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Microbiology in science and biology textbooks: STS approach and applicability of knowledge

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ABSTRACT

This research analyzed content related to Microbiology covered in Science and Biology textbooks, considering the importance of this resource in Basic Education and the necessity to explore the knowledge in the addressed area from the perspective of Science, Technology, and Society (STS). The research was conducted by selecting the topic of Microbiology in textbooks, followed by establishing criteria for qualitative analysis of the works, based on the National Textbook Guide of the National Textbook Plan (PNLD), and creating a scoring table assigned to the analyzed criteria. It was noticed that the majority of the books approached Microbiology moderately or satisfactorily, although one of the Science textbooks did not make any reference to the theme.

KEYWORDS: Microbiology Teaching. Science and Biology Teaching. Science Education.

1 INTRODUCTION

The Teaching of Sciences and Natural Sciences and their Technologies with a Science, Technology, and Society (STS) approach should contribute to guiding students towards an effective participation in the teaching-learning process, particularly concerning the need to understand the connection between scientific knowledge and its direct or indirect influences across all sectors of society.

In the current school context, the Textbook (TB) still stands as an essential tool. At times, it is the sole resource available for teachers and students, thus some studies emphasize its importance in curriculum organization. Given its significance, constant research is required for the continuous updating of TBs (SILVA; OLIVEIRA, 2013). Concurrently, the National Textbook Program (PNLD), along with its updates, not only ensures the standard of quality of educational materials but also aims to support the implementation of the National Common Curricular Base (BNCC).

Regarding contextualization, interdisciplinarity, and STS approach in textbooks, as these aspects constitute major tools to aid in the science teaching-learning process, investigating these aspects is important to determine whether the TBs used in Basic Education are contributing positively or negatively (PEIXE *et al*., 2017). Additionally, studies about the development of Didactic Units, the appropriate use of the teacher's manual, and the teacher's autonomy in relation to the use of TBs and other teaching materials become equally pressing. Research in Education with this perspective can contribute to classroom teaching and to the understanding of Science disseminated in people's daily lives.

Particularly, teaching Microbiology in Basic Education is considered a challenge due to various obstacles that restrict the applicability of knowledge and consequently the learning of teachers and students. Among the main obstacles, the high level of abstraction demanded from students and the lack of contextualization and interdisciplinarity are elements that negatively influence and need to be highlighted so that this and other sub-areas of Natural Sciences and their Technologies can be better addressed in classes and expressed in teaching materials.

Interdisciplinarity appears in this context as a pedagogical work perspective that promotes dialogue among various knowledge areas and their contents, in order to strengthen, qualify, and contextualize the learning process of students at their respective levels of education (FORTUNATO; CONFORTIN; SILVA, 2013). Therefore, it also becomes a necessary approach in TBs, to enhance the teaching-learning process and to assist in the development of problem-solving skills.

From this perspective, although on one hand Microbiology is considered complex, on the other, it encompasses a series of concepts, also complex, but allowing direct application in social issues, such as the action of microorganisms in decomposition, in the food and pharmaceutical industries, in bioremediation, in water and sewage treatment, in the functioning of various living beings and ecosystems, among other considerations. Although these approaches enable contextualization and interdisciplinarity, there is a prevalence of alternative conceptions, often associated with the fact that people commonly relate microorganisms exclusively to infectious diseases (AZEVEDO; SODRÉ-NETO, 2014; OLIVEIRA; AZEVEDO; SODRÉ-NETO, 2016).

The lack of contextualization in classes can be the determining factor for the significant prevalence of misconceptions about Microbiology (SODRÉ-NETO; COSTA, 2016). The applicability of concepts seems to be absent in classes or disjointed from the specific content of the field, even though they are well expressed in some textbooks (TBs). Consequently, everyday situations, such as the presence of microorganisms in all ecosystems, including enabling the existence of animals and plants through transformations of matter in terms of primary production and decomposition, and harmonious relationships like symbioses, should predominate at the beginning of classes as a stimulus for interest and the desired dialogue, aiming for learning through knowledge construction.

Considering the importance of TBs as the most common source of information in Basic Education and the prevalence of alternative conceptions or lack of knowledge about applied Microbiology, often evidenced in research on Science and Biology Education, the objective of this work was to analyze how the content is covered in Science and Biology TBs, primarily to identify whether the didactic works approach Microbiology concepts from a STS perspective, permeating aspects of contextualization, interdisciplinarity, and consequently, the applicability of knowledge.

2 METHODOLOGY

The research was conducted in three consecutive stages: firstly, Science and Biology TBs used in municipal, state, and private schools in the states of RN and PB were selected; then, criteria for qualitative analysis of the works were established, based on the National Textbook Guide of the National Textbook Program (PNLD) from 2015 (BRASIL, 2014); finally, a score was assigned to the analyzed criteria in another table. All established criteria were directed towards the analysis of Microbiology present in the TBs.

2.1 Selection of textbooks

The choice of TBs was made using the collections available in the target schools, from which the 2010 and 2015 editions published for Elementary and High School were selected. For each selected work, a code was assigned, starting with the letter C to represent Science TBs and the letter B for Biology TBs, followed by consecutive numbers according to the random order of analysis. For example, the first analyzed Science TB received the code C1, and the first analyzed Biology TB received the code B1. A total of eight Science TBs (for Middle School) and nine Biology TBs (for High School) were analyzed and are identified and organized in Tables 1 and 2, respectively.

Table 1 - List of Science textbooks used in Middle School selected for analysis

Code	Work	Author	Publisher	Year of Edition
C1	Investigar e conhecer- 6th Grade	LOPES, S.	Saraiva	
C2	Investigar e conhecer - 7th Grade	LOPES, S.	Saraiva	2015
C3	Investigar e conhecer - 8th Grade	LOPES, S.	Saraiva	2015
C4	Investigar e conhecer - 9th Grade	LOPES, S.	Saraiva	2015
C5	Companhia das Ciências - 6th	USBERCO, J. *et al.*	Saraiva	2015
C6	Companhia das Ciências - 7th	USBERCO, J. *et al.*	Saraiva	2015
C7	Companhia das Ciências - 8th	USBERCO, J. *et al.*	Saraiva	2015
C8	Companhia das Ciências - 9th	USBERCO, J. *et al.*	Saraiva	2015

Source: Data organized by the authors (2023).

Table 2 - List of Biology textbooks used in High School selected for analysis

Code	Work	Author	Publisher	Year of Edition
B1	BIO – Edição Especial (Volume I)	LOPES, S.	Saraiva	
B2	BIO - Edição Especial (Volume II)	LOPES, S.	Saraiva	2015
B3	BIO - Edição Especial (Volume III)	LOPES, S.	Saraiva	2015
B4	Biologia- Diálogos com a vida (Part 1)	FAVARETTO, J. A.	FTD	2015
B5	Biologia- Diálogos com a vida (Part 2)	FAVARETTO, J. A.	FTD	2015
B6	Biologia- Diálogos com a vida (Part 3)	FAVARETTO, J. A.	FTD	2015
B7	Biologia (Ser protagonista 1)	SANTOS; AGUILAR; OLIVEIRA	SM	2010
B8	Biologia (Ser protagonista 2)	SANTOS; AGUILAR; OLIVEIRA	SM	2010

Source: Data organized by the authors (2023).

2.2 Criteria for Analysis

The analysis of the books was conducted with a focus on content related to Microbiology, with the primary objective being to evaluate how this topic is integrated into Science and Biology TBs used in Middle and High School.

Regarding the evaluative criteria, an adapted list from the criteria applied by the National Textbook Program 2015 (BRASIL, 2014) was used, divided into three dimensions (Table 3).

Table 3 - Analysis of microbiology themes in Science and Biology TBs (National Textbook Program 2015) according to formative dimensions

Analyzed Dimensions in Biology and Science Textbooks PNLD 2015	Criteria under analysis
Dimension I CONTEXTUALIZATION AND INTERDISCIPLINARITY (Concepts, definitions, and everyday interactions)	Human health (positive and negative interferences); Microbiology importance; Visual resources (self-explanatory images coherent with the text).
Dimension II APPLICABILITY OF TEACHING (Dynamics, experiments, and laboratory procedures)	Approach to microbiology concepts and practices; Proposition of experimental questions.
Dimension III EMPOWERMENT AND CRITICALITY (STS Approach)	Use of complementary texts.

Source: Adapted from Brasil (2014).

Dimension I of analysis aimed to observe, above all, whether the textbook presents contextualization of the microbiology theme regarding human health and the importance of microorganisms, as well as to identify the way visual resources are integrated in the works, with an emphasis on analyzing images in each textbook. The goal was to assess which images provide an approach to everyday life and also contextualization.

Dimension II had the purpose of observing whether the textbook discusses the applicability of teaching with regard to approaching microbiology content focused on the proposition of questions and consequently integrative practices, highlighting laboratory practices.

Dimension III aimed to analyze empowerment and criticality with a focus on the Science, Technology, and Society approach. The goal was to examine whether the textbook includes complementary texts that favor satisfactory reading and understanding.

2.3 Method of Criteria Evaluation

For the evaluation of each criterion established in the analysis dimensions of the textbooks, numerical values were assigned according to Table 4. Each textbook

was analyzed thoroughly and individually, assigning the appropriate value to each analysis criterion and, if necessary, listing relevant observations for each work.

Table 4 - Numerical scale values assigned for analysis of Science and Biology textbook criteria

Values	Considerations for each value
4	The work satisfactorily covers the criterion
3	The work moderately covers the criterion
2	The work unsatisfactorily covers the criterion
1	The work does not cover the criterion

Source: Authors (2023).

3 RESULTS AND DISCUSSION

There is a constant concern for the quality of education, involving both aspects of teaching practice and issues related to available teaching materials. The quality of materials has been frequently investigated, in research such as this, focusing on the content presented in terms of didactic sequences and also alternative modalities for approach. Often, experimentation, for example, is interpreted as a complementary or confirmatory practice of an apparently established theory. This idea, discussed in the analysis of Dimension II of this work, impacts the contextualization of themes (Dimension I) and consequently the STS approach also in complementary texts present in the textbooks (Dimension III).

In this research, the proposed dimensions follow in the sequence of the subtopics below with the respective analyses and discussions of the results.

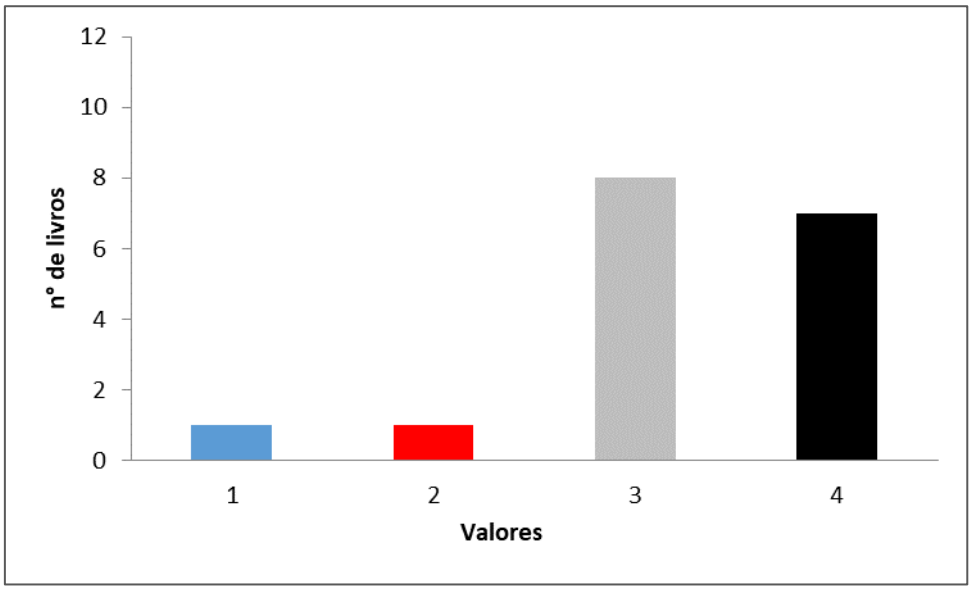
3.1 Dimension I - Contextualization and Interdisciplinarity (Concepts, Definitions, and Everyday Interactions)

Dimension I was directed towards human health and the importance of microbiology in a contextualized and interdisciplinary manner. It also encompassed visual resources, considering their fundamental role in the teaching-learning process of Science and Biology.

Human Health

Regarding the approach to human health related to Microbiology, eight textbooks were classified with a value of 3 (C1, C5, C7, B1, B2, B4, B7, and B9), indicating a moderate coverage of the criterion, and seven textbooks were given a value of 4 (C2, C3, C6, B3, B5, B6, and B8) for satisfactorily covering the criterion (Figure 1).

Figure 1 - Number of textbooks classified with each value regarding the criterion of human health related to microbiology.



Source: Research data (2023).

It was observed that among the textbooks classified with a value of 3, the content was explained without very detailed information. In textbook C1, in the chapter titled "Soil Pollution," the author mentions some risks that improper waste disposal can pose to human health. Furthermore, it discusses some diseases caused by microorganisms. Still on the topic of health, the chapter titled "Water and Living Beings" discusses some microorganisms present in water puddles. In textbooks C5, C7, B1, B2, B4, B7, and B9, the authors presented bacterial and fungal decomposition, as well as possible waterborne diseases.

It is relevant to address aspects of Microbiology associated with human health, although it is proportionally significant to emphasize the evidence of the positive consequences of microbial activities for various organisms and environments. Bernardi *et al.* (2019), in an investigation into the prior conceptions of elementary school students about microorganisms, show that these organisms are predominantly seen from the perspective of causing diseases in humans and are thus simplified in relation to the complexity of microbial contributions in various other domains.

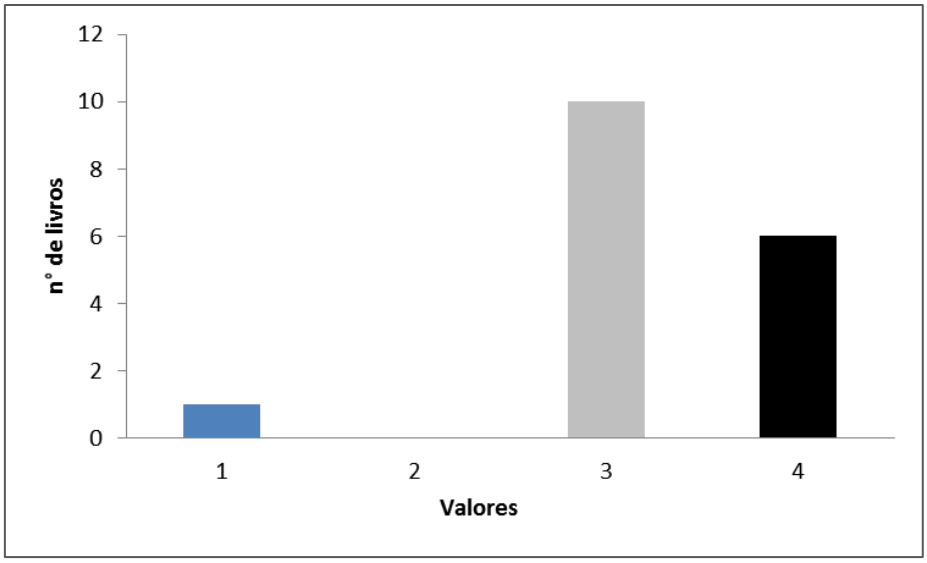
The textbooks that were assigned a value of 4 are characterized by providing a satisfactory approach to human health related to microbiology, as the relationship between microorganisms and human health was described at various points throughout the chapters. This coverage encompasses diseases that can be caused by these organisms, descriptions of transmission methods, prevention and treatment, and even the use of microorganisms in the production of important pharmaceuticals like penicillin. Among the textbooks, C2 stands out for not only covering diseases caused by viruses and bacteria but also discussing viruses used in biological control and "*Smallpox and the Discovery of the Vaccine*".

C4 was assigned a value of 2 for unsatisfactorily covering the topic. It briefly mentions the action of microorganisms aiding in human digestion. Only C8 received a value of 1, as the textbook did not make any mention of human health involving microbiological content.

Importance of Microbiology

Regarding the importance of microbiology, the majority of textbooks, ten of the analyzed works (C1, C2, C3, C4, C6, B1, B6, B7, B8, and B9), received a value of 3 (Figure 2). Although present, it was observed that the importance of microbiology is presented succinctly throughout the book or there is an emphasis only on the medical importance of microorganisms, through the description of diseases caused by them.

Figure 2 - Number of textbooks categorized with each value regarding the criterion of the importance of microbiology.



Source: Research data (2023).

Books C1, C2, C3, C4, C6, B8, and B9 present some diseases caused by microorganisms, especially viruses and bacteria. In B1 and B7, the authors discuss basic principles related to microbiology, such as the differences between eukaryotic and prokaryotic microorganisms, sexual and asexual reproduction, and the use of the microscope.

Another significant portion of the books, six of them (C5, C7, B2, B3, B4, B5), satisfactorily covers the importance of microbiological content (Figure 2). In these works, a greater wealth of details was observed regarding the importance of microbiology, including the inclusion of this theme in directly or indirectly related content.

Book C5 mentions the production of certain foods like curd and yogurt, promoting contextualization to deconstruct the idea that microorganisms are solely disease-causing agents. In the same direction, Brandão (2011) states that these organisms have great economic potential, producing medications and food, as well as being employed in genetic engineering techniques, enabling the production of hormones like insulin, for instance. Additionally, virtually all living organisms, including humans, depend on symbiotic relationships with certain species of bacteria that contribute both to their immune defense and the production of vitamins and digestion of food.

Book B2 addresses microorganisms through a question: "*Why study viruses, prokaryotes, protists, and fungi?*" This approach seeks contextualization and

highlights the investigative nature of knowledge in Science. Similarly, book B3, also classified as satisfactorily covering the criterion, effectively presents the relationship of microorganisms with vaccines, transgenic organisms, ecosystem structure, energy flow, and the matter cycle. Books B4 and B5 also reference the participation of microorganisms in ecological relationships, the economy, and biotechnology. Marcelino and Marques (2017) emphasize the importance of addressing biotechnology, which is present in everyday life across various fields and can also help people acquire new knowledge.

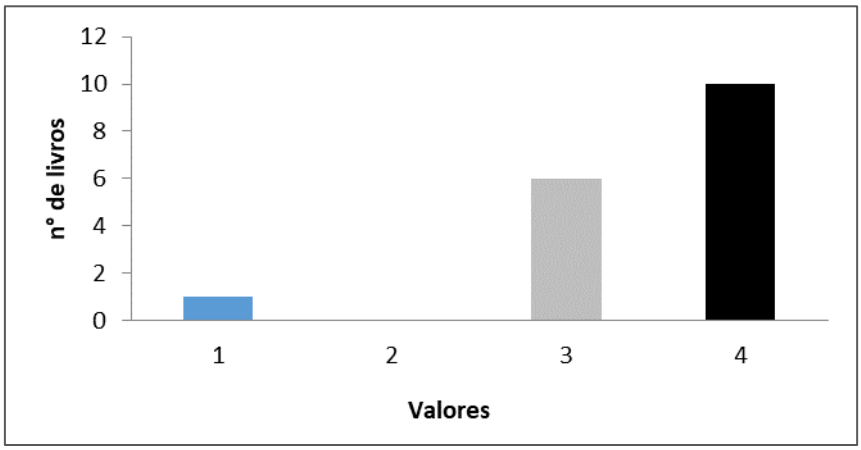
Although the six highlighted textbooks satisfactorily covered the importance of microbiology, the majority of them still moderately addressed it. These findings align with Azevedo and Sodré-neto (2014), Silva and Menolli Junior (2016), and Batista, Cunha, and Cândido (2010) in their studies on bacteriology, mycology, and virology in textbooks, respectively, where the importance of these microbiology topics was moderately covered in a large portion of the books, without deeper exploration. A more comprehensive approach to this topic is therefore necessary, both to demystify the impression that microorganisms are essentially disease-causing agents and to enhance understanding of the numerous positive consequences of microbial activity.

Visual Resources

Visual resources in textbooks, when combined with concepts conveyed through verbal language, act as essential elements in the communication of scientific knowledge (COUTINHO; SOARES, 2010), as they can assist in solidifying ideas through images or illustrations, provided they are clear and accompanied by appropriate captions and scales.

Regarding visual resources, a total of ten books received a classification of value 4 (C2, C6, B2, B3, B4, B5, B6, B7, B8, and B9) (Figure 3). In these books, visual resources were well represented and demonstrated aspects of interdisciplinary and contextual understanding.

Figure 3 - Number of textbooks categorized with each value regarding the criterion of visual resources.



Source: Research data (2023).

Books C2, C6, B2, B3, B4, B6, B7, B8, and B9 presented more up-to-date images with corresponding explanatory captions, exploring topics related to daily activities, such as the presence of microorganisms naturally in various environments, emphasizing the importance of photosynthetic microorganisms, and the use of microorganisms in biotechnology for producing medications, food, and other human consumables.

With a value of 3, six books (C1, C3, C4, C5, C7, and B1) displayed visual resources with moderate interpretation and were classified as such due to predominantly featuring older and conventional images. These included depictions of insulin production, cheese, yogurt, and beverages by microorganisms, as well as illustrations depicting the presence of microorganisms in material cycles, highlighting symbiotic relationships with plants and other microorganisms for the proper functioning of terrestrial and aquatic ecosystems.

Despite having self-explanatory captions in some cases, updating these visual resources and their corresponding captions is of paramount importance, as it can aid the learning process. The majority of the analyzed books featured a significant number of images integrated into the text, and for this reason, no work was classified with a value of 2.

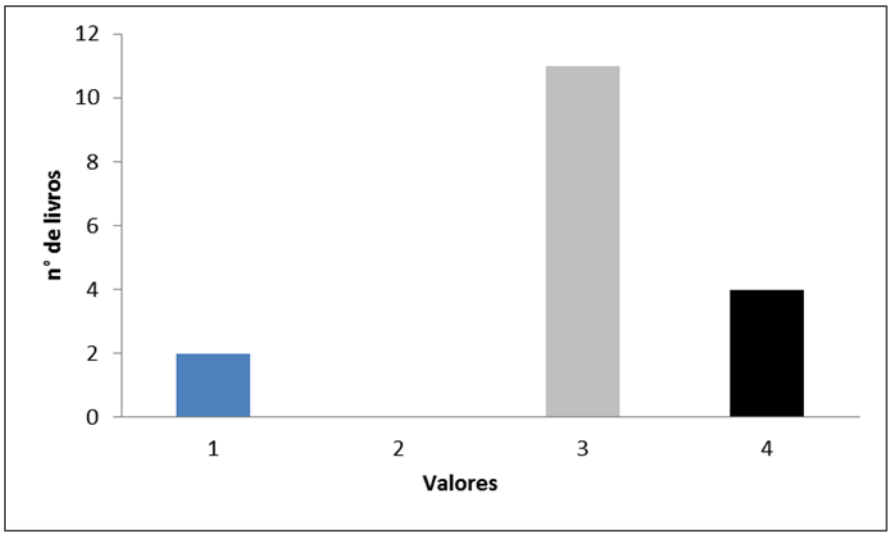
3.2 Dimension II - Applicability of Teaching (Dynamics, Experiments, and Laboratory Procedures)

Dimension II focused on interpreting the alignment of concepts and practices related to microbiology to analyze the applicability of teaching in the textbooks. Additionally, it also involved analyzing the proposition of experimental questions in content related to this theme. The interpretation emphasized these aspects based on the assumption that the inclusion of practices in textbooks and, consequently, the encouragement of their execution in the classroom can enhance learning in microbiology.

Alignment of Concepts and Practices Related to Microbiology

Eleven textbooks (C2, C3, C4, C5, C6, C7, B2, B3, B5, B6, and B7) were classified with a value of 3, four textbooks (B1, B4, B8, and B9) with a value of 4, and the other two textbooks (C1 and C8) with a value of 1 for not addressing this criterion (Figure 4).

Figure 4 - Number of textbooks categorized with each value regarding the alignment of concepts and practices related to microbiology.

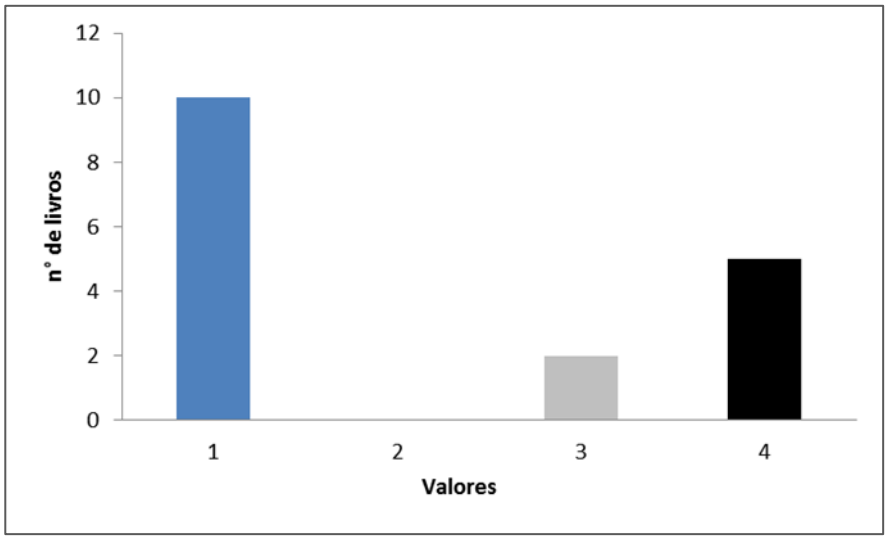


Source: Research data (2023).

Proposition of Experimental Questions

The majority of textbooks (C1, C3, C4, C7, C8, B1, B2, B3, B4, and B6) did not include the proposition of experimental questions related to microbiological content and were classified with a value of 1 (Figure 5).

Figure 5 - Number of textbooks categorized with each value regarding the proposition of experimental questions.



Source: Research data (2023).

The described results are similar to those presented by Azevedo and Sodré-Neto (2014) in their research on bacteriology, where they identified only one out of the eleven analyzed textbooks with a proposed practical activity. Silva and Menolli Júnior (2016) described that regarding experimental activities about fungi, only three out of the eight textbooks they analyzed offered this type of activity.

Regarding the importance of these experimental questions included in the textbooks, the results are concerning and indicate the need for the incorporation of more and better experimental approaches. Deitos and Malacarne (2020) argue that teachers, when facing Science textbooks in relation to proposed experimentation questions, should identify inappropriate content and conceptions so that these moments support full learning. This also includes attention to the methodology to be followed and the construction of a facilitating space for the construction of scientific knowledge, enabling students to engage directly. Experimentation, according to Oliveira and Soares (2010), brings several contributions to motivate and capture students' attention, as well as encouraging decision-making and aiding in the understanding of the nature of Science.

Five textbooks (C6, B5, B7, B8, and B9) satisfactorily addressed this aspect and were classified with a value of 4. The textbook C6 addresses various experimental questions, such as in the chapter about bacteria, where it presents a practice titled "Are there bacteria on my piercing?" using the same type of strategy for the approach to viruses and protozoa in the following chapters. This demonstrates the author's concern in suggesting experiments at the end of each chapter on microbiology-related content.

Similarly to C6, the textbooks B5, B7, B8, and B9 developed their chapters with microbiology themes, establishing connections with everyday life through proposed experiments to highlight the presence and microbial activity, ranging from food and biofuel production to environmental colonization.

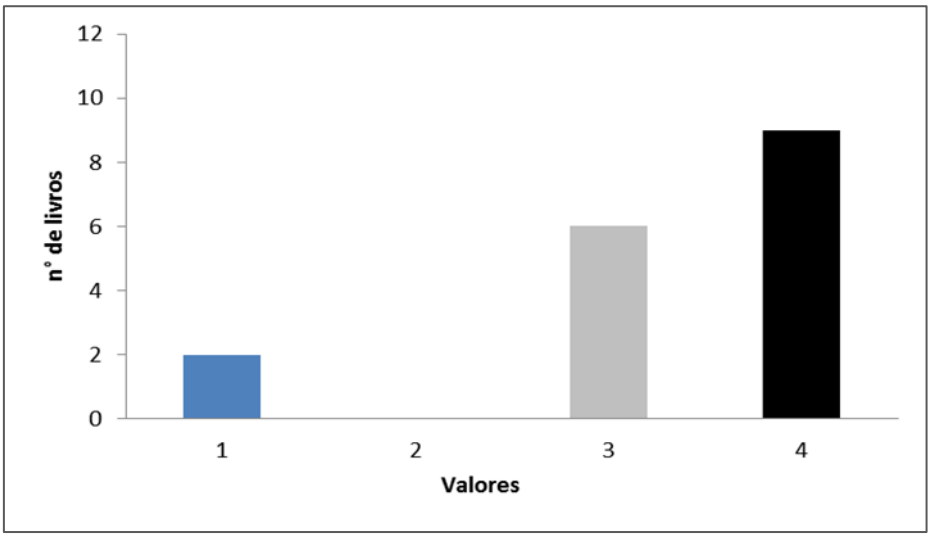
3.3 Dimension III - Empowerment and Critical Thinking (STS Approach)

Dimension III served for the analysis of the use of supplementary texts in the textbooks to assess their contributions to students' empowerment and critical thinking. It also addressed the inclusion of the Science, Technology, and Society (STS) approach in supplementary texts with an emphasis on microbiology themes.

Use of Supplementary Texts

Regarding the analysis of the presence of supplementary texts, nine textbooks (C2, C3, C6, B1, B2, B5, B7, B8, and B9) were classified with a value of 4 (Figure 6).

Figure 6 - Number of textbooks categorized with each value regarding the use of supplementary texts.



Source: Research data (2023).

The textbook C2 presents supplementary texts in all chapters, which can further favor contextualization and understanding of the subjects addressed. Additionally, despite being a textbook used in Middle School, more than one supplementary text addressing the use of viruses in biological control, one of the important applications of this type of microorganism, was identified. The importance given by the teacher to this type of reading can enhance students' understanding of Science as more closely connected to reality, preventing students from interpreting science as something isolated.

The other textbooks that addressed this aspect satisfactorily also contribute with texts that connect microorganisms to real-world issues, emphasizing ecological and economic significance, as well as the medical importance of these organisms.

In the textbook B7, it is worth noting an example of texts that appear in this work, titled "*Microscope against Crime*" and subtitled "*Science, Technology, and Society*". The author emphasizes the importance of this Science, Technology, and Society (STS) movement in the teaching-learning process, agreeing with Sodré-Neto and Costa (2016) regarding the inseparability of S, T, and S. Similarly, in the textbook B8, at the end of each chapter, the author makes sure to use contextualized supplementary texts and also uses "*Science, Technology, and Society*" as a subtitle.

In each chapter of the textbook B9, supplementary texts also appear, seeking to engage the reader in the STS environment. To achieve this, the author uses titles addressing biotechnology, genetics, transgenics, vaccines, and other topics that attract people's attention.

The six textbooks classified with a value of 3 (C1, C4, C5, C7, B4, and B6) were so classified for presenting fewer supplementary texts with a Microbiology approach or offering concise approaches to the proposed topics.

Although having supplementary texts, the textbooks C8 and B3 did not present approaches to Microbiology-related topics in these readings, and therefore they are presented with a value of 1.

4 CONCLUSIONS

Principles of contextualization and interdisciplinarity are generally present in the analyzed Science and Biology textbooks, and the National Textbook Program (PNLD) can contribute significantly to the continuity and quality of these approaches. On the other hand, the discussion highlights the prevalence of the absence of these factors in teaching research, perhaps due to professionals not keeping up with the proposed activities or readings present in the textbooks, for various reasons, including a lack of interest in staying updated.

Similarly, when it comes to connections between Microbiology concepts and practices, although they are present in most textbooks, the experimentation proposals themselves are found at the end of each chapter or unit, as if this type of practice only served to consolidate a particular theory. Therefore, it is essential to emphasize the investigative function of experimental practice and alert the teacher to their responsibility to problematize and create learning situations.

Regarding the proposal of supplementary materials from the STS perspective, a large portion of the evaluated textbooks also proves efficient, providing greater ease of access to readings that address specific subjects and their potential applications.

The data presented and discussed here emphasize that Microbiology, despite being present moderately or satisfactorily according to most analyzed criteria, still has some limitations related to textbook-based teaching and learning. This reinforces not only the need for ongoing research on textbooks used in Basic Education, especially in Natural Sciences and their Technologies but also the need to encourage teachers to make appropriate use of the teaching materials, including the teacher's manual.

It is also suggested that the analysis of teacher's manuals be a topic for future research, as this type of material has a specific construction that can underpin teaching practice with additional information and experimentation suggestions that may not necessarily appear in the student-oriented textbooks.

MICROBIOLOGIA EM LIVROS DIDÁTICOS DE CIÊNCIAS E BIOLOGIA: ABORDAGEM CTS E APLICABILIDADE DO CONHECIMENTO

RESUMO

A pesquisa analisou conteúdos relativos à Microbiologia contemplados em Livros Didáticos (LD) de Ciências e Biologia considerando a importância deste recurso na Educação Básica e a necessidade de se explorar os conhecimentos da área abordada sob a perspectiva de Ciência, Tecnologia e Sociedade (CTS). A pesquisa foi desenvolvida a partir da seleção do assunto de Microbiologia em LD, seguida pelo estabelecimento de critérios para análise qualitativa das obras, baseando-se no Guia Nacional do Livro Didático do Plano Nacional do Livro Didático (PNLD) e na confecção de uma tabela de pontuação atribuída aos critérios analisados. Percebeu-se que a maioria dos livros abordou a Microbiologia de forma moderada ou satisfatória, apesar de um dos LD de Ciências não fazer qualquer referência ao tema.

PALAVRAS-CHAVE: Ensino de Microbiologia. Ensino de Ciências e Biologia. Educação em Ciências.

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