Human genetics and didactic transposition: the expression of skin color, eye color, and height in Brazilian and Portuguese textbooks

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Abstract

The knowledge produced by genetic science is constantly expanding. However, the "taught knowledge" is not just a simplification of the knowledge produced by science, since it is also a result of values and practices. The objective of this study is to analyze how some examples of the expression of human characteristics in school textbooks approximate or deviate from reference knowledge found in literature. Secondary school textbooks were analyzed: six Brazilian collections and three Portuguese collections. Three topics were analyzed (skin color, eye color and height) and data were compared to scientific reference literature concerning these topics, which was composed of recent scientific papers and teacher training reference books. This analysis used the methodology developed in previous studies by Franzolin (2012) on "categories of types" and "categories of implications" and the KVP model (Clément, 2006). This study shows that most textbooks are close to the reference literature in mentioning the polygenic determination of the analyzed characteristics (skin color, eye color and height) and the influence of the environment in the expression of these characteristics. Textbooks which deviate from reference literature may cause barriers to the central content understanding. In the Portuguese context, it was evident that the practice of adopting new topics in the curriculum lead to the elimination of such information, not valued in official curriculum documents.

Keywords: genetic science; school textbooks; curriculum; didactic transposition.

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Introduction

The knowledge produced by genetic science is constantly expanding (Bizzo, 1998; Dougherty, 2009; Flodin, 2009; Shapiro, 2010), leading to reflection of what is important to teach in school (Ayuso and Banet 2002; Bizzo 1998; Clément and Castéra, 2013; Dougherty, 2009). The Human Genome Project enables to understand that most human characteristics are not only determined by a pattern of simple inheritance, where a pair of genes was supposed to be enough to explain its expression. Most of the humans' characteristics are determined by a complex pattern of multi-factorial expressions which are the product of the interaction of multiple genes and the influence of environmental dynamics (Dougherty, 2009).

However, genetics taught in school may vary in its approximation to the academia generated knowledge or by what teachers learned during their training, within the general framework of didactic transposition. Chevallard (1991) considers that this is a process of adapting the "knowledge to be taught" into "taught knowledge" in a way that becomes understandable by young people. However, from a sociological perspective, "taught knowledge" is not just a simplification of knowledge produced by science. The school is also a producer of culture (Chervel, 1992) and knowledge for didactic purposes only (Forquin, 1992). Moreover, the creation of school knowledge also involves the community interests and the reference to their social practices (Develay 1992, as cited in Carvalho, 2009; Martinand, 1981, as cited in Clément, 2006). Thus, constituting knowledge to be taught in school is influenced by knowledge, values and practices (Clément, 2006).

Moreover, according to Chevallard (1991), although necessary, the process of didactic transposition can contain "inappropriate dysfunctions". For this reason, "epistemological surveillance" is necessary; this is a type of verification of the relevance of the results of the didactic transposition process. Studies that analyze the knowledge of genetics in textbooks have revealed that the gap between the knowledge produced by science and what is taught not always is positive. It can cause learning obstacles and provide a deterministic view of genetics (Clément and Castéra, 2013; Silva, Ferreira and Carvalho, 2009).

In an attempt to contribute to the epistemological surveillance process, the objective of this study is to analyze how some examples of the expression of human characteristics in school textbooks approximate or deviate from reference knowledge found in literature. Three human features currently present in the genetics sections of Brazilian textbooks were chosen for this investigation: skin color, eye color and height.

Methodology

Eight secondary school textbooks were analyzed: five Brazilian collections (approved by the National Textbook Program (2012/2015)), and three Portuguese collections which are most commonly used in schools. The books that were analyzed are identified as A, B, C etc., preceded by the initials LD (**L**ivro **D**idático, meaning Textbook in English) (Table 1). The **B**razilian books are followed by **br** and the **P**ortugese books followed by the initials **pt** (for example LDA-br). Aside from the textbooks, a set of notepads (**C**adernos in Portuguese) from a group of Biology students from the state of São Paulo were analyzed and were identified with the initials CSP.

Based on our research group previous results which are in preparation for publication, we decided to analyze three human characteristics currently present in genetic topics in Brazilian textbooks: skin color, eye color and height. This choice was based in the fact that these three features are common to all individuals, rather than dealing with rare diseases or genetic characteristics. From the data obtained from each of these three topics, we analyzed the most frequent or relevant ones.

The content presented in textbooks was compared with the reference literature knowledge, by using the methodology developed in previous studies on "*categories of types"* and "*categories of implications"* by Franzolin (2012) and amplified here. The scientific reference literature concerning these topics was composed of recent scientific papers and reference books for teacher training that are shown in Table 1.

Table 1. Analyzed textbooks and literature of reference.

Analyzed textbooks		
Textbook code	ISBN	Year of publication
LDA (Brazilian)	978-85-7675-527-2	2010
LDB (Brazilian)	978-85-08-13028-3	2010
LDC (Brazilian)	978-85-08-12960-7	2010
LDD (Brazilian)	978-85-16-09293-1	2013
LDE (Brazilian)	978-85-16-09285-6	2013
LDJ (Portuguese)	978-972-647-050-0	2014
LDK (Portuguese)	978-972-0-42174-6	2014
LDL (Portuguese)	978-972-761-829-3	2012

Literature of Reference

Beleza, S., Johnson, N. A., Candille, S. I., Absher. D. M., Coram, M. A., Lopes, J. et al. (2013). Genetic Architecture of Skin and Eye Color in an African-European Admixed Population. *PLoS Genetics 9*(3), 1-15.

Griffiths, A. J. F., Wessler, S. R., Lewontin, R. C., & Carroll, S. B. (2013). *Introdução à Genética*. Rio de Janeiro: Guanabara Koogan.

Jablonski N. G., & Chaplin, G. (2012). Human skin pigmentation, migration and disease susceptibility. *Philosophical Transactions of Royal Society B.* (367), 785–792.

He, M., Xu, M., Zhang, B., Liang, J., Chen, P., Lee, J. et al. (2015). Meta-analysis of genome-wide association studies of adult height in East Asians identifies 17 novel loci. *Human Molecular Genetics, 24*(6), 1791–1800.

Liu, J., Hutchison, K., Perrone-Bizzozero, N., Morgan, M., Sui, J., & Calhoun, V. (2010). Identification of Genetic and Epigenetic Marks Involved in Population Structure. *PLoS ONE 5*(10), 1-8.

Liu, F., Visser M., Duffy, D. L., Hysi, P. G., Jacobs, L. C., Lao, O. et al. (2015). Genetics of skin color variation in Europeans: genome-wide association studies with functional follow-up. *Human Genetics* (134), 823–835.

Content analysis method (Bardin, 2007) was used: for each analyzed piece of data, a registration unit was created, and identified as urn (ur=registration unit, n=the identification number for the unit). Each identified deviation was marked as dn, (d=distance, n=identification number of the deviation).

The KVP model (K=knowledge, V=values, P=social practices) introduced by Clément (2006) was also used. In addition to knowledge, it considers the importance of values and social practices in analyzing the process of didactic transposition. In order to better identify knowledge, practices and values, this study includes Brazilian and Portuguese books which allow a comparison between two different contexts. Furthermore, using the KVP model, the methodology involved: 1) a horizontal analysis of the analyzed recent textbooks; 2) vertical analysis, which consisted of analyzing changes that have taken place over the years; 3) consulting the documents and literature of reference on the history of biology education; 4) comparing the results of this analysis in order to identify KVP influences (Figure 1).

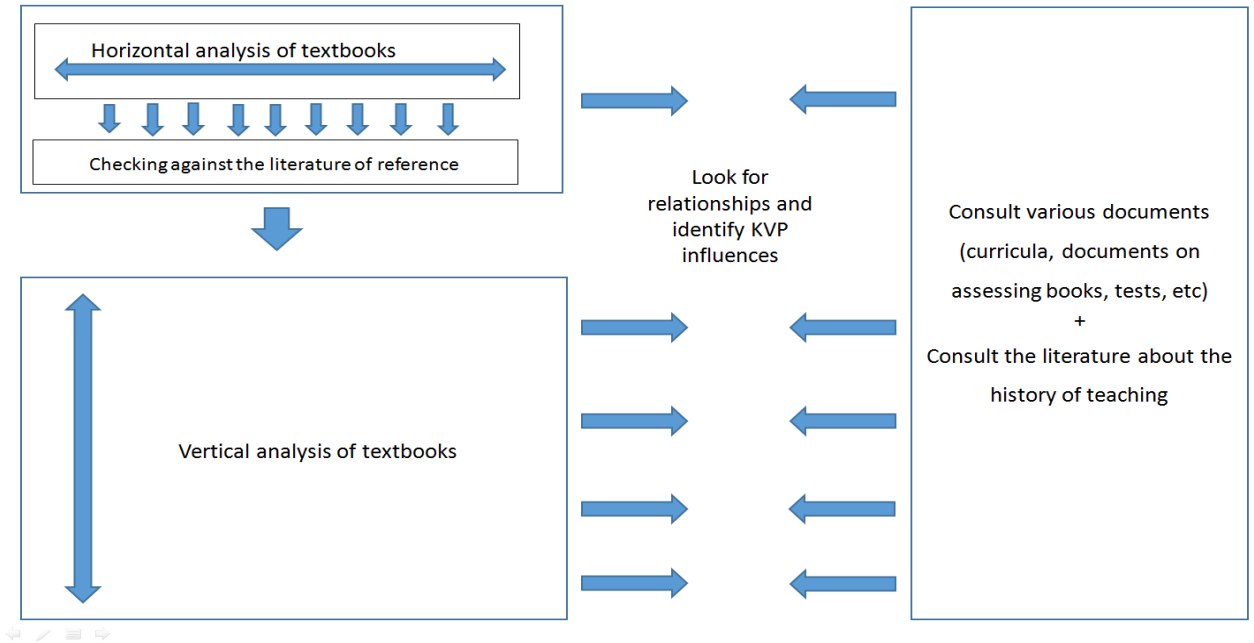

Figure 1- Research design including both Franzolin (2012)'s methodology and Clément (2006)'s KVP model.

Results and discussion

Chapters related to genetics of most textbooks showed to be close to the reference materials in quoting eye color, skin color, and human height, considering them as "*characteristics which are genetically determined"* (ur1) "*by alleles of various genes (polygenic)"* (ur2) (Table 2). There are textbooks which are also close to the reference materials, saying that "*these characteristics show continuous variation"* (ur3).

With respect to skin color and height, several books are approximate to the references in saying that these are "*characteristics which are not completely genetically determined"* (ur5), and are "*influenced by environmental factors"* (ur6). Additionally, some books are also approximate to the references in saying that "*various gene pairs have an additive effect"* (ur7).

In contrast to skin color and height, no data were found in the references about eye color which would permit an analysis of the influence of the environment on this topic. The practice of mentioning environmental influence on the expression of skin color and height, as well as the fact that many genes influence the expression of these characteristics, provides a vision of genetic complexity. In the Brazilian textbooks, this *practice* was already present in 1988 (in another textbook by the author of LDE-Br) and in 1994 (LDC-Br).

Table 2 presents a summary of the registration units identified in the Brazilian textbooks (LDA-Br to LDE-Br) and Portuguese textbooks (LDJ-Pt to LDL-Pt).

Comparisons with previous editions (horizontal analysis, see Fig.1) of Brazilian textbooks show that this *practice* is also related to *values*, a concern which has gradually been reinforced to avoid genetic determinism. For example, previous editions of 1975 by the same LDE-br authors and of 1980 by the same LDC-br authors, exemplify quantitative genetics on the characteristics here analyzed but they do not address the environmental influence on them, although they refer the environment effect in other circumstances. However, later editions by the same authors, in 1988 (LDE-br) and in 1994 (LDC-br), already show this concern, highlighting in the quantitative inheritance chapter that the continuous variation do not depends only of the individual's genes, but is also due to environmental factors.

Registration units	It is a genetically determined characteristic	It is a characteristic determined by alleles of various genes (*poligenic*)	It is a characteristic that demonstrates continuous variation	It is a quantitative characteristic (presents quantitative variation)	It is a characteristic which is not completely determined by genetics	It is a characteristic influenced by environmental factors	The various gene pairs have an additive effect
code(ur)	ur1	ur2	ur3	ur4	ur5	ur6	ur7
EYE COLOR							
LDA-Br	X	X	X				
LDB-Br							
LDC-Br	X	X					X
LDD-Br							
LDE-Br	X	X					
LDJ-Pt	X						
LDK-Pt	X*	X*					
LDL-Pt	X	X					
SKIN COLOR							
LDA-Br	X	X	X	X	X	X	
LDB-Br	X	X	X		X	X	X
LDC-Br	X	X		X	X	X	X
LDD-Br	X	X		X			X
LDE-Br	X	X		X	X	X	X
LDJ-Pt							
LDK-Pt	X	X*					
LDL-Pt	X	X		X	X	X	
STATURE							
LDA-Br	X	X	X	X	X	X	
LDB-Br			X				
LDC-Br	X	X		X	X	X	
LDD-Br							
LDE-Br	X	X		X	X	X	X
LDJ-Pt							
LDK-Pt	X	X*					
LDL-Pt	X	X		X	X	X	

* mentioned generally, without specific reference to humans

Table 2. Summary of the registration units identified in the Brazilian textbooks (LDA-Br to LDE-Br) and Portuguese textbooks (LDJ-Pt to LDL-Pt).

In the Portuguese textbooks, only one (LDL-Pt) of the analyzed collections showed this environmental concern in the gene expression. Another practice, as compared to Brazil, can explain this result. It was noted that the expression of skin color, eye color, and height approach practice is presented in more detail and is related to quantitative genetics discussion along with valuing a statistical treatment of genetics. In contrast to the Brazilian textbooks and the Portuguese LDL-Pt, both Portuguese LDJ-Pt and LDK-Pt do not address quantitative inheritance. This issue of patterns of expression and variation appears in Brazilian textbooks since the 1930s (Rialva, 1931) and 1940s (Mello Leitão, 1940). This can be explained by the fact that recent literature (Bizzo et al., 2012) indicates that books by Mello Leitão were widely used throughout Brazil, making it the largest reference for writing other textbooks in the country.

Despite the closeness to the literature of reference, deviations were also found as shown in Table 3.

Table 3 - Deviations refer to content about expression of eye color, skin color, and human stature in Brazilian and Portuguese educational materials in the area of biology which were analyzed, along with the literature of reference (cd=deviation code, BR=Brazil, PT=Portugal, Cat_t=categories of type of deviations found, TE=equivalent term, MT=metaphor, DC=conceptual deviation, DDP= deviation in the description of the process, GO=generalization of the occurrence, CNA= content not updated, OI=information omitted, CAT_i =categories of implications of deviations, f=facilitators for learning, m=maintainers of the essence of learning, ep=barriers to the understanding of isolated knowledge, ec=barriers to the understanding of central knowledge, ecg=barriers to the understanding of central knowledge with severe social implications)

	Comparison between knowledge		Material where deviations were identified		Categories	
Cd	Knowledge presented by literature of reference	Knowledge presented in secondary educational material	BR	PT	Cat_t	Cat_i
d01	Eye color is determined by *various genes*	*Omits the information* presented by the reference, only stating that light eye color is recessive and dark is dominant, after mentioning monogenetic inheritance	-	LDJ-Pt	OI	ec
d02a	Skin color is described as a *complex* trait	Skin color is described as a *quantitative* trait despite clearly mentioning the influence of the environment on the determination of this trait	LDA-Br LDC-Br LDE-Br	LDL-Pt	CNA	m
d02b	Skin color is described as a *complex* trait	Skin color is described as a *quantitative* trait and the influence of the environment on the determination of this trait is not explained	LDD-Br	-	CNA	ec
d03	Height is described as a *complex* trait	Skin color is described as a *quantitative* trait despite clearly mentioning the influence of the environment on the determination of this trait	LDA-Br LDC-Br LDE-Br	LDL-Pt	CNA	m
d04	Skin color is also determined by the *influence of the environment*	*Omits information* presented by the reference, only saying that skin color is genetically determined	LDD-Br	LDK-Pt	OI	ec
d04	Height is also determined by the *influence of the environment*	*Omits information* presented by the reference, only saying that height is genetically determined	-	LDK-Pt	OI	ec

In the 1950s, discussion of continuous variation determined by the action of various genes appears in textbooks, using skin and eye color as examples (Barros, 1956). This practice of presenting quantitative genetics in Brazilian textbooks may be due to the importance given in the first decades of the 20th century to the 'mathematization' of Biological Sciences in order to give them a higher scientific status (Marandino, Selles, and Ferreira, 2009).

In Portugal, the collection obtained for the vertical analysis did not allow us to conduct such an extensive analysis, but it did allow for the confirmation of a notable occurrence. The authors of LDK-Pt published another collection for the same publisher prior to 1993 which discussed quantitative inheritance, mentioning the three characteristics under study (skin color, eye color and height), but the influence of the environment was mentioned in a separate topic. However, these topics were removed in the later editions to create space for other subjects which became more valuable in the national curriculum such as genetic engineering, gene regulation and oncology. Along with the topic of human heredity, quantitative inheritance ceases to be addressed in later editions after 1993, and the topic Heredity and the Environment is no longer found in editions after 2003, giving room for the relation of the environment with mutations and cancer. Despite the relevance of the new addressed topics, there is no longer evidence of the authors' concern to avoid genetic determinism, they even use the term "genetic programming" right after quoting the genetic determinism of skin color, eye color and height.

These results may be related to the influence of national curriculum documents in Portugal. The current Portuguese curriculum of Biology for the 12th grade (Ministério da Educação, 2004), first of all, does not give the same importance to the mathematization of biology as in Brazil. It even stresses that "the resolution of paper and pencil exercises should not be considered an end in itself, but rather a means for students to understand how it is possible to interpret and predict the transmission of certain characteristics" and even recommends avoiding "solving exercises involving three or more pairs of alleles" and "solving exercises on epistasis, distance calculation between genes and chromosomal maps" (Ministério da Educação, 2004, p. 19-21). There is no evidence of concern in regards to teaching "quantitative genetics" content, and the question of genetic determinism does not appear as an obvious concern in this curriculum either.

Another factor that may have influenced the concern in avoiding genetic determinism in Brazilian textbooks may be the fact that they would necessarily have to be approved in the evaluation of PNLD (National Textbook Programme). Researchers in the Biology teaching area are involved in the PNLD evaluation process, including those that, in some way, deal with issues relation to genetic determinism (El-Hani et al., 2007; Gerick et al., 2012). Therefore, authors and publishers seek to tailor their books to be approved by PNLD.

In Portugal, the textbook evaluation process is different and does not include the 12th grade which deal with genetic matters.

Another possible factor influencing the differences on the concern about the phenotypic varieties in both countries, Brazil and Portugal, is that the former has a long tradition in immigration whereas the latter has the tradition of being a country of emigration. In this context, skin color of ethnic groups seem to be a matter of greater concern for Brazilian curriculum than for the Portuguese one. Studies on immigration and racism were rare in Portugal before the mid-90s, since then it has become an important socio-political issue (Cabecinhas, 2003). In contrast to Portugal, Brazil is a country where miscegenation is part of the makeup of its population. In this context, concerns about miscegenation are not new, having been, on the one

hand, a concern of the eugenic movements that influenced the presence of genetics education in their teaching in the beginning of the 20th century (Bizzo, 1995). On the other hand, the concern to combat discrimination of differences is a concerned expressed not only in the Constitution of the Federative Republic of Brazil (1988), but also found in the first criteria for evaluation of the PNLD in 1996, excluding books that present prejudice or discrimination of any kind (http://www.fnde.gov.br/programas/livro-didatico/livro-didatico-historico, retrieved in 20/02/2016).

Conclusion

This study contributes to the epistemological vigilance as quoted by Chevallard (1991), showing that most textbooks stay close to the reference works in mentioning the polygenic determination of the analyzed characteristics (skin color, eye color and height) and the influence of the environment. In this way, they provide an understanding of genetic complexity. Using the KVP model (Clément, 2006), values and practices influencing the determinism approach could be identified: 1) the importance of the genetic mathematization, which leads to the practice of teaching quantitative genetics and such human characteristics as examples; 2) the concern to avoid bias on a population composed of different ethnic groups that can influence the results; 3) the textbooks evaluation.

However, in other respects, authors can further improve their textbooks to avoid genetic determinism as other studies have indicated (Clément and Castera, 2013; Silva, Ferreira and Carvalho, 2009).

Moreover, we found textbooks which deviate from the literature of reference, mainly by omitting this information, which may cause barriers to central understanding of the content. In the Portuguese context, it was found that the practice of adopting new topics in the curriculum can lead to the elimination of this information.

Thus, the understanding of the closeness of textbooks contents ("taught knowledge") and academic knowledge of reference for teacher training, as well as the research to values and practices may make us reflect on the taught knowledge and its relevance.

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