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Analysis of Arguments about Mendel's First Law in High School Natural Sciences Textbooks

Análise dos Argumentos sobre a Primeira Lei de Mendel em Livros Didáticos de Ciências da Natureza do Ensino Médio

Análisis de Argumentos sobre la Primera Ley de Mendel en Libros de Texto de Ciencias Naturales de Secundaria

Suellen Fonsêca da Conceição Santos, Elder Sales Teixeira, e Rosiléia Oliveira de Almeida

Abstract

Studies have highlighted the contributions of argumentation to the teaching of Natural Sciences. However, analyses investigating its presence and quality in textbooks are still scarce. This qualitative study examines arguments expressed in the statements of Mendel's First Law in high school Natural Sciences textbooks approved by the PNLD/2021. For the analysis, Toulmin's Argument Pattern was adopted as the theoretical and methodological framework, complemented by the instrument proposed by Penha and Carvalho (2015) and adapted by Silva (2021). Among the seven textbook collections analyzed, one does not present any argumentative elements in its approach to Mendel's First Law, five display only partially satisfactory argumentation, with elements that do not fully fulfill their functions, and only one contains a satisfactory argument, in which each identified element adequately serves its purpose. The results reveal significant gaps in the arguments related to Mendel's First Law, highlighting the need to improve this approach in textbooks.

Keywords: argumentation, Natural Sciences, textbook, Mendel's First Law

Resumo

Estudos têm destacado as contribuições da argumentação para o ensino de Ciências da Natureza. No entanto, ainda são escassas as análises que investigam sua presença e qualidade nos livros didáticos. Este estudo, de natureza qualitativa, investiga argumentos expressos nos enunciados da Primeira Lei de Mendel em livros didáticos de Ciências da Natureza do Ensino Médio, aprovados pelo PNLD-2021. Para a análise, adotou-se o Layout de Argumentação de Toulmin como referencial teórico e metodológico, complementado pelo instrumento proposto por Penha e Carvalho (2015) e adaptado por Silva (2021). Entre as sete coleções analisadas, uma não apresenta elementos argumentativos na abordagem da Primeira Lei de Mendel, cinco exibem argumentações apenas parcialmente satisfatórias, com elementos que não cumprem integralmente suas funções, e apenas uma contém um argumento satisfatório, em que cada elemento identificado cumpre sua função adequadamente. Os resultados evidenciam lacunas significativas nos argumentos sobre a Primeira Lei de Mendel, apontando a necessidade de aprimorar essa abordagem nos livros didáticos.

Palavras-chave: argumentação, Ciências da Natureza, livro didático, Primeira Lei de Mendel

Resumen

Diversos estudios han destacado las contribuciones de la argumentación para la enseñanza de las Ciencias Naturales. Sin embargo, aún son escasos los análisis que investigan su presencia y calidad en los libros de texto. Este estudio, de naturaleza cualitativa, investiga los argumentos expresados en los enunciados de la Primera Ley de Mendel en libros de texto de Ciencias Naturales de la Educación Secundaria, aprobados por el PNLD/2021. Para el análisis, se adoptó el Esquema de Argumentación de Toulmin como marco teórico y metodológico, complementado por el instrumento propuesto por Penha y Carvalho (2015) y adaptado por Silva (2021). Entre las siete colecciones analizadas, una no presenta elementos argumentativos en el abordaje de la Primera Ley de Mendel, cinco exhiben argumentaciones solo parcialmente satisfactorias, con elementos que no cumplen plenamente sus funciones, y solo una contiene un argumento satisfactorio, en el que cada elemento identificado cumple adecuadamente su función. Los resultados evidencian lagunas significativas en los argumentos sobre la Primera Ley de Mendel, señalando la necesidad de mejorar este enfoque en los libros de texto.

Palabras clave: argumentación, Ciencias Naturales, libro de texto, Primera Ley de Mendel

Introduction

The teaching of Genetics is often perceived by students as difficult to understand, as it requires the consolidation of concepts from other areas, such as Mathematics (Borges et al., 2017), and the teaching approach employed influences learning. Using argumentative strategies can enhance this comprehension, as, to argue, the student needs to have a more critical understanding of the content. Furthermore, engagement in favor of science, through the construction of good arguments, contributes to the reduction of scientific denialism (Vilela & Selles, 2020).

Gregor Mendel's studies brought advances in the field of Genetics and contributed to the understanding of the existence and transmission of hereditary factors/traits. His research evidenced the relationship of proportionality between hereditary characteristics in *Pisum sativum peas* (Kavalek & Muscardi, 2019).

Understanding Genetics requires skills to build hypotheses about invisible factors. This understanding prepares students to discuss controversial issues. We consider that argumentation is essential for science (Teixeira et al., 2015), as it facilitates the appropriation of concepts and stimulates scientific reasoning.

Discussions in the field of education point out that the use of textbooks as a tool for guiding argumentation has been negligible (Motta & Vier, 2019). Given this finding, it is urgent to include argumentative aspects in textbooks (Souza et al., 2016), considering that these are of fundamental importance in the education of students in basic education, so that they know how to argue in a more elaborate way even at this level of education (Rosa, 2017).

In a study on the teaching of genetics, teaching strategies applied in elementary, secondary, and higher education were analyzed based on 37 articles published in an academic journal between 2017 and 2021. It was found that most strategies focus on secondary education, followed by higher education and elementary school, with games, practical activities, and inquiry-based teaching being the most recurrent (Rodrigues et al., 2022).

Furthermore, according to the results of the aforementioned study, pedagogical proposals focused on Mendel's laws and other content that comprises classical genetics were identified in greater proportion. For Rodrigues et al. (2022), the use of appropriate teaching materials and active methodologies is essential for effective learning, as it encourages students' active participation and interest in the content in question.

In the same vein, Bernardo et al. (2023) emphasize the importance of using strategies that promote "the development of critical thinking and the student's ability to express opinions and take a stance on the various topics covered by biology" (p. 2). In this context, argumentation is a key resource, as it stimulates students and enables them to build the foundations that prepare them to defend or refute the knowledge they have acquired, which strengthens the learning process.

Complementarily, Oliveira et al. (2025) analyzed scientific production on the teaching of Genetics since the 1990s and identified the main strategies used as socio-scientific questions, active methodologies mediated by technologies, conceptual maps, and models of literacy in Genetics. The authors also emphasize the need to bring research and pedagogical practices closer together, placing Brazil among the ten countries with relevant production in scientific literacy and highlighting the importance of strategies that improve students' understanding. Thus, it can be observed that such studies focus mainly on proposals aimed at improving conceptual understanding, reaffirming the concern with improving the teaching of Genetics.

With specific regard to the analysis of the approach to Genetics in Biology textbooks, the study by Silva et al. (2025) reveals the existence of misconceptions in the approach to complex concepts. According to Silva et al. (2025), with regard to the textbooks approved by the PNLD in 2021, in some cases, the content on genetics contains erroneous information, in which "polygeneic and/or multifactorial inheritance characteristics are presented as Mendelian inheritance" (p. 17). The problem presented further reinforces the role of the teacher in mediating the learning of this content, awakening students' critical thinking by legitimately disseminating content related to hereditary transmission.

Thus, argumentation is characterized as part of an approach that prioritizes the development of argumentative skills in students; therefore, its role is not limited to an isolated resource, but constitutes one of the aspects that should comprise the strategies necessary for promoting science education that seeks to develop critical thinking (Bernardo et al., 2023).

It is important to emphasize that argumentation skills are not developed strictly through access to ready-made content, but it can be built through differentiated teaching strategies. Such strategies provide teachers with the tools to mediate these processes and foster discussions that enable students to present and debate their ideas and knowledge. As textbooks are among the main sources used by students to develop ideas and knowledge, they can be considered equally relevant for encouraging students to produce good, solid arguments about scientific knowledge, even if they are not the only sources for this purpose.

Textbooks can be interpreted as a guiding thread for the interactions necessary for the construction of knowledge, while at the same time enhancing the teacher-student relationship (Spiassi & Silva, 2008). However, according to Borges et al. (2017), they sometimes contain "very specific vocabulary, an excess of technical terms […]," which do not help students understand the content (p. 62).

In view of the questions raised, this study aims to analyze the arguments expressed in the statements of Mendel's First Law in high school Science textbooks approved by PNLD/2021. The study is based on Toulmin's Argumentation Layout (2006), used to assess the quality of the argumentative structure. As this model does not present criteria for classifying the content present in the argument (Teixeira et al., 2015), we used the analytical tool by Penha and Carvalho (2015), adapted by Silva (2021), which was adjusted to the context of this study for the aforementioned purpose.

In this section, we present the general aspects of this study. Next, we will present the theoretical framework—Toulmin's Argumentation Layout and the contributions of Mendel's First Law to Genetics—the methodology of this study, the results, and the conclusions reached.

Theoretical Framework

Toulmin's Argumentation Layout

Argumentative processes are present in everyday life (Jiménez-Aleixandre & Brocos, 2015). In the educational context, a quality argument is one in which the elements fulfill their function and whose justification is sufficient to link the data to the conclusion.

For an argument to be considered high quality, it must meet structural criteria related to argumentative logic and the specificities of the theoretical field (Penha & Carvalho, 2015), which will give the argument the necessary credibility. Arguments are concepts constructed and justified based on premises that support a conclusion (Toulmin, 2006). Given this, it is essential to bring students closer to scientific discourse through the use of argumentation.

Through Toulmin's Argumentation Layout, it is possible to identify the elements that make up the argument. Researchers advocate the use of this tool for the construction and analysis of arguments (Erduran et al., 2004; Penha & Carvalho, 2015), highlighting

its pedagogical advantages for the understanding of scientific knowledge (Teixeira et al., 2015). The use of Toulmin's Argumentation Layout in the teaching process contributes, above all, to a better understanding of the content covered, given that, based on this model, it is possible to construct scientific arguments.

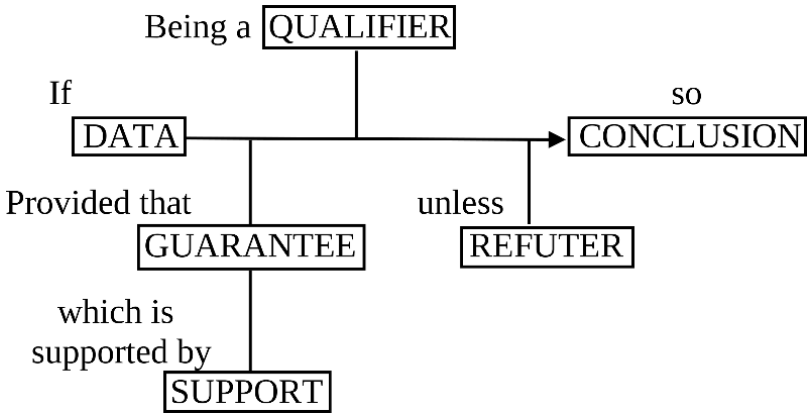
For Toulmin (2006), an argument is composed of the following elements: a) Data (D) – assertions that provide the basis for the conclusion; b) Justification (J) – principle that links the data to the conclusion; c) Conclusion (C) – established central idea. Justifications are essential for understanding and constructing an argument, as they link the data to a conclusion in a legitimate manner (Teixeira et al., 2015).

More complex arguments may require elements such as:

a) Basis (B) – supports the justification; b) Qualifier (Q) – evaluates and strengthens a conclusion; c) Refutation (R) – exceptions that contradict the justification, invalidating the conclusion (Toulmin, 2006) (Figure 1).

Figure 1

Toulmin's Argumentation Layout



Source: Toulmin (2006)[1].

Gregor Johann Mendel and the Law of Segregation of Factors

Gregor Mendel Gregor Mendel (1822–1884), an Augustinian monk, biologist, and botanist, did not receive recognition for his scientific contributions during his lifetime. His studies on the crossbreeding of peas (Pisum sativum), the result of research that lasted about eight years, had a major impact. Mendel's ideas stemmed from his experiences in thought collectives, where part of his knowledge was built (Leite et al., 2001). The process of hybridization was already in use at that time. According to Kavalek and Muscardi (2019), Mendel organized existing knowledge to develop his studies. Mendel's great distinction was his mathematical interpretation of the results.

1 We emphasize that, in this study, the terms "guarantee" and "support" in the argument were replaced by the terms "justification" and "basis," respectively. This replacement was necessary because, after translating the original instrument, the replacement terms were found to be more appropriate for the function they perform in the Portuguese language.

The methodology used in the experiments and the way he mathematically interpreted the results differed from the contemporary works of his time (Martins & Prestes, 2016).

Mendel analyzed characteristics such as seed shape and color, pod shape and color, plant height, flower color, and flower position on the plant individually. According to Mendes (2013), the plants analyzed should: "1. Have contrasting and constant characteristics; 2. Produce hybrids that, during the flowering period, can be protected from the influence of any foreign pollen [...]" (p. 90).

After crossing, Mendel analyzed the offspring, the transmission of characteristics between generations, identifying "pure" plants (Fridman, 2012). He called the pure plants the parental generation or P generation. The crossing between plants of the P generation gave rise to the daughter generation (F1); in it, only one characteristic was expressed. When self-fertilizing the F1 generation, the F2 generation was produced, which presented two characteristics in different proportions, leading to the conclusion that there were dominant and recessive factors in a ratio of 3:1. He proposed that hereditary factors segregated in the formation of gametes, establishing Mendel's First Law, or Law of Segregation of Factors.

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Mendel elucidated how hereditary traits are transmitted to other generations, which ensures the mechanism of heredity. His studies were only validated after his death, when research conducted by De Vries, Correns, and Tschermak obtained similar results (Guimarães, 2016), increasing the credibility of his investigations.

In addition to revolutionizing genetics, Mendel's experiments had pragmatic importance, as they were developed, according to Borges et al. (2017), "to meet the needs of society at the time, which needed more cultivable plant species" (p. 62).

However, textbooks address Mendel's Laws in a superficial and uncritical manner, attributing genius to him (Kavalek & Muscardi, 2019), and further reinforce this idea by defining him as the "father of genetics," when, in reality, his discoveries were based on previous studies, as already mentioned.

Attributing credit to the researcher for understanding heredity fosters the construction of an uncritical view of science. For Melo et al. (2022), "interest in heredity did not begin with Mendel, obviously, and throughout the 19th century, several scientists presented theories to explain this phenomenon" (p. 8), based on the idea of heredity. Mendel's main contribution was to explain the segregation of factors in gamete formation and interpret the results based on proportionality.

Before Mendel, dominant characteristics were understood as "intact," while hidden characteristics were understood as "latent." Mendel redefined these concepts by assuming that "..., the characters that are transmitted with little or no change in hybridization and therefore constitute the characters of the hybrid are called dominant, and those that become latent in the process are called recessive" (Mendel, 1866, cited in Bateson, 1913, p. 342).

Mendel chose well-defined contrasting characteristics, observing that, for every four plants, three expressed a certain dominant characteristic, and only one expressed a recessive characteristic. Thus, the results showed a 3:1 ratio. For Jiménez-Aleixandre and Brocos (2015), "learning science involves, among other things, learning to construct and evaluate evidence-based explanations" (p. 142). In this way, Mendel's studies can foster pro-argumentative situations in the classroom, and based on Mendel's First Law, students can construct scientific arguments that justify the expression or absence of certain hereditary characteristics.

Methodological Aspects of the Research

This is a qualitative study, descriptive and exploratory in nature, through which it is possible to describe the relationships between different aspects (Gil, 2011), which, according to Triviños (2012), "requires the researcher to gather a series of information about what they want to research and describe" (p. 109), as well as to explore these perspectives, aiming to broaden the view of the problem studied (Triviños, 2012), which is in line with the objective of our study.

The choice of PNLD/2021 books for analysis is justified due to recent changes in the educational field and the need to include arguments in textbooks, considering their relevance to scientific learning. PNLD/2021 approved books from seven collections, each organized into six volumes, which can be worked on in a non-sequential manner.

We chose to analyze the content of Mendel's First Law because of its complexity and relevance. The criterion for inclusion in the corpus was the approach to the content. Initially, we conducted searches using the terms: Mendel, Mendel's First Law, and Law of Segregation of Factors. Next, the volumes that addressed or referred to Mendel's First Law were analyzed in detail.

Of the seven collections, only six present Mendel's First Law. As in the LD2 collection, there are no records of Mendel's First Law; this was not part of our analysis, since one of the inclusion criteria referred to the approach to the content in at least one of the volumes of each collection. Thus, we created a table that relates the collection to the volume in which the content was identified (Figure 2).

Figure 2

Identification of selected textbooks and analyzed volumes

References of selected books	Volume analyzed	Identification in research
Canto, E. L., & Leite, E. C. C. (2020). *Moderna Plus: o conhecimento científico. Ciências da Natureza e suas tecnologias*. Moderna.	5	Textbook 1 (LD1)
Godoy, L., Dell, R. M., & Melo, A.W. (2020). *Matéria, energia e a vida: Ciências da Natureza e suas tecnologias*. FTD.	-	Textbook 2 (LD2)
Lopes, S., & Rosso, S. (2020). *Evolução e Universo: Ciências da Natureza e suas tecnologias*. Moderna.	5	Textbook 3 (LD3)
Mortimer, E., Horta, A., Mateus, A., Munford, D., Franco, L., Matos, S., Panzera, A., Garcia, E., & Pimenta, M. (2020). *Matéria, energia e vida uma abordagem interdisciplinar: Ciências da Natureza e suas tecnologias*. Scipione.	2	Textbook 4 (LD4)
Novais, V. L. D., & Antunes, M. T. (2020). *Conexões: Ciências da Natureza e suas tecnologias*. Moderna.	5	Textbook 5 (LD5)
Santos, K. C. D. (2020). *Diálogo: Ciências da Natureza e suas tecnologias*. Moderna.	4	Textbook 6 (LD6)
Zamboni, A., & Bezerra, L. M. (2020). *Ser Protagonista: Ciências da Natureza e suas tecnologias*. SM educação.	6	Textbook 7 (LD7)

Tools and Criteria for Analyzing the Argument

To analyze the arguments, we used Silva's (2021)[2] analytical tool, adapted from Penha and Carvalho's (2015) instrument. The analysis instrument was originally created by Penha and Carvalho (2015) to analyze socioscientific issues in different fields. In turn, in his study, Silva (2021) evaluated arguments in discursive situations produced in the classroom.

However, as our study focused on analyzing arguments presented in the textbook, it was necessary to adjust the analysis criteria. To this end, we adapted the aforementioned instrument to our research context, which enabled us to analyze the arguments in the textbooks using the aforementioned parameters. Thus, the analysis of the study in question was restricted to the following criteria: Formal coherence, Sufficiency, Support, and Validity.

The criterion of "Formal coherence" verifies the structure of the argument in the textbook; for this, the presence of the respective elements was considered: data (D); justification (J); conclusion (C); and foundation (F), according to the elements that make up the structure of Toulmin's (2006) layout. In this study, the criterion referring to "Validity" assesses the adequacy of the argument to the theoretical field, to ensure that the conclusion established is correctly linked to the data analyzed, through justifications that have the functionality of making a coherent interconnection.

2 Silva's (2021) analytical tool, focused on the explicit teaching of argumentation in Physics, is based on the original proposal by Penha and Carvalho (2015), designed to assess the quality of argumentation in socio-scientific activities.

The criteria related to "Belonging" and "Legitimacy," proposed in the study conducted by Silva (2021), were not considered, given that the research objectives differ from each other. The study developed by Silva (2021) focused on analyzing the argumentative discourse produced by students in the classroom, which, in a way, differed from the research object of this study, in which the presence and quality of the argumentative aspects recorded in the approach to the content of Mendel's First Law were analyzed. Thus, as the other criteria described below are relevant to the objective of this study, the analysis was carried out using the evaluation criteria.

For each criterion, a score ranging from 0 (zero) to 2 (two) was assigned. For the criterion of "Formal Coherence," specifically, a value of 0 (zero) was assigned, which corresponds to "No," when none of the structural elements belonging to Toulmin's Layout fulfill their function and there is an absence of "Formal Coherence"; 1 (one), when not all structural elements perform their function adequately, this criterion being considered "Partially" met; and 2 (two), corresponding to "Yes," when all structural elements, in addition to being present, fulfill their function within the structure proposed by Toulmin (2006).

The criterion of "formal coherence" is used to verify the structure of the argument in the textbook; to this end, the presence of the following elements was considered: data (D); justification (J); conclusion (C); and foundation (F), in accordance with the elements that make up the structure of Toulmin's layout (2006). In this study, the criterion referring to "Validity" assesses the adequacy of the argument to the theoretical field, to ensure that the conclusion established is correctly linked to the data analyzed, through justifications that have the functionality of making a coherent interconnection.

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For the other criteria, the same score was assigned, ranging from 0 (zero) to 2 (two), with 0 (zero) for the absence of the analyzed aspect; 1 (one), when there is partial compliance with the analyzed aspect; and 2 (two), when there is cohesive identification

of the aspect in the context of the analyzed content. Thus, this record is made based on the absence, partial presence, or presence of the criteria of: Sufficiency (S)[3], Support (R)[4] e Validity (V)[5], in the content of the argument. The analysis tool used to evaluate both the quality and structure of the argument in the textbook is shown below (Figure 3).

Figure 3

Tool for assessing the quality and structure of the argument

Rubrics for evaluating the argument		
Criterion	**Score**	**Description**
Formal Coherence (C) The components that make up the argument perform their functions according to Toulmin's model.	0	No component adequately performs its structural function.
	1	Some of the components perform a structural function.
	2	All of its components perform their structural functions.
Sufficiency (S) The **justification** is sufficient to establish the relationship between the data and the conclusion.	0	The justifications are not sufficient.
	1	The justifications are partially sufficient.
	2	The justifications are entirely sufficient.
Support (R) The **rationale** supports the justification.	0	The rationale is not satisfactory[6].
	1	The rationale is partially satisfactory.
	2	The rationale is entirely satisfactory.
Validity (V) The **conclusion** of the argument is valid.	0	The conclusion responds incorrectly in relation to the data and justifications.
	1	The conclusion partially responds to the data and justifications.
	2	The conclusion fully responds to the data and justifications.

Source: the authors, based on Silva (2021).

Finally, after analyzing each of the four criteria set out in the instrument used separately, the argument could be classified into one of three categories: it was considered "Unsatisfactory" when none of the four criteria was met with a score of 2 (two); as "Partially satisfactory" when only one, two, or three of the four criteria are assigned a score of 2 (two); or as "Satisfactory" when all four criteria are successfully met, thus being assigned a score of 2 (two).

3 The "Sufficiency" criterion corresponds to the relationship between data and conclusion through justification.
4 The "Support" criterion considers whether the basis provides grounds for the justification.
5 The "Validity" criterion considers whether the identified conclusion is valid for the scientific community.
6 The term "Satisfactory" refers to the element in question.

To better guide our analysis, using Toulmin's Argumentation Layout as a reference, we constructed an example of an argument considered satisfactory on the content of Mendel's First Law, which was used as a parameter for the analysis of excerpts that form the argument presented in each of the textbooks that are part of the scope of this study (Figure 2).

Figure 4

Satisfactory argument model on Mendel's First Law

(D) If	**(C) Thus**
Mendel crossed plants from different pure strains which, when reproduced, produced seeds from the same strain [...] Mendel made a first cross between a pure plant with yellow seeds and a pure plant with green seeds, through cross-pollination, in the Parental Generation. The result of this crossbreeding produced hybrid plants that belonged to the daughter generation or F1 Generation, and all plants in this generation had yellow seeds. After that, Mendel performed self-fertilization, now between plants of the F1 Generation, which resulted in plants with yellow seeds and plants with green seeds in a ratio of 3:1. Mendel called this generation the F2 Generation.	Plant characteristics are determined by a pair of factors, which separate during gamete formation, with only one factor going to each gamete.
(J) Since	
Each character is determined by a pair of factors, which are found in pairs in organisms. One factor generates characteristics that are expressed in all generations, which Mendel identified as dominant, and another factor generates characteristics that were not expressed in all generations and were recorded in a smaller proportion, which are recessive. Mendel analyzed seven characteristics, each with two contrasting aspects that were easy to distinguish. The characteristics analyzed showed a 3:1 ratio for dominance and recessiveness.	
(F) Supported by	
Heredity principles that allow us to infer that there is a mechanism for transferring hereditary factors from one generation to the next, which ensures genetic variability.	

However, it should be noted that the argument is not expected to be presented in the textbook explicitly as in the example above. Although a model has been constructed for analyzing the argument about Mendel's First Law, changes may occur, taking into account the context in which the argument was constructed.

It is essential that the content presents the essential elements for constructing an argument so that students can recognize the logic involved in constructing argumentative thinking and also, as Rios (2021) points out, "analyze certain topics, prioritize their importance, solve problems, and carry out activities by gathering the opinions of others and integrating them into a whole" (p. 9).

Given this, it is essential that teachers who choose to work with the argumentative perspective and use the textbook as a basis are aware of a model that helps them identify the elements that constitute an argument. This will allow them to guide students in constructing a scientific argument.

Analysis of Arguments about Mendel's First Law in PNLD/2021 Textbooks

Next, we present an analysis of the arguments presented in the textbooks. We emphasize that the excerpts that follow in the breakdown of the argument are not recorded here in their entirety[7], as they are sufficient for understanding and analyzing the construction of the argument about the content analyzed. We note that LD1 contains two excerpts that can be used to construct an argument, which were analyzed separately, as described below.

[8]**LD1 (textbook 1) —** Excerpt 1. Breakdown of the argument: data (G); justification (J); rationale (R); and conclusion (C):

D: Mendel chose *Pisum sativum* pea plants as his study material. Because the reproductive elements of the pea flower [...] are enclosed within the keel formed by the petals, self-fertilization usually occurs. Before beginning a cross, Mendel made sure that he was dealing only with plants of pure strains for each characteristic studied. A pure strain is one that, through self-fertilization, produces only plants identical to itself.

J: Mendel focused on seven characteristics, each with two contrasting aspects, or states, that were easy to distinguish. Mendel observed that [...] the self-fertilization of F1 hybrid plants produced offspring consisting of plants with yellow seeds and plants with green seeds.

F: Mendel recorded ratios between dominant and recessive states in different characteristics. For Mendel, there was a [...] pattern of inheritance for all seven characteristics he studied in peas.

C: Mendel concluded that the green color characteristic of the seed did not actually disappear in the F1 generation plants, but was masked, reappearing in the F_2 generation. Mendel called the state of the characteristic that manifested itself in hybrid plants "dominant" and the state of the characteristic that remained hidden "recessive." The similarity in proportions between the dominant and recessive states in different characteristics led Mendel to think that there must be a general law.

In excerpt 1, the elements of data, justification, and conclusion were found. However, the justification does not fulfill its function. Although it mentions that Mendel studied contrasting aspects of seven characteristics, the justification does not highlight the identification and separation of the factors that resulted in the manifestation of these characteristics in different proportions.

An argument enables the organization of thought in a logical manner (Scarpa, 2015). Thus, in the construction of an argument, the presence of a justificatory process is essential, considering its importance in the construction of argumentative reasoning. The justification presented is not sufficient for the construction of a coherent scientific argument.

7 The brackets indicate the deletion of passages that are included in full in the LDs referenced in the analysis corpus.

8 We emphasize that textbooks LD1, LD2, LD3, LD4, LD5, LD6, LD6, LD7, in bold, correspond to each collection that is part of the scope of this study and that "D," "J", "R" and "C" correspond, respectively, to: data, justification, rationale and conclusion, elements that make up Toulmin's Argument Model.

The criteria of "Formal Coherence" and 'Sufficiency' were "Partially" met, as the justification was identified, but it does not link the data to the conclusion. The justification has limitations in that it does not justify the separation of factors, nor does it comment that this was Mendel's discovery. The criterion of "Support" is met, since the rationale refers to heredity, which was known at the time of Mendel, and alludes to the process of transmission of characteristics between generations. The conclusion records the proportionality in the results observed by Mendel, which led him to formulate the Law of Segregation of Factors. Thus, "Support" and 'Validity' were criteria that were "Fully" met.

Only two of the four criteria analyzed fulfill their function in this argument, which was therefore considered "Partially satisfactory" from the structural and content quality standpoint of Mendel's First Law. Since only 50% of the criteria analyzed correspond to the structural and quality functions of the argument, they are not sufficient to support the development of an argument based on the information found. Given this, excerpt 1 of LD1 was considered "Partially satisfactory," as described in Figure 5.

Figure 5

Evaluation of the argument about Mendel's First Law in LD1 — excerpt 1

Rubrics for evaluating the argument				
Criterion	**Description**	**Score**		
		No (0)	**Partially (1)**	**Yes (2)**
Formal Coherence (C)	The components that refer to the structure that forms the argument perform their functions according to Toulmin's Argumentation Layout.		x	
Sufficiency (S)	The **justification** is sufficient to establish the relationship between the data and the conclusion.		x	
Support (R)	The **rationale** is satisfactory to support the justification.			x
Validity (V)	The **conclusion** of the argument is valid.			x
Argument classification		**Partially satisfactory**		

Source: the authors, based on Silva (2021).

Excerpt 2 of LD1 (textbook 1) is structured around premises, which is characteristic of a logical argument, in which a connection between a general idea and specific ideas is expected. Toulmin (2006) proposes that assertions should provide support for the conclusion, a condition characteristic of justificatory processes.

LD1 — Excerpt 2. Breakdown of the argument: data (D), justification (J), rationale (R); conclusion (C):

D: According to the Mendelian model, all female gametes formed by pure tall plants contain the A factor, since pure tall plants form only one type of gamete, with the A factor. In turn, all male gametes formed by short plants (aa) contain the (a) factor.

J: The key point of Mendel's hypothesis is the separation of hereditary factors during gamete formation. The factors of each pair separate (or, in Mendel's words, segregate) during gamete formation, so that each gamete will contain only one of the factors of the pair in question;

F: Each gamete receives only one type of factor, so that approximately half of the female gametes produced by the hybrid plant will contain the factor for tall stature (A) and the other half will contain the factor for short stature (a). The same occurs with male gametes. [...] The expected result of this cross is that three tall plants (1 pure AA and 2 hybrid Aa) will be formed for each short aa plant (necessarily pure). Each hereditary characteristic is determined by a pair of factors, one inherited from the maternal parent and the other inherited from the paternal parent;

C: Mendel developed a hypothesis to explain the results obtained: gametes meet randomly in pairs, giving rise to individuals of the next generation.

Although the essential elements have been identified, the criterion of "Formal Coherence" has been partially met, as the justification does not fulfill its function. The justification also partially meets the criterion of "Sufficiency" by mentioning the separation of factors in the formation of gametes, but it does not indicate that there was a pattern in the seven characteristics analyzed. Ceschim et al. (2020) point out that "Mendel made quantitative descriptions of the different characteristics that plants exhibited in each generation" (p. 215). In this excerpt, "Support" is provided by describing the existence of hereditary factors, and the "Validity" criterion is met by reinforcing that factors are responsible for the formation of individuals in the next generation. As not all elements fulfilled their function, this argument was considered "Partially satisfactory", as described in Figure 6.

Figure 6

Evaluation of the argument about Mendel's First Law in LD1 — excerpt 2

Rubrics for evaluating the argument				
Criterion	**Description**	**Score**		
		No (0)	**Partially (1)**	**Yes (2)**
Formal Coherence (C)	The components that refer to the structure that forms the argument perform their functions according to Toulmin's Argumentation Layout.			x
Sufficiency (S)	The **justification** is sufficient to establish the relationship between the data and the conclusion.		x	
Support (R)	The **rationale** is satisfactory to support the justification.			x
Validity (V)	The **conclusion** of the argument is valid.			x
Argument classification		**Partially satisfactory**		

Source: the authors, based on Silva (2021).

The argumentative aspects in the LD2 collection were not systematized in the same way as the other collections that comprise the scope of this study, as they do not address the content of Mendel's First Law. The absence of this subject in a complete collection of high school textbooks is a significant flaw, since only one copy of this collection refers to the "Introduction to Genetics," but does not address the content. The omission of such relevant content can compromise the learning of fundamental concepts in an area considered complex.

Next, we will present a breakdown of the excerpt identified in the LD3 collection. In it, although three of the four items analyzed fulfill their function, the approach to the content is associated with terms that came after Mendel's Laws. This and other aspects will be discussed in more detail after the presentation of the excerpt.

LD3 (textbook 3) — Breakdown of the argument: data (D); justification (J); rationale (R); and conclusion (C):

D: Mendel began his crossbreeding with plants belonging to strains he called pure, i.e., strains that do not exhibit modification in a given characteristic and that, when crossed with each other, produce only offspring of the same variety. Obtaining pure strains in peas is easy, as self-fertilization is the natural process of reproduction in this species.

J: Mendel, even before knowing about the existence of alleles, chromosomes, and meiosis, [...] assumed that [...] factors occur in pairs in the cells of the body and individually in gametes.

F: Mendel [...] correctly interpreted the behavior of factors in inheritance [...].

C: For all the characters he studied, Mendel always obtained the same proportions, both in F1 and in F2, [...] Mendel called the variety that manifested itself in the F1 generation dominant, and the variety that remained hidden in F1 recessive, only reappearing in the F2 generation and with less frequency [...]. Each characteristic is determined by a pair of factors that separate during gamete formation, with only one factor from the pair going to each gamete. The gametes, therefore, are pure. He then concluded that his results were not random, as there was a clear pattern.

In LD3 (textbook 3), the content of Mendel's First Law is associated with the process of meiosis, which can hinder the formulation of arguments about the law, since studies on meiosis came after Mendel's discoveries. Although there are similarities, knowledge about meiosis was developed after Mendel's Laws were consolidated.

The explanation of Mendel's First Law linked to terms such as alleles, chromosomes, and meiosis can make it difficult for students to understand. In basic education, it is common for misconceptions to arise in the consolidation of the concept of meiosis, which hinders the understanding of more complex content (Borges et al., 2017), and the association of this concept with Mendel's discoveries tends to confuse students to the point that they do not understand it.

In this sense, the importance of teacher mediation in promoting understanding of the relationship between Mendel's First Law and meiosis is emphasized. While Mendelian law describes the principles of hereditary transmission, meiosis is the cellular process that enables it, through the segregation and distribution of alleles during gamete formation.

With regard to the structural elements under analysis, all were observed to be present. "Sufficiency" is "partially" met, given that the justification points to an important aspect, which is the separation of factors. However, by associating this separation of factors with terms such as chromosomes, alleles, and meiosis, it does not fully fulfill its function.

Furthermore, neither the data nor the conclusion mention these terms used in the justification. Therefore, based on the structural pattern proposed by Toulmin (2006), the text does not promote a logical connection between the data and the conclusion, nor does it mention the proportionality between dominance and recessiveness.

The "Support" criterion is "Fully" met, as it specifies, through the rationale, the existence of heredity, which is mentioned in the excerpt when referring to the behavior of factors related to heredity. The conclusion is valid because it states Mendel's First Law and specifies that he identified the existence of proportionality through his experiments.

Thus, "Validity" was also "Fully" met. Therefore, as three of the four criteria analyzed fully fulfill their function at the structural level and in terms of the quality of the content analyzed, the argument is considered "Partially satisfactory" (Figure 7).

Figure 7

Evaluation of the argument about Mendel's First Law in LD3

Rubrics for evaluating the argument				
Criterion	**Description**	**Score**		
		No (0)	**Partially (1)**	**Yes (2)**
Formal Coherence (C)	The components that refer to the structure that forms the argument perform their functions according to Toulmin's Argumentation Layout.			x
Sufficiency (S)	The **justification** is sufficient to establish the relationship between the data and the conclusion.		x	
Support (R)	The **rationale** is satisfactory to support the justification.			x
Validity (V)	The **conclusion** of the argument is valid.			x
Argument classification		**Partially satisfactory**		

Source: the authors, based on Silva (2021).

The argumentative aspects analyzed in the LD4 collection will be presented below. First, we emphasize that, in the excerpt below, it is clear that the justification presented does not fulfill its function, since, in his experiments, Mendel analyzed aspects of a specific plant. Thus, when discussing Mendel's Laws, using characteristics inherited from the "parent" as a reference is not scientifically consistent.

LD4 (textbook 4) — Breakdown of the argument: data (D); justification (J); rationale (R); conclusion (C):

D: [...] Mendel's main occupation was to work on and meticulously describe the process and results of hybridization with peas (*Pisum sativum*). The choice of peas as the object of study was not random. This legume belongs to the same family as beans and soybeans and was planted in the monastery where Mendel worked.

In addition, in his observations, Mendel realized that peas were easy to grow, had a short reproductive cycle, and produced many seeds. Mendel then began to cross different varieties and observe the results obtained.

J: During gamete formation, the genetic factors of characteristics separate.

Hereditary characteristics are determined by factors inherited from the parental generation in equal proportions, i.e., 50% of the characteristics come from each parent; thus, each characteristic should be formed by a pair of genetic factors (one from each parent). Individuals of purebred lines have identical gametes for a given characteristic, while hybrids will produce distinct types, also in the same proportion (50% of each type).

F: [...] Mendel's model predicted the inheritance of characteristics considered dominant over those considered recessive.

C: Each character is determined by a pair of genetic factors. These [...] factors [...], in the formation of gametes, are separated and, thus, each parent transmits only one factor (50%) to their offspring.

In LD4, we identified the presence of the essential elements of the argument, but the justification does not fulfill the function of connecting the other elements, making "Formal Coherence" only 'Partially' met (Toulmin, 2006). The criterion of "Sufficiency" is also not met, precisely because the justification uses language that is later than that used by Mendel. This collection presents problems similar to those in LD3, which highlights the need to review the approach to the subject in textbooks.

Even so, the problem observed in the LD4 argument is more striking, considering that, although all criteria have been identified, only the foundation fulfills its function adequately. In addition to presenting a justification that, although present, does not fulfill its function in the argument in the least.

Still on LD4, the "Support" criterion is "Satisfactory," as it recognizes hereditary transmission, and the "Validity" of the conclusion is "Fully" met, as it presents accepted scientific concepts. However, the connection between the elements is flawed, making the argument "Partially satisfactory," since, according to Toulmin (2006), an argument is not defined only by its elements, but by the function that each element performs (Figure 8).

Figure 8

Evaluation of the argument about Mendel's First Law in LD4

Rubrics for evaluating the argument				
Criterion	**Description**	**Score**		
		No (0)	**Partially (1)**	**Yes (2)**
Formal Coherence (C)	The components that refer to the structure that forms the argument perform their functions according to Toulmin's Argumentation Layout.		x	
Sufficiency (S)	The **justification** is sufficient to establish the relationship between the data and the conclusion.	x		
Support (R)	The **rationale** is satisfactory to support the justification.		x	
Validity (V)	The **conclusion** of the argument is valid.			x
Argument classification		**Partially satisfactory**		

Source: the authors, based on Silva (2021).

In view of the aspects highlighted, it is considered that, among all the collections analyzed that have argumentative aspects, LD4, in its approach to the content of Mendel's First Law, is the collection that, in general, has argumentative aspects with more pronounced limitations in relation to the elements fulfilling their function within the argumentative structure proposed by Toulmin (2006). This aggravating factor becomes even more relevant, given that the problem found refers to the absence of a plausible and scientifically relevant justification, with only the conclusion fulfilling its function among the elements analyzed.

When analyzing LD5 (textbook 5), it was observed that the structural elements fulfill their function in full, ensuring that "Formal Coherence" is "Fully" met. Similarly, the criteria "Sufficiency" and "Support" are also met, as they correctly address the separation of genetic factors and their relationship with heredity.

The conclusion is valid, as it presents a 3:1 ratio and reinforces the regularity of Mendelian ratios. Thus, this argument is "Satisfactory," being the only collection in which all elements fulfill their functions, which is relevant, since argumentation in teaching can improve scientific understanding (Nascimento & Vieira, 2008).

LD5, among all the collections analyzed, was the only one in which the argumentative aspects fulfill their function. These characteristics can be observed both in terms of their structural function and in aspects related to the validation of the argument in the theoretical field.

LD5 (textbook 5) — Breakdown of the argument: data (D); justification (J); rationale (R); conclusion (C):

D: Pea plants were particularly favorable for Mendel's studies, both because they were simple to grow and manipulate, and because they had several contrasting characteristics that were easy to observe. A pure strain is a population of individuals

that do not exhibit variability in a given characteristic and that, when crossed with each other, produce only offspring with the same variety. Mendel focused his studies on seven characteristics, which could be present in two easily distinguishable varieties.

J: In his research, Mendel identified patterns of inheritance and established the laws that now bear his name. Mendel assumed that each pair of factors separates during gamete formation.

F: In his experiments, Mendel crossed plants from different pure strains. A pure strain is a population of individuals that do not vary in a given characteristic and, when crossed with each other, produce only offspring with the same variety. Mendel then analyzed how these characteristics manifested themselves in the offspring. Mendel called the units that condition hereditary characteristics "hereditary factors" and postulated that they occur in pairs in individuals and are inherited in equal amounts from each parent.

C: Mendel did this count for all seven characteristics, obtaining, in all cases, a ratio close to 3:1 in the F2 generation varieties. He therefore concluded that this was not a coincidence, but a pattern that needed to be explained. Mendel identified a regularity, which he called the Law of Segregation of Factors, also known as Mendel's First Law, which can be summarized as follows: the factors that determine a hereditary trait exist in pairs and are separated during the process of gamete formation.

Additionally, when it comes to LD5, one may note, as described in Figure 9, the identification of the elements and the classification of the argument based on each element and the fulfillment of the function that each of them performs.

Figure 9

Evaluation of the argument about Mendel's First Law in LD5

Rubrics for evaluating the argument				
Criterion	**Description**	**Score**		
		No (0)	**Partially (1)**	**Yes (2)**
Formal Coherence (C)	The components that refer to the structure that forms the argument perform their functions according to Toulmin's Argumentation Layout.			x
Sufficiency (S)	The **justification** is sufficient to establish the relationship between the data and the conclusion.			x
Support (R)	The **rationale** is satisfactory to support the justification.			x
Validity (V)	The **conclusion** of the argument is valid.			x
Argument classification		**Satisfactory**		

Source: the authors, based on Silva (2021).

It should be noted that one of the aspects that differentiates LD5 from the others is the language used in this volume, which is closer to scientific language. Textbooks that use language close to science have the potential to contribute to reducing the gap between school knowledge and knowledge produced by science, allowing for greater conceptual understanding. This approach enables books to be not only a source of information, but also an instrument for critical and reflective learning.

While it is essential for students to learn to argue scientifically, exercising the justification of ideas and the analysis of scientific evidence, the central role of the teacher in this process stands out, mediating the reading of texts, promoting debates, stimulating discussions, and guiding the use of scientific language, an aspect that contributes to the development of both conceptual learning and critical and argumentative skills. Thus, it is understood that argumentation is constructed through the student's own learning process, mediated by the teacher, with textbooks as support.

LD6 (textbook 6) also constitutes an argument that does not fully fulfill its function, since, although all criteria have been identified, only the foundation fulfills its function adequately. Given this, we can observe, panoramically, the evaluation of this argument in the breakdown of the following excerpt.

LD6 (textbook 6) — Decomposition of the argument: dado (D); justification (J); rationale (R); conclusion (C):

D: The plant chosen by Mendel has flowers with closed petals, preventing pollen grains from entering or leaving. Therefore, this plant only performs self-fertilization, that is, the male gamete of a flower fertilizes the female gamete of the same flower, with no exchange of gametes (cross-fertilization). Self-fertilization allows most characteristics to be maintained from one generation to the next, thus reducing genetic variability. Due to this genetic uniformity, the strains are called pure. Mendel obtained pure varieties of the plant, whose characteristics did not vary over generations.

J: He deduced that tall plants (F1) possessed a determining factor for short plants and that this was inhibited by the expression of another factor for tall plants.

F: The studies conducted by Austrian monk and scientist Gregor Johann Mendel (1822–1884) contributed to our understanding of the mechanisms of heredity.

C: The factor that was expressed [...] in the F1 generation [...] was named the dominant factor, and the inhibited factor was called recessive. Currently, the factors mentioned by Mendel are called genes. Mendel's studies led to the conclusion that the factors are alleles and that they are responsible for characteristics that separate in the formation of gametes. Gametes have a single factor for each gene. This is Mendel's first law, also known as the Law of Segregation of Factors.

"Sufficiency" is also "partially" met, as the justification does not explain the separation of factors and their importance. The "Support" is adequate, since it mentions heredity, but the 'Validity' is only partial, since it introduces concepts unknown to Mendel, such as alleles. Overall, the argument is "Partially satisfactory" because only one criterion has been fully met, as shown in Figure 10.

Figure 10

Evaluation of the argument about Mendel's First Law in LD6

Rubrics for evaluating the argument				
Criterion	**Description**	**Score**		
		No (0)	**Partially (1)**	**Yes (2)**
Formal Coherence (C)	The components that refer to the structure that forms the argument perform their functions according to Toulmin's Argumentation Layout.		x	
Sufficiency (S)	The **justification** is sufficient to establish the relationship between the data and the conclusion.		x	
Support (R)	The **rationale** is satisfactory to support the justification.			x
Validity (V)	The **conclusion** of the argument is valid.		x	
Argument classification		**Partially satisfactory**		

Source: the authors, based on Silva (2021).

When analyzing the LD7 collection (textbook 7), a similar approach to LD4 was identified, as both present the content in more contemporary language. As already pointed out, the use of inappropriate terms, without contextualizing the history of the development of certain content, can compromise student understanding, in addition to omitting the contributions of different scholars, as can be seen in the following excerpt, which highlights that factors are inherited from "father and mother."

LD7 (textbook 7) — Breakdown of the argument: dado (D); justification (J); rationale (R); conclusion (C):

D: The sweet pea [...] used by Mendel [...] reproduces by self-fertilization.

[...] In his experiments, Mendel used purebred plants, that is, those that, through self-fertilization, produced only individuals identical to themselves [...]. Mendel chose two pure plants, each presenting a variant of one of the characteristics he had previously selected (for example, one with yellow seeds and another with green seeds), and [...] when observing the descendants of each cross, he recorded only the results of that characteristic under analysis.

J: Mendel proposed that each of the characteristics analyzed was determined by a pair of hereditary factors.

F: These two factors would consist of one factor inherited from the mother and another from the father [...] during gamete formation, he further assumed that the factors in each pair would separate (or segregate), causing each gamete to carry only one factor.

C: Analyzing the results, he concluded that in hybrid plants (F1 generation), the variant of one of the parents was "masked" or "recessive." He called the variants that did not manifest in F1 recessive, and those that were present in 100% of individuals in F1 dominant. For each trait studied, the variants were distributed in the F2 generation in

a ratio of approximately three plants with the dominant variant to only one plant with the recessive variant (3:1). Mendel noted that the ratio in which each trait manifested itself across generations followed patterns [...] and concluded that [...] the factors that determine a hereditary trait segregate during gamete formation, so that each gamete contains only one factor.

In LD7, the minimum elements were identified, however, the justification and rationale are flawed. The justification does not mention their separation, making the "Sufficiency" only partial. The 'Support' is also "Partially" met, as it states that the factors are inherited from the parents, without considering that Mendel analyzed plants.

This modern approach, without acknowledging other scientific contributions, may compromise the student's understanding, which requires the teacher to adopt an approach that helps the student develop critical understanding in this regard. The conclusion is correct, but the content of Mendel's First Law is addressed incorrectly, which leads us to classify the argument as "Partially satisfactory" (Figure 11).

Figure 11

Evaluation of the argument about Mendel's First Law in LD7

Rubrics for evaluating the argument				
Criterion	**Description**	**Score**		
		No (0)	**Partially (1)**	**Yes (2)**
Formal Coherence (C)	The components that refer to the structure that forms the argument perform their functions according to Toulmin's Argumentation Layout.		x	
Sufficiency (S)	The **justification** is sufficient to establish the relationship between the data and the conclusion.		x	
Support (R)	The **rationale** is satisfactory to support the justification.		x	
Validity (V)	The **conclusion** of the argument is valid.			x
Argument classification		**Partially satisfactory**		

Source: the authors, based on Silva (2021).

Systematization of Arguments about Mendel's First Law Found in PNLD/2021 Textbooks

After specific analysis of each argument identified in the textbooks, it was possible to construct a table that systematizes how argumentation is employed in the content on Mendel's First Law in the textbooks approved by PNLD/2021. The results found through this study demonstrate that the inclusion of argumentative elements in the approach to the content under analysis is negligible, given that, even though they present the minimum elements necessary for the construction of an argument, part of them do not properly fulfill their function in the development of the argument.

One out of the seven collections approved by PNLD/2021 does not address the content of interest to this study, while argumentative elements were identified in the other six ones. However, even though there are indications of the structural presence of argumentative elements, as proposed in Toulmin's (2006) argumentative structure, it is observed that most do not fulfill their function from the point of view of the quality of the content addressed.

In general, the arguments were classified into two categories. Those whose elements were identified but which do not fully fulfill their functions were considered "Partially satisfactory." The arguments considered "Satisfactory" were those that present formal coherence and approach the content from an argumentative perspective, as summarized in Figure 12.

Figure 12

Classification of arguments in textbooks

Argument Quality Evaluation						
Textbook (LD)	**Score**	**Formal Coherence (C)**	**Sufficiency (S)**	**Support (R)**	**Validity (V)**	**Argument classification**
LD1 Arg. 1	0					Partially satisfactory
	1	x	x			
	2			x	x	
LD1 Arg. 2	0					Partially satisfactory
	1		x			
	2	x		x	x	
LD3	0					Partially satisfactory
	1		x			
	2	x		x	x	
LD4	0		x			Partially satisfactory
	1	x		x		
	2				x	
LD5	0					Satisfactory
	1					
	2	x	x	x	x	
LD6	0					Partially satisfactory
	1	x	x		x	
	2			x		
LD7	0					Partially satisfactory
	1	x	x	x		
	2				x	

Source: the authors, based on Silva (2021).

In general terms, among the seven arguments analyzed, six do not simultaneously present adequate and qualitative structural logic, being classified as "Partially satisfactory," while only one argument is considered "Satisfactory."

The arguments of LD1 (excerpts 1 and 2), LD3, LD4, LD6, and LD7 were classified as "Partially satisfactory." Although grouped in the same category, it can be observed that these arguments do not fulfill their function in relation to different requirements, which distinguish them in terms of the complexity of the limitations identified, but in common they present inefficiency in the elaboration of the justification. LD1 (excerpt 2) and LD3 present problems in the "Sufficiency" requirement. LD1 (section 1) and LD4 have more pronounced gaps, as, in addition to presenting problems in the justification, they have partial formal coherence. Among all those in this category, LD6 and LD7 present more profound problems, as three of the four elements do not fulfill their function, distancing them from Toulmin's (2006) argumentative structure.

Another relevant issue is that LD1 presented a peculiarity in relation to the others, regarding the arrangement of arguments, being the only volume that presented two arguments on the same content. This could be understood positively, since both were identified as "Partially satisfactory." Thus, this choice highlights a certain degree of argumentative quality in the book. If both excerpts had been arranged together, they would have contributed more effectively to the understanding of the content and argument.

A common problem in arguments classified as "Partially satisfactory" refers to the element that least fulfills its function: justification. The justifications were not sufficient to establish the formation of a minimum argumentative structure. Thus, inefficient formal coherence predominates in the excerpts analyzed.

Among the argumentative elements, justifications are the most required in the construction of an argument or argumentative reasoning, when it is necessary to defend a point of view and justify certain passages from the data to the conclusion. In this sense, the gaps in the analyzed books become even more evident in terms of the arrangement of elements that favor argumentation in science classes in relation to Mendel's First Law and other content that requires its understanding.

From this, it can be concluded that most of the books analyzed do not justify the data in such a way as to construct arguments based on the evidence provided. If this were the case, they would contribute directly to student learning, given that learning to think is closely related to the exercise of argumentation (Kuhn, 1993).

In this sense, the absence of a coherent justification may compromise the possibility of developing argumentative teaching practices based on the content provided in textbooks. It is worth noting that if textbooks do not provide sufficient elements for constructing a good argument about scientific content, how can students construct an adequate argument if there is no mediation to assist them in this regard?

LD5 is the only example that has a coherent argument from the point of view of structure and quality of content, so it can be used as a reference for the argument about Mendel's First Law presented in the textbook. Thus, this argument is conducive to the development of pro-argumentative situations in the classroom.

The excerpt analyzed presents scientific content, with a basic theory and justification that leads to the conclusion, in addition to having a foundation that reinforces the justification presented. It is consistent with the assertion by Orofino and Trivelato (2015), who state that "scientists argue when they explain a phenomenon according to certain theories, presenting evidence that supports their point of view" (p. 120).

Arguments such as those in LD5 enable students to develop a critical view of the content, become familiar with scientific language, and, above all, use scientific knowledge to justify their position through an exercise that needs to be intensified in science teaching in order to prepare them not only to argue about scientific concepts but also to take a critical stance in society.

Given the limitations identified in textbooks, the role of the teacher as a mediator becomes even more fundamental in the teaching process. Considering that a considerable portion of the textbooks analyzed in this study do not offer sufficient justification for the construction of arguments, teachers can use strategies that encourage students to develop critical thinking skills. This mediation may include the use of investigative situations, questions, and discussions that encourage analysis and argumentation, so that learning is not restricted to reading the content provided in the book.

It should be noted that, although textbooks are very important resources, they are not solely responsible for promoting learning in general, nor do they always present an approach that helps in the construction of arguments. However, teachers who use them intentionally can enhance their function by associating them with teaching practices that promote critical reflection and the articulation between scientific knowledge and students' prior knowledge. In this way, the mediation carried out by the teacher is a relevant element for the teaching of complex content, such as Mendel's First Law, to contribute effectively to the development of students' argumentation skills.

Final Remarks

Of the seven collections analyzed in this study, one omitted Mendel's First Law, which is extremely relevant for understanding genetics in general. This collection shows no evidence of addressing this law, which made it impossible to analyze. There is only one piece of content entitled "Introduction to genetics," but the emphasis is on current concepts in genetics and the explanation of sexual reproduction.

The omission of Mendel's First Law is problematic, given the importance of the historical construction of science being addressed in different areas of teaching. In addition, Mendel's Laws are essential for understanding important aspects of heredity.

This problem is not limited to the impossibility of analysis, but also to the implications of this absence for student learning, since most of them use textbooks as a reference. Thus, the question arises as to how the other genetics content will be understood in the absence of one of the main reference contents in this field. Another aggravating factor is that teachers will have to use additional strategies to fill this gap.

Six out of the collections studied address the aforementioned content; however, some of the elements that make up an argument do not fulfill their function, which prevents the arguments from being considered satisfactory. In some of the books, current terms and concepts are used that are erroneously attributed to Mendelian discoveries.

We can also highlight situations in which textbooks do not contextualize content in a way that helps students understand the limitations that existed in Mendel's time. Mendel's studies were based on the notion of heredity, a topic that had already been discussed at the time; therefore, he cannot be given all the credit for explaining heredity.

We emphasize that only one collection addresses the content of Mendel's First Law in an argumentative context and presents sufficient elements for the construction of an argument according to the perspective proposed by Toulmin (2006). In this collection, the structure and quality of the argument were identified, and it can thus be considered a satisfactory argument.

We conclude, therefore, that the arguments about Mendel's First Law in the textbooks analyzed are, for the most part, ineffective. Although the basic argumentative structure is presented, the quality of the argument is compromised when certain elements do not fulfill their function from a Toulminian point of view, a problem that was evident in most of the arguments analyzed, such as in the justifications, which, although identified, did not effectively fulfill their function.

With regard to student learning, considering textbooks as a reference for developing argumentative processes, the data presented becomes even more concerning, since justifying processes are fundamental for the development of critical thinking.

With regard to student learning, considering textbooks as a reference for developing argumentative processes, the data presented become even more concerning, since justificatory processes are fundamental for improving argumentative skills and bringing students closer to scientific language.

In addition to the gaps identified in textbooks, through this study, we emphasize the urgency of providing teachers with quality training that prepares them to effectively use argumentation as a teaching strategy.

It is necessary for teaching professionals to have knowledge beyond the textbook, especially with regard to argumentation, in order to promote such knowledge in the classroom. These issues go beyond the need to understand the importance of textbooks as reference tools for teaching and recognize that they have limitations that need to be urgently reviewed, which is, in a way, omitted by educational reforms. The results point to significant limitations in textbooks, which can hinder the teaching of Mendel's First Law from an argumentative perspective. Thus, we highlight the need for teachers to have access to explicit teaching of argumentation so that they are prepared to adopt argumentative teaching strategies.

In view of this, this study can contribute to the field of education, more specifically in the area of genetics teaching. The analysis of the arguments presented in textbooks made it possible to assess the limitations in the approach to the concept under study and

identify the almost total absence of strategies that promote the development of critical thinking. We emphasize that the way the arguments are presented in textbooks does not always allow them to fulfill their function, both from a structural point of view and in terms of the quality of the argument. Considering the importance of textbooks in the education of students, this problem highlights the need to review the criteria adopted by the PNLD for the approval of teaching materials.

The Toulmin (2006) layout, used as an analytical tool, proved to be extremely relevant to this study, as this model made it possible to evaluate the quality of the arguments presented in the books. The contributions of this research to science education lie in the critical identification of argumentative patterns present in textbooks, highlighting the gaps identified, as well as in the proposal of parameters for analyzing the adequacy of arguments about Mendel's First Law.

Once the gaps in the approach to Mendel's First Law in textbooks have been identified, this research provides support, above all, for the development of teaching materials consistent with the development of teaching practices based on an argumentative perspective, as well as serving as a basis for future research focusing on textbook analysis. Thus, the contributions of this work to Science Education include offering a critical analysis that can serve as a reference for the development of textbooks on Natural Sciences, which aim to promote argumentation in Basic Education (particularly on the subject of Genetics), as well as serving as a theoretical and methodological guide for the promotion of textbook analysis from an argumentative perspective.

Thus, the contributions to Science Education range from serving as a reference for the development of textbooks that offer the necessary support for teaching practices that foster argumentation in Basic Education, to the theoretical and methodological articulation aimed at promoting the analysis of arguments, the development of argumentative skills, the appropriation of scientific language, and argumentative teaching practices with the purpose of contributing to the teaching of Genetics.

Finally, we suggest the development of studies that offer new elements capable of supporting argumentative teaching practices, such as research that develops and applies teaching sequences or argumentative scientific texts on Mendel's First Law, which can serve as support for Science teachers.

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