite low on the sub-criteria corresponding to circumstantial factors (*favourable factors* and *obstacles*) (Table 2). In summary, despite the fact that both textbooks (but mainly textbook A) are aligned with "the historical current" in STSE education [8] (p. 607–608), neither of them provided complete information for contextualization of science and technology events.

Second, a focus on scientific and technological achievements, without describing the processes that led to these achievements, may lead to the view that scientific and/or technological problems have been overcome with no difficulties [73]. Therefore, we applied the sub-criteria *obstacles* as social problems, *costs* as economic problems, and *limitations* as technical problems, that scientists and technologists have to surmount. Nevertheless, both textbooks scored quite low in all three sub-criteria (Table 2).

Third, both textbooks approached the *risks* and *impacts* of science and technology. In approaching risks, they conform to the "logical reasoning current" in STSE education [8] (p. 612). However, some meaningful differences were found. Textbook A focussed on the social impacts of gene technology, perhaps explainable by the role of genetics in the recent German history, which represents a heavy burden on German memory [27], and is mirrored through some statements (e.g., "Till 1942, more than 70.000 of the 'sick' people [were] killed by SS doctors"; [65] (p. 111)). That is, the collective memory of the Nazi eugenic programs interferes with the communication about human genetics [27]. Textbook B exemplified a coherent and informative reasoning regarding risks, but based on one topic only: transgenic microorganisms in laboratories. Some statements (e.g., "[they] are considered to be biologically safe. When outside of the laboratory, they are neither viable nor able to transfer their DNA to other organisms" [66] (p. 138)) convey an optimistic, but also simplistic message: if security rules are tightly controlled, nothing can go wrong.

Fourth, both textbooks failed to adequately refer to environmental relationships of science, technology, and society. With only one reference, textbook A nearly neglected the environmental-related sub-criteria, (Table 2). That is, in our view, a weakness of textbook A and is worthy of improvement. Textbook B, although mentioning environmental impacts, did so infrequently (Table 2). In this respect, our findings are in line with results of the analyses of Finish [87] and French textbooks [88] as, "in many cases they don't take environmental effects into consideration" [90] (p. 148). Here, we suggest references to "environmental problems that originate from science and technology" [8] (p. 618). For instance, case studies about "experimental releases of genetically modified (GM) insects" [89] (p. 1) may meet this demand.

Fifth, the textbooks differed particularly in their discussion of controversial issues. Textbook A scored high in all sub-criteria, focussing mainly on social impacts. Textbook B explicitly formulated controversial issues and we recognize the didactical utility of this way of conveying messages. However, controversial issues might be better illustrated if excerpts of documents illustrating diverse perspectives, interests, and values, are provided (as in textbook A). Regarding decision-making processes, textbook A relieved scientists and technologists, as a whole, from the responsibility for negative effects of science and technology. It consistently proposed activities that emphasize the importance, for citizens, of being informed about social application of genetics and gene technology. Additionally, this textbook presented activities that foster the ability to raise arguments and to define perspectives. In contrast, textbook B called attention to the need for basing decisions upon empirical evidence, but denounced the trend for blaming scientists and technologists for the potential undesirable effects of technologies, in this case, of genetically modified plants.

In summary, we revealed textbooks' strengths and weaknesses in STSE content, as well as their differences in approaching STSE issues. We consider that textbook A presented a more balanced contribution for teaching and learning the complex relationships involved. Regrettably, relationships to the environmental level were poorly accounted for and nearly lacking. However, textbook A was on track for a more realistic paradigm concerning the understanding of science, technology, and society. On the other hand, textbook B provided valuable core concepts and includes all four STSE dimensions but lacked information that is fundamental to understanding how they relate and interact with each other.

8.3. Textbooks and DSNVS

Neither textbook provided the complete information for contextualization of science and technology events, which constitutes a first indicator of DSNVS [32]. In respect of interplay between science and technology, analyses exposed a second indicator of DSNVS. Once per book, we found the incorrect idea of technology as merely applied science (Table 2), which has been argued as the root of DSNVS [32]. However, both textbooks implicitly contradicted this view by distinguishing scientific and technological activities. Additionally, they diverged from DSNVS by mentioning mutual support of science and technology as distinct entities. Textbook B emphasized obvious support provided by technological equipment to scientific progresses (e.g., by microscopes). Mainly in the biotechnology chapters, both textbooks contributed to a fair view of the interplay between science and technology with considerable examples of advancements in genetics that depended on gene technology tools, as well as on advancements in gene technology based on genetics knowledge.

The textbooks differed in presenting *science and technology as a means to solve societal problems*. Textbook B overemphasized the social applicability of science and technology products as an advantage which has also been seen as an indicator of DSNVS [32], in our case the third. Overemphasizing these products is often connected with the tendency to blame science and technology for the degradation of the environment [32], reflected in the emphasis placed on risks and impacts. We did not find this tendency within textbook B. As far as the sub-criterion *risks* is concerned, textbook B conveyed the simplistic message (see above) that the responsibility is that of scientists and technologists. Here, we see a fourth indicator of DSNVS. As written above, textbook A insufficiently characterized societal contexts that led to science and technology advancements (see criterion *events and contextualization*), which might point to the presence of DSNVS. However, with respect to the considerable relevance given to social impacts of science and technology (see criterion *risks* and *impacts*), as well as to its performance concerning the criterion *controversial issues*, textbook A diverged from the socially neutral profile, and, therefore, from the DSNVS.

Summarizing, we found interconnected DSNVS indicators partially mirrored in our textbooks, but also some contradictions. Textbook B is more consonant with the DSNVS than textbook A. Finally, we suggest naming this misconception as DSNVST by adding T for technology.

8.4. Textbooks and Students' SL

In regard to the development of students' SL, both textbooks revealed their orientation by providing learning material concerning STSE issues in genetics and gene technology. Nevertheless, they still lack important information and convey naive and incorrect ideas about science and technology. Neither textbook completely highlighted the view of science and technology that scholars have been proposing as requirements of SL. Some of the ideas, though conveyed by the textbooks, are scarcely developed (amongst others, for instance, *costs* of technologies and *impact* of technologies *in environment*; Table 1). In both textbooks, we found statements that indicate to the co-existence of ideas that can be seen as DSNVST indicators and ideas that point out non-DSNVST views. Potential explanations might be: (i) STSE material might have been added from different sources to a syllabus in an attempt to enrich this curriculum [76]; (ii) some confusion concerning the recent incorporation of the concept SL and its components (e.g., NOS) in educational systems; or (iii) specific national dynamics in the elaboration of STSE discourses as well as in their reception [27]. For instance, the Nazi history, but also the co-dominance of the Catholic and the Protestant religion in Germany may prevent the dominance of one world view over the other, thus increasing communication about risks and, particularly, about the social impact of genetic issues [27]. German media coverage of Human Genome Research has been characterized by involving a considerable variety of voices, demonstrating scepticism about science and scientific achievement [27]. A similar pattern was also observed in the coverage of other genetic issues such as health and environmental concerns [90]. We assume that such a variety of voices coexisting in the media coverage is also mirrored in the public opinion, and, therefore, is expected to be transferred to textbooks. Indeed, it was reflected in our sample in the context of *controversial issues*. Both textbooks provided references to different perspectives, and textbook A often presented external sources of information, such as excerpts of newspaper articles, of web pages, among others. This phenomenon could explain the coexistence of indicators of opposite views of science and technology in the analysed sample.

In our view, it is important that textbooks present science and technology events with significance for the socio-cultural context of the target population. However, we advise textbook writers to select events in view of their potential for representing the interactions between science and technology and between them and society and the environment. Textbook writers should therefore go beyond simply referencing science and technology events. Textbooks should elucidate the way through which a certain final product has been realized, preferably both from the internal (scientific community) and from the external (society) perspectives of the scientific and technological enterprises [40,41]. A classic example of such an event is the Human Genome Project (as demonstrated to certain extend by O'Mahony and Schäfer [27]), as it possesses all the necessary elements: which entities were involved; which disciplines contributed; how it was funded; what difficulties were faced; what potential it had; which technical or knowledge limitations constrained the research; what kind of risks were involved; which legislation framed it; how the society reacted; which interests played a role in decisions; who took decisions; and, finally, how the results were interpreted by the media. In summary, simple references to events and some disconnected details should be replaced by complete, structured and diverse case studies of scientific and technological events, thus supporting the conveyance of a more realistic SL. Additionally, links to environmental concerns should be considered; for instance, problems of seed patenting. Either in the national or in the global context, this issue may lead to a multidisciplinary debate, where advantages, disadvantages, social, and environmental risks of technologies can be exposed and explained to the students. We deem such a framework indispensable in order to render possible the conveyance of a fair portrayal of scientific and technological activity and to foster the development of students' SL.

9. Conclusions

Our study confirms that the confrontation of epistemological reasoning with evidence in science teaching may provide a practical basis for analysing educational discourse involving STSE issues. We have demonstrated the suitability of our set of criteria and sub-criteria and of our methods: The criteria provided guidance for both a qualitative and a quantitative textbook analysis in the domain of STSE issues. In further research or for practical purposes, our set might be used as a check list for verifying which ideas are conveyed to students and which are missing. Applying our criteria and sub-criteria may expose the proficiency of textbooks in approaching STSE issues and, therefore, in being helpful for promoting students' SL. Our quantitative analysis is adequate for emphasizing the relative predominance of single ideas by highlighting the ones that are clearly stressed, the ones slightly mentioned, or those that are absent. The observed balance or imbalance between the expressed ideas about science and technology may enable researchers to identify both the internal coherence of textbooks concerning the (positively or negatively) correlated ideas, and the views of science and technology that textbooks convey. Additionally, our methodology provides understanding about the intentional or the arbitrary character of decisions that underlie (the making of) textbooks, thus highlighting the arguments for SL [1] behind the textbook's conception. All in all, it allows the differentiation of different textbook profiles. Despite the methodological limitations inherent in the size of the sample, we argue for the suitability of the employed combination of methods for the detection of notable divergences within a heterogeneous country or for carrying out an international comparison between diverse socio-cultural contexts. Regarding the history of science in biology textbooks, Markert [42] (p. 318) found "strikingly similar results in different countries (e.g., Great Britain, Canada, Greece, Spain, United States), for different target audiences (students in secondary school, college, university), in different disciplines (biology, chemistry, physics) and for several decades". Whether a similar match will exist in STSE issues remains an open question which we are examining in ongoing work. We also argue for the applicability of our framework in other contexts of biology (e.g., ecology) or in other subjects, such as chemistry (e.g., nuclear power). Equivalent analyses in those domains would contribute to enhance transferability and validity of our criteria and methods. We recognize the similarity of our results to that of previous analysis of textbooks in terms of knowledge about science carried out by other researchers both in other countries and in Germany (see above). While maintaining some caution with generalizations, we argue that the current contribution of biology textbooks to SL is outlined in our work.

It is to be noted that any engagement in an epistemological debate, or classifying textbooks, was beyond the scope of the present work. Instead, we sought to identify aspects requiring improvement (e.g., including environmental STSE aspects) and the presentation of good practices (e.g., social impact of science and technology). In this sense, we stress that our analysis has exposed the political basis for constructing a framework to include STSE in the biology curriculum. It has also provided evidence of the transposition of epistemological ideas driven by the four decade-long debate on the inclusion of STSE issues in science education [8]. However, important ideas are still absent and others are overemphasized, thus displaying, at least partially, the DSVSNT. We argue therefore that presenting this distorted view in textbooks is an obstacle for students' construction of a fair image of science and technology, therefore limiting students' SL.

In summary, the introduction of STSE issues represents a challenge to curriculum developers and to teachers, even though it seems to be an international trend [55]. The progressive intention of adding STSE material into the curriculum, either by curriculum makers into syllabi, by textbook writers into textbooks or by teachers in their science lessons must be accompanied by the awareness that one's views of science and technology might influence the views conveyed to students. On the other hand, in-service teachers (mainly the less experienced ones) strongly rely on textbooks (e.g., [37,45,88]. They express reluctance or difficulty in approaching controversial issues [23,91]. Hence, our findings, when incorporated into science educators' training and in further training programs, may provide a framework for curricula makers, helping the incorporation of STSE issues into curricula; may provide a reference for textbook writers, pointing out a way to approach such issues; and may guide teachers in exploring STSE issues in their classes. Furthermore, our set of criteria might be useful for publishers to formulate their textbook guidelines; for encouraging textbook writers to include STSE issues in textbooks and guiding textbook writing; for orienting textbook selection by teachers; and finally, for shaping the criteria used by textbook reviewers and evaluating committees.

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Author Contributions

Florbela Calado completed the textbook analyses, Franz-Josef Scharfenberg finalized the statistical analyses. Florbela Calado wrote the first version of the manuscript which by all three authors concertedly was refined to the final printed version.

Conflicts of Interest

The authors declare no conflict of interest.

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