Brazilian teachers' perceptions of genetics as school contents

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Abstract

This work analyses the answers to questionnaires and interviews with high school biology teachers in the public state school from 20 of the 26 Brazilian states. The sample was composed by a methodology based on convenience, and spans Brazilian diversity. Faced with a scenario in which genetics appears as a field of knowledge in which paradigm shifts happen over a short span of time, in this study we intend to observe how teachers in Brazilian basic education deal with the latest issues in genetics, and which topics generate major challenges in the field of understanding and in the process of didactisation of knowledge. The data collected yielded information on what is being prioritized in genetics teaching in Brazilian public schools. It reveals that while teachers consider classic Mendelian genetics and topics such as mitosis and meiosis to be important, they choose to avoid related issues, such as gametogenesis, as well as subjects which can promote critical thinking and citizenship, such as genetic manipulation. With regard to this last topic, the data clearly show that the problem is not related to importance recognition of the theme, but a real challenge for teachers to meet their own expectations, and those of the students, regarding this topic. Our data allows us to conclude that teachers need updated and in-depth training in the area of biotechnology, in order to better inform discussions on related themes, otherwise students will continue to have few opportunities to develop critical thinking and act as informed citizens.

Keywords: genetics teaching; Brazilian diversity; didactic transposition; critical thinking

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Introduction

The teachers participating in this research were biology graduates during a time of great advancements in the genetics area, which has also impacted other areas of this science, such as zoology. Phylogenetic systematics, for example, arrayed itself in new apparel with the inclusion of genetic characters in the construction of cladograms. Therefore, it was in the 60s, with the inclusion of the molecular biologist in the phylogenetic systematist group, that the philosophical discussions broadened in regards to the methodology proposed by Willi Hennig in the 50s (Santos and Klassa, 2012). According to this group, the evolution of genes should be characteristic for the building of cladograms. The major thrust in Brazil was in the 90s when the systematists began to consider molecular data as phylogenetic tools. Currently Brazil has a significant number of specific works in this area of knowledge.

Academically, the progress made in molecular genetics has allowed, for example, the restructuring of the phylogeny of several groups of organisms, which caused drastic changes in taxonomy, since mitochondrial and nuclear genes were used to carry out phylogenetic reconstructions. As a result of this restructuring there are excessive nominations, i.e., description of new species, subspecies, families, etc, generated by the use of the molecular systematics. Currently many systematists recommend the use of integrative taxonomy — which aims to define the taxonomic units from multiple and complementary perspectives, such as phylogeography, comparative morphology, population genetics, ecology, embryology, behaviour, among others — to solve the problem of excessive nomination (Dayrat, 2005). Among other advances at the end of the twentieth century and early twenty-first century, there are the findings of enzymes such as reverse transcriptase and proteomic mechanisms, creating paradigm shifts in the very dogma of biology, hitherto well established and irrefutable. The concept of gene, for example, has changed over the years (Flodin, 2009) and today we know that there are the transpositions elements generate by DNA mobility, which brought us new insights into the proteins evolution (Shapiro, 2010).

This new knowledge generated in the field of genetics can be seen as a self-correction process from the science of development itself. The article published by Allchin (2015) presents an overview specifically about the self-correcting myths of science, including advances from the biology dogma. According to the author this myth supports the belief of science as a higher form of knowledge and reinforces the socio-cultural influence in the production and refutation of scientific data generated at different times.

Like this, the genetic teaching in the schools should not necessarily reach all the changes in science. For example, it is essential for the understanding of Mendelian inheritance mechanism, the main base of classical genetics, that the student can understand other topics related to genetics, such as gametogenesis, recombination and chromosome evolution, etc. In this sense, the latest research in genetics, such as proteomics, may not make sense for students if they haven´t the knowing of this basic genetics contents. First of all, in light of a more epistemological viewpoint, we can consider it necessary to have a certain gap between knowledge taught in school and that generated by scientists. Scholarly knowledge that is to be taught should undergo a didactic transposition, in other words, be adapted so that it is understandable to the learner (Chevallard, 1991). From a more sociological perspective, it is important to consider that knowledge taught in schools must not be just a simplification of the knowledge produced by science. Schools are producers of school culture (Forquin, 1992) and knowledge can be produced specifically for educational purposes (Chervel, 1992). Considering the fact that schools do not only teach knowledge from academia, one may affirm that it also teaches knowledge from social practice references (Develay, 1992, as cited in Carvalho, 2009; Martinand, 1981, as cited in Clément, 2006). Therefore, school knowledge is also the result of practices and values (Clément, 2006).

However, one cannot ignore that the advancements in molecular genetics impacted not only the training of biology teachers, but also in the production of didactic material generating new challenges for handling a lot of different biological content within the school context, including, for example, the content of phylogenic systematic (Rodrigues *et al.*, 2011; Santos and Calor, 2007; Santos and Klassa, 2012). Several researchers became concerned with the teaching of topics that connect genetics with biotechnology as well as Dawson and Soames, 2006; Martínez-Gracia, Gil-Quílez, and Osada, 2005; Pedrancini *et al.*, 2007; Pedrancini *et al.*, 2008; Xavier, Freire and Moraes, 2006; and Usak *et al.*, 2009. Moreover, with the Human Genome Project, characteristics that used to be considered simple, determined only by a pair of genes, are now considered to be complex, leading researchers to argue that it is no longer a matter of just mastering mathematical problems involving Mendelian genetics for students to be able to explain their own characteristics (Bizzo, 1998; Dougherty, 2009). They argue that the students need to understand that there is not a simple relationship between genotype and phenotype. Its characteristics are determined by developmental and environmental factors and the interaction between genes.

Faced with a scenario in which genetics appears as a field of knowledge in which paradigm shifts happen over a short span of time, in this study we intend to observe how teachers in Brazilian basic education deal with the latest issues in genetics, and

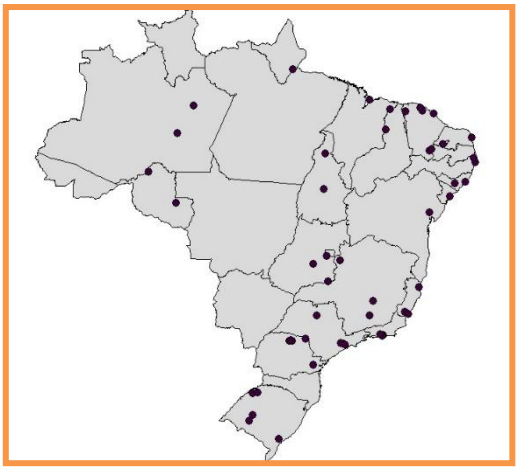
which topics generate major challenges in the field of understanding and in the process of didactization of knowledge.

Methodology

The *corpus* used in this present study was composed by applying questionnaires to 65 high school biology teachers in 2014 and 2015. They worked in from public state schools in 20 of the 26 Brazilian states as well as the Federal District (Figure 1), and had graduated between 1985 and 2014. Of teachers participating in the research, 60% have specialization course, 28% have master's degrees and 3% have doctorates. As for the number of hours worked in the school, 43% meets more than twenty hours per week, 38% meets forty hours a week, 17% meet more than forty hours per week and only 2% meets less than twenty hours per week. The sample was composed by a methodology based on convenience, and spans Brazilian diversity. The items that comprised the questionnaire were constituted by compiling genetics content taught in courses for licensure in biology, based on interviews conducted with teachers working in basic education during the pilot project which preceded this present study. Additionally, semi-structured interviews were conducted for this study with ten participating teachers. The audio of these interviews was recorded and subsequently transcribed, according to Project NURC (Educated Urban Linguistic Standard) norms. Quantitative data were obtained and expressed in absolute and relative percentages, along with qualitative data, which were subjected to content analysis (Bardin, 2009).

The discussion of the survey data was based on the concept of education as a democratic practice, where the teacher's interference should permeate the classroom space and reach the organization of content that she or he considers important to be taught at school. It is this autonomy which is defended in this research as essential for the teacher to fulfil her or his role, in all its fullness. Among the theoretical references for this discussion, we used the work by Schön (1992) about the reflective teacher, and that of Liston and Zeichner (2003), who advocate the importance of the teacher also reflecting on his or her own practice, along with reflections on the collective environment, the relationship between school and society, and reflections on the goals and purposes of education, about what teachers intend to teach and for what reasons.

Figure 1: Location of the Brazilian cities of the teachers participating in the survey.



Results and discussion

Questionnaires and interviews showed which themes generate greater challenges during didactization of content, to make it relevant when teaching about genetics, and which materials teachers access to prepare their classes.

Gametogenesis: theme left out when planning courses

When asked to mention which themes they left out when planning their courses, many teachers cited "Gametogenesis (Spermatogenesis and Oogenesis). However, they did not say the same for the topics such as "Mitosis/Meiosis" and "Mendel's 1st and 2nd Laws", which are closely related to the first. In light of these results one can raise some questions. Is the teacher making connections when planning his classes? And is the teaching of both gametogenesis and mitosis/meiosis, and the 1st/2nd Laws of Mendel treated in a way emphasizing the role of these processes in the diversity and evolution of organisms, as is expected in the current teaching of biology? These issues become even more relevant when observed from data acquired in research, that the great majority of teachers consider that knowledge produced by genetics and taught in schools are essential for students to understand the evolution process, as 94% of the teachers will attest to, and to understand the problems of environmental order, as 89% of the teachers claim.

Paternity test, Genealogical tree and Genetic manipulation: themes excluded from teaching

Topics such as "Paternity testing", "Genealogical tree", and "Genetic manipulation" were also cited by teachers as possible exclusions. Research done by Castelão (2012) points to a number of considerations regarding the motivation for teaching genetics. In this case, genetics is approached more as an area that motivates learning by presenting current topics that

are attractive to students such as cloning, stem cells, biotechnology, among others. However, based on the data of this research, to suppress topics such as "Paternity Tests", "Genealogical Tree" and "Genetic Manipulation" that are present in today's scenario, and under great media projection, the teacher could miss the opportunity of bringing interesting topics to the classroom for discussion among the students. Obviously, this discussion should not be kept at a superficial level but rather illustrate complex issues for understanding molecular genetics.

A large-scale survey was conducted by Castéra and Clément (2012) in 23 countries, including Brazil, in order to obtain information about teachers' concepts of the determinism of human behaviour. The results showed that part of those interviewed believe in genetic determinism as a form of justifying the differences in gender or the superiority of certain human ethnic groups. In light of such alarming data, the authors emphasize the importance of rethinking the way biology is taught, as teaching science is an important tool for building citizenship causing the critical individual to fully participate in social life. The authors also stressed the importance of rethinking, specifically the teaching of genetics, as a way of promoting tolerance and to understand the diversity of the human populations.

Genetic manipulation: one of the themes students and teachers feels most difficult

When asking a teacher which subjects he considered the students had the most difficulty in understanding, the most preponderantly mentioned subjects were "Genetic Manipulation" (58%), followed by "Cytological basis of heredity", "Chromosomal theories of heritage," "Genetic mutations and chromosomal mutations," mentioned by 55% of the teachers, and "Mitosis and Meiosis," mentioned by 52% of the teachers participating in the survey. However, when asking the teachers what their greatest difficulty in understanding and dealing with the different genetic topics was, "Chromosomal theories of heritage" and "Genetic manipulation" are once again the most mentioned, but at a much lower percentage of 29%. When asking the teachers which of the suggested topics they (the teacher) have the most difficulty in when preparing their classes, "genetic manipulation" is mentioned once again at 40% followed by "experiments with stem cells" mentioned by 32% of the teachers participating in the survey. "Genetic manipulation" is preponderantly mentioned by teachers from all the regions, whether as a topic that generates more difficulties in understanding, both by the students and by the teachers. In the case of the teachers, the difficulty in "genetic manipulation" is not reflected only in the understanding process, but also in preparing the classes. It's interesting to note that "genetic manipulation" was also cited as one of the subjects that could be excluded when planning Biology classes.

In this scenario, it is clear that dealing with the topic of "genetic manipulation" is still a challenge for the teachers, even though it is ever present in the social context. The debates on Genetically Modified Organism (GMOs), for example, are not only present in the academic field, but in the media. This is an area in biology that has made great advances the last 20 years. Therefore, it is essential that the teacher be able to update himself with bibliographic references and also participate in discussions with colleagues in courses, such as teacher training. Basic education school teachers are the main mediators for teaching "genetic manipulation" and its ramifications, which including issues with bioethics. Hence the need for the democratization of science, so that the knowledge produced by the academy reaches the teacher and consequently the students.

Regarding the content inherent in genetic manipulation, Pedrancini *et al*. (2008), when researching the relation between scientific knowledge and the student's spontaneous knowledge in High School regarding GMOs, we observed that the media played the greatest role in influencing the student's opinion on the advantages and disadvantages of GMOs. According to Bachelard (1996), the appropriation of scientific knowledge does not occur by the continuity of common sense knowledge, but is derived from the conceptual changes similar to shifts in paradigms. Paradigm shifts are characterized by breaks and discontinuities, and not only by the accumulation of information acquired over a period of time. The school is where a student should acquire scientific knowledge that would enable him to question the superficial content generally presented by the media. Several surveys have shown that students who finish High School continue to giving explanations that are limited to spontaneous and sensory knowledge of various phenomena (Banet and Ayuso, 1995; Pedrancini *et al*., 2007).

As already mentioned, issues regarding bioethics permeate the contents on "genetic manipulation." It is important that the teacher realize that this type of knowledge is accompanied by social, political, economic and ethical implications. It is, therefore, necessary that the school give room for discussion and debate. Research done by Silva and Krasilchik (2005), aimed at investigating how high school students comprehend the ethical dimensions of biological knowledge from the bioethical perspective, showed that much of the students' positioning is motivated by personal reasons, which are very close to their personal family lives, interpersonal relations, religious and cultural influences, among other aspects. The authors propose evaluating if the teacher training courses offer discussion and debate exercises to promote the relation between received/transmitted knowledge from the bioethics perspective. Guimarães, Carvalho and Oliveira (2010) conducted research with high

school students with the aim of seeing how the students deal with issues related to genetic manipulation on human beings. It was evident to the researchers that there were two groups of students, where one of them holds a religious perspective and the other doesn't. However, genetic manipulation in search of an esthetic improvements, or positive eugenics, was rejected by both groups. According to Guimarães,Carvalho and Oliveira (2010), variations in opinion regarding one topic can, in large part, be due to the social representation of the students. The authors based themselves on several theorists to discuss the representations that members of society use in order to live in their world. Among the theorists is Willian Cobern, who identifies this as *world views* and points to the problems that can arise when teachers and students are different. Cobern believes this issue makes the learning of science unsatisfactory because there is no dialogue between the student's culture and scientific discourse presented by the teacher (Cobern, 1996).

In the analysis of data obtained in this study, one notes that the teachers believe that genetic education should be present in the student's civic education. However, those same teachers report that they have difficulty during the didactization process of certain content referring to this type of discussion. It is crucial that the teachers be offered the means to dedicate themselves to training courses, or on a post graduate level, that would allow the school teachers to approach scientific knowledge produced by academia and reference bibliographies in order to provide other sources of information, not only that which is available in the school environment, such as textbooks, for example.

Only 20% of the teachers who participated in the survey feel that knowledge produced by academia reaches the school environment; 54% say such knowledge partially reaches the schools, and 26% say scientific advancements does not reach the school level. When asking the teachers if they feel that the textbooks available to teach biology are considered to be satisfactory, 60% say the textbooks are partially satisfactory, 22% say they are not satisfactory and 18% say they are satisfactory.

The data presented indicates that knowledge produced in the academic circle does not reach the school level, from an integrated and contextualized perspective of the content. Moreover, although the teachers use the textbooks provided by the school to update themselves on the advancements recently made in genetics, they feel it does not meet, for the most part, their expectations, and therefore are not adequate for meeting demands in the classroom.

As previously mentioned, one should take into account that knowledge taught in the classroom, school knowledge, is not only to serve the interest of academia, but also to meet the needs generated from social expectations (Akeinhead, 2003; Goodson, 2010; Lopes, 1999), presenting knowledge and practices (Chervel, 1992). Classroom knowledge involves the choice of knowledge to be taught and required didactization for understanding (Chevallard, 1991; Chevallard and Bosch, 2014; Forquin, 1992), but it is also influenced by different social practices (Develay, 1992, as cited in Carvalho, 2009), and by the values present in society at large, such as opinions, beliefs, ideologies, among others (Clément, 2006).

Nevertheless, establishing a dialogue between scientific research and teaching is a prerequisite for building meaningful, contextualized and renewable learning. However, the way to work with elements produced by the academic community within the school context is a great challenge, mainly because collaborative work between researchers and school teachers often time does not come to pass. Moreover, it is important that the elements of school culture have a place in the integration process of what is produced by academia with the didactization processes of that knowledge. Research shows a distancing between the knowledge of genetics that is produced by academia and the knowledge taught in textbooks (Clément and Castéra, 2013; Franzolin, 2007; 2012; Silva, Ferreira and Carvalho, 2009). Such distancing is not always conductive to learning and, in some cases, could be due to the Didactic Transposition Delay (DTD) (Quessada, and Clément, 2007).

A point to be proposed for reflection is the fact that much of the basic education school teachers use textbooks as their resource for updating themselves on the area of genetics. Data shows that not all teachers are satisfied with their school's choice of textbooks as a teaching source for their classes. It is especially evident from texts reported by some of the teachers, that there is a mismatch between the curriculum of the State in which they teach and the content presented by the textbooks distributed to the schools. Fragmentation between the content, often times present in the textbooks, was one of the problems reported by some teachers.

Therefore, it is important to note that the distance between curriculum and textbook, for example, prevents the content to be addressed in an integrated and contextualized manner, which also impacts the teaching of genetics. According to Goldbach and Bedor (2009), some problems and challenges that arise in most national textbooks are mainly in regards to three characteristics: fragmentation, decontextualization and lack of outdated content. Therefore, it is important that the teachers be able to appropriate themselves of other teaching resources to conduct their genetics classes.

Conclusion

The data collected yielded information on what is being prioritized in genetics teaching in Brazilian public schools. It reveals that while teachers consider classic Mendelian genetics and topics such as mitosis and meiosis to be important, they choose to avoid related issues, such as gametogenesis, as well as subjects which can promote critical thinking and citizenship, such as genetic manipulation.

With regard to this last topic, the data clearly show that the problem is not related to importance recognition of the theme, but a real challenge for teachers to meet their own expectations, and those of the students, regarding this topic.

This piece of research did not aimed at proposing curriculum changes. However, analysis of our data allows us to conclude that teachers need updated and in-depth training in the area of biotechnology, in order to better inform discussions on related themes, otherwise students will continue to have few opportunities to develop critical thinking and act as informed citizens.

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