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# Types of Deviation in Genetics Knowledge Presented in Textbooks Relative to the Reference Literature

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**Abstract**

The present study seeks to examine how basic knowledge presented in textbooks for the teaching of genetics in secondary schools approximates or deviates from academic knowledge of the subject. Among transposed scientific knowledge of greatest importance in education is knowledge of genetics. Therefore, knowledge taught in schools is necessarily subject to two influences. The first is *laxity*, which is the tendency to alter scientific knowledge, when presenting it in textbook form, to make it accessible to learners. The other is *rigorism*, which is the opposite of laxity, i.e., the tendency to approximate knowledge taught to scientific knowledge, seeking to transmit it correctly, with a commitment to scientific principles. Different types of deviations were identified in textbooks from Brazil and the United States. To determine how knowledge presented in textbooks deviates from that presented in the reference bibliography, concepts were classified according to type of deviation, using the following categories: *equivalent term* , *metaphor*, *conceptual deviation*; *deviation in the description of the process*, *generalisation of occurrence*, *content not updated*. The present study finds that the deviations cannot be classified as conceptual errors and are not necessarily related to the concepts themselves. Deviations were mostly categorised as *generalisations of occurrence*. The highest frequency of this type of deviation was independent of the concept examined or of the country of origin of the group of textbooks analysed.


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## 1. Introduction

The present study seeks to examine how basic knowledge presented in textbooks for the teaching of genetics in secondary schools approximates or deviates from academic knowledge of the subject. Different types of deviations were identified in textbooks from Brazil and the United States.

The study is justified by the importance of teaching scientific knowledge and the role of textbooks in the educational process.

Despite its complexity, a key characteristic of scientific knowledge is its reliability, which arises from the role of consensus in the scientific process (Ziman, 1985). Although scientific knowledge is not considered superior to other types of knowledge, it is the school's role to develop in children a worldview compatible with the knowledge generated by science (Cobern, 1996). However, for such knowledge to become comprehensible to students, it must undergo a didactic transposition (Chevallard, 1991) through the medium of textbooks (Forquin, 1992). Among transposed scientific knowledge of greatest importance in education is knowledge of genetics. Therefore, knowledge taught in schools is necessarily subject to two influences. The first is *laxity*, which is the tendency to alter scientific knowledge, when presenting it in textbook form, to make it accessible to learners. The other is *rigorism*, which is the opposite of laxity, i.e., the tendency to approximate knowledge taught to scientific knowledge, seeking to transmit it correctly, with a commitment to scientific principles (Franzolin & Bizzo, 2009).

Textbooks are among the major determinants of the knowledge taught in schools (Ball & Feiman-Nemser, 1988; Brasil, 2003; Instituto Nacional de Evaluación y Calidad del Sistema Educativo, 2004; Lee, Eichinger, & Anderson et al., 1993; Solbes, 1987). Several significant studies of the content of textbooks (examples include Alves & Carvalho, 2007; Caravita et al., 2007; El Hani et al., 2007; Skujienė et al., 2007; among others) were recently published at the *International Meeting on Critical Analysis of School Science Textbook*, held in Tunisia in 2007.

Some of these studies (El Hani et al., 2007; Ferreira & Justi 2004; Gericke & Hagberg, 2007) follow an approach close to that adopted in the present study, analysing the conceptual content of genetics, as presented in written text. However, the present study differs from other studies in several respects.

The difference between the present study and that of Gericke and Hagberg (2007) is that the latter authors focus on the specific conceptual content of "gene", seeking to classify different approaches to the concept. The present study, by contrast, analyses different presentations of knowledge within broad topics, comparing versions presented in textbooks with those found in a reference bibliography.

El Hani et al. (2007) identify treatments of genetics and cell and molecular biology concepts in Brazilian biology textbooks that were excluded, for quality reasons, by the National Program of Textbooks for Secondary Education (Programa Nacional do Livro Didático para o Ensino Médio - PNLEM) from a list of books to be used in classroom instruction by Brazilian public school teachers . Their study presents data relevant to the present study but differs from ours with respect to sampling. In particular, they sample books that failed the PNLEM evaluation; additionally, the authors use data from a governmental evaluation. Another important difference is that, although both studies examine the accuracy of the knowledge available in textbooks, compared with academic knowledge, the study of El Hani et al. describes conceptual problems with the material analysed, while the present study analyses the approximation and deviation relationships between knowledge presented in textbooks and academic knowledge in the reference bibliography.

In turn, Ferreira and Justi (2004) analyse various aspects related to how Brazilian biology and chemistry textbooks treat the concept of DNA. With respect to conceptual accuracy, the authors find that in biology textbooks, some DNA models are at odds with scientific models. However, Ferreira and Justi do not provide further explanation of how the comparison between knowledge in textbooks and scientific knowledge was conducted. Therefore, it is unclear what reference was used to represent knowledge produced by science.

The present study not only differs from studies published by other authors; it presents new elements not addressed in earlier investigations by the research group that developed it. A previous study analysed some basic genetics concepts from other areas of biology, including "genetic material", "chromosome", "gene", "homologous chromosomes", "allele", "homozygosis", "heterozygosis", "phenotype", "genotype", and "dominant" and "recessive" (Franzolin, 2007). These are basic concepts present in primary and secondary education textbooks. The present study analyses in detail other genetics concepts not examined in the previous study. These concepts were selected not only for their presence in textbooks but also because they are the concepts most frequently mentioned

by Brazilian teachers and professors (Franzolin, 2012) as essential for secondary students to learn about in becoming critical citizens. Furthermore, despite using the same analytical method in both studies, in the present study, the method is enhanced and contains new elements, allowing for classification of deviations into *type* categories.

Thus, the present study adds new elements to the current research framework.

## 2. Methods

This study examines textbooks from two countries to determine whether data from one country are location-specific or can be identified in another country. For Brazil, three textbooks from the nine approved by PNLEM's 2005 evaluation were selected for examination. For the United States, high school teachers were asked which textbooks they used. Three of these were then analysed.

To examine how genetics concepts are presented in textbooks and their approximation to and deviation from knowledge produced in academia, a representative reference bibliography, adopted by the 2009 Undergraduate Program in Biological Sciences of the University of São Paulo (Universidade de São Paulo), was used.

The basic bibliography for the course, *BIO0203 Genetics* (Griffiths et al., 2008), was adopted as the main reference bibliography, and a critical study of it was carried out. To incorporate elements that would enable a more critical examination of the selected reference bibliography, a personal interview with one of the authors, Richard Charles Lewontin, was conducted. The purpose of the interview was to better understand its process of construction and the consistency of its contents. However, although the bibliography was used as the main reference, two other works utilised in the same course were also evaluated whenever deviations between content presented in the main reference and in a textbook were identified or when the main reference did not contain enough information to assess knowledge presented in a textbook.

The concepts analysed are those most frequently viewed as essential in secondary education by Brazilian biology teachers and university professors of genetics and molecular biology in Brazil. These include *meiosis, Mendel's Laws* and *gene expression* (Franzolin, 2012). Each piece of information found in a textbook was compared with correlated knowledge presented in the reference bibliography. If a deviation was identified it was tabulated and then classified. To determine how knowledge presented in textbooks deviates from that presented in the reference bibliography, concepts were classified according to type of deviation, using the following categories: *equivalent term* (use of synonymous terms); *metaphor* (expression used in an unusual sense, due to its analogy or similarity to what is being explained); *conceptual deviation* (concept used in such a way that its meaning does not match that of the referent); *deviation in the description of the process* (process description that is significantly different from that presented in the reference); *generalisation of occurrence* (using specific knowledge in a general context); *content not updated* (textbook knowledge considered close to scientific knowledge at one time but not currently).

## 3. Results

Figure 1(a) shows that the majority (59%) of the deviations found were categorised as *generalisation of occurrence*, i.e., in most cases, the author presents information without specifying that a phenomenon occurs only under certain circumstances, thereby presenting a particular occurrence as if it were general. Figure 1(b) shows that this type of deviation is independent of the content analysed.

Some examples of *generalisation of occurrence* deviations identified include when a textbook states that RNA synthesis occurs in the nucleus, while the reference states that nuclear RNA synthesis occurs *only in eukaryotes*. In another example, a textbook states only that at the conclusion of the first meiotic division, the nuclear membrane is reconstituted, while the reference states that *in many organisms*, at the conclusion of the first division of meiosis, this reconstitution *does not occur*. Yet another textbook notes that synthesised RNA *migrates* to the cytoplasm, whereas, according to the reference, *in the case of prokaryotes, this migration does not occur*.

It is observed that authors often describe mechanisms that are specific to certain organisms, such as eukaryotes, but do not make the specificity clear to the student. Students may thus erroneously conclude that the process is the same in all living beings, or they may develop an anthropocentric view of the process. It is hypothesised that in this case, authors fail to clarify that a mechanism is not universal because a process that occurs in eukaryotes corresponds to a process that occurs in humans. This raises the question of whether such a view is influential for

students. In interviewing students, Pedracini et al. (2007) identified anthropocentric expressions in students' oral accounts of DNA: "DNA is our identity, where our characteristics are formed" or "DNA is the characteristics of people". When investigating how secondary students relate the concepts of location and organisation of genetic material, Silveira (2003) found that, for students, the relationship between living organisms and cells is evident only in mammals, particularly in humans.

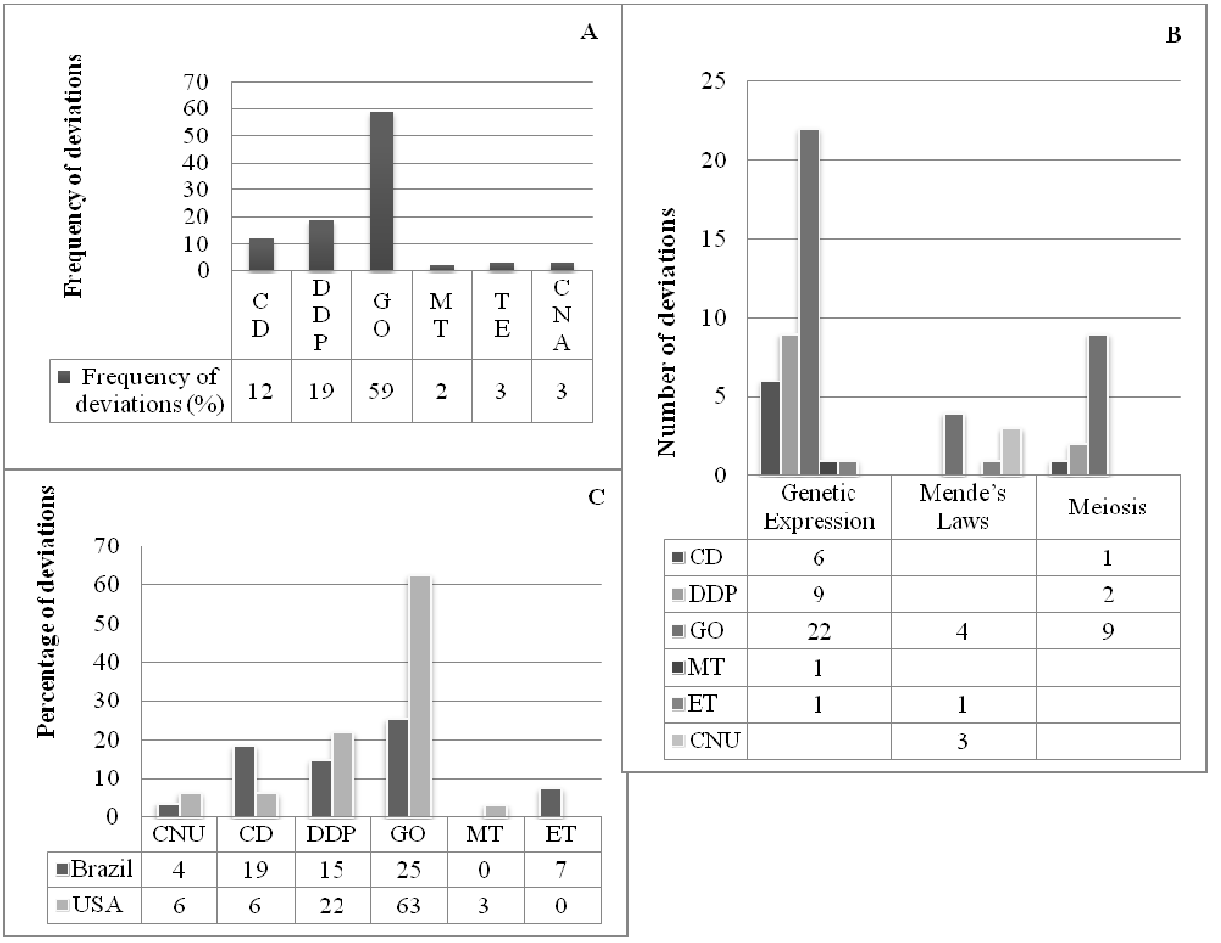


Fig. 1. (a) percentage of deviations of each type in relation to the total number of deviations identified; (b) total number of deviations of each type per concept analysed; (c) percentage of deviations of each type in relation to the total number of deviations in textbooks from each location (Brazil and USA) (ET = equivalent terms; MT = metaphor; CD = conceptual deviation; DDP = deviation in the description of the process; GO = generalisation of occurrence; CNU = content not updated).

Another example of generalisation found in this study is the idea that purebreds produce individuals equal to the originals when mated like-to-like. This generalisation may lead students to believe that all characteristics are inherited together and neglect the process of independent segregation or other mechanisms that determine individual characteristics. In this case, the term "equal", disassociated from the expression "for a certain characteristic," can encourage a deterministic genetic view. Other examples that also reinforce this view were found by Clément and Castéra (2013), for instance, in images, found in books from several countries, of twin brothers who are identically dressed. It was also found that not all textbooks contain the same generalisations. Some authors can present knowledge in simple, clear ways that are close to the presentations of the reference texts without the need to generalise.

Figure 1a also shows that *deviation in the description of the process* is the second most common type of deviation (19%), followed by *conceptual deviation* (12%). When material from the two different countries is analysed separately (Figure 1c), it is found that *generalisations* still correspond to the greater percentage of deviations identified. With respect to deviations in books from the USA, it is observed that *deviation in the description of the process* remains the second most common type (22%), followed by *conceptual deviation* (6%). However, in Brazilian textbooks, *conceptual deviation* is the second most common type (19%), followed by *deviation in the description of the process* (15%).

*Deviation in the description of the process* can be illustrated by the example of a textbook that states that the mRNA molecule, when it is transcribed, migrates to the ribosome, while the reference states that the ribosome forms gradually under the mRNA molecule.

An example of *conceptual deviation* was found in one textbook, which states that *bivalents* are found in pairs when arranged at the equator of the cell. Students who know what a bivalent is may interpret this as implying that there is a pairing between *two pairs* of homologous chromosomes and not simply between *two homologous chromosomes*. In that case, four chromosomes would be involved in the pairing and not just the two homologous chromosomes. Although this example was classified as a *conceptual deviation*, it is evident that in this and other *conceptual deviation* examples, such reasoning does not reflect the authors' reasoning more generally, as other passages about pairing during cell division state that it occurs between a pair of homologous chromosomes and not between two pairs. Thus, this and other deviations found in this study are classified as *conceptual deviations* rather than *conceptual errors*. According to the definition of a *conceptual error* used for several years in official evaluations of textbooks and presented by Bizzo (2009), a *conceptual error* must combine several characteristics that occur simultaneously. A *conceptual error* must "be based on assumptions that are not accepted by the scientific community; constitute a way of conceiving and explaining relationships (mental model); be based on adaptive knowledge in the school context; and be false and not adaptable to real-life situations" (Bizzo, 2009, p. 45).

Although they are not considered *conceptual errors*, *conceptual deviations* deserve attention because they may hinder understanding of essential features of basic concepts. A textbook that states that bivalents are arranged in pairs at the equator of the cell during the first meiotic division may create confusion about the number of chromosomes and how they pair up and are distributed. If the student does not understand how many chromosomes participate in the process and how they pair up and separate, it is difficult for the student to grasp the most basic feature of meiosis, which is the distribution of chromosomes. Lewis and Wood-Robinson (2000) find that students have difficulty understanding how the distribution of chromosomes in cell division takes place. This difficulty can be amplified by information found in the textbooks analysed.

## 4. Conclusions

By analysing the types of deviation that exist between information about genetics presented in Brazilian and American secondary education textbooks and reference materials, the present study finds that the deviations cannot be classified as conceptual errors and are not necessarily related to the concepts themselves. Deviations were mostly categorised as *generalisations of occurrence*, i.e., specific information used in a general context. When specific information is attributed to a context in which the information is not pertinent, students may be led to believe, for example, that mechanisms are similar in several organisms, whereas, according to the reference, they differ in different organisms. The highest frequency of this type of deviation was independent of the concept examined or of the country of origin of the group of textbooks analysed.

Perhaps the high frequency of generalisations is due to their subtlety, as generalisations often present information that is close to the reference knowledge. It was also observed that not all textbooks contain such deviations and that some present knowledge in a simple, clear way that is more in keeping with the reference sources. For example, instead of just stating that RNA synthesis occurs in the nucleus, one textbook notes that nuclear RNA synthesis *occurs in eukaryotes* Thus, it is questionable whether such generalisations are necessary.

The data presented here can be used both by textbook authors and those who assess the quality of textbooks. Taking into account the methods employed here, this paper can also be used as a model for researchers analysing different types of content. The present approach constitutes an alternative to investigations that simply identify

deviations in textbooks as conceptual errors. Furthermore, the results can be used by teachers. Through awareness of deviations of textbooks from academic knowledge, teachers become better equipped to assess the role of textbooks and might perform any necessary interventions in the classroom to facilitate the learning process.

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