IDENTIFYING ALTERNATIVE CONCEPTIONS ABOUT EVOLUTION IN PORTUGUESE HIGH-SCHOOL STUDENTS: A REFLECTION BASED ON NEW AND PUBLISHED DATA

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ABSTRACT: Research about teaching and understanding of evolution focusing on the alternative conceptions held by students identified problems related to the understanding or even acceptance of evolution. This work analysed texts about evolution written by Portuguese students and identified alternative conceptions in 89.06% of them; 57.81% of the texts had more than one alternative conception. The alternative conceptions identified in Portuguese students reinforce the probable link between the development and persistence of such conceptions and absence of an evolutionary framework until later years in school. The results obtained in this analysis contribute to the growing body of research claiming for an early introduction of evolution in school curricula.

KEYWORDS: evolution, alternative conceptions, teaching

GOAL: The major goal of this work was to identify alternative conceptions about evolution in Portuguese secondary school students and analyse it in light of similar studies.

THEORETICAL FRAMEWORK

Evolution is the basis to the understanding of all contents of biology but there is abundant literature providing compelling evidence of persistent alternative conceptions related to evolution (e.g. Gregory, 2009). Research about teaching and understanding of evolution focusing on the conceptions held by students identified problems related to the understanding or even acceptance of evolution that can be

mostly related to cultural influences (e.g. Pazza *et al.*, 2010). Students came from a variety of contexts and particular social constructions and each carry its own personal beliefs and values that are shaped from their environment. As such, alternative conceptions are not a product but a personal creation of the individual and of his/hers ideas about their environment. Changing a conception does not occur in a simple and immediate way. It is thus necessary to use teaching strategies that provoke students to reflect and think about confronting their ideas with what is accepted by science. This does not mean that conceptual change will occur but it will certainly allow teaching about evolutionary contents to become tangible and open to a productive discussion. In this context, studies aiming at identifying alternative conceptions of students are important as they can highlight inaccuracies about scientific knowledge (Campos y Nigro, 1999), guiding teachers to overcome such problems and given support to a reform of the biology curricula. An earlier introduction of evolution in school curricula, starting from pre-school or elementary school, could help student to learn about the natural world in an evolutionary context thus preventing the development of alternative explanations (Campos, Sá-Pinto, 2013).

METHODOLOGY

Data collection

We analysed texts from a contest calling pre-university students to write about evolution (partially published in Campos et al., 2013). The analysed texts are from students attending the 11th grade due to 1) the high number of participations from these students and 2) the fact that in Portugal this is when students learn about evolution in detail.

Qualitative data analysis

We used a qualitative content analysis approach to identify alternative conceptions about evolution in the texts. Given the open nature of the contest, the analysis was blind to previously defined categories or specific subjects. We focused on the identification of words or phrases that did not conform to the accepted understanding of evolution and evolutionary mechanisms (i.e., alternative conceptions). We used a three-step process: *1) Individual assessment:* Each of us read the texts, identified alternative conceptions about evolution and organized it in a table were each line referred to a single text and each column to the conceptions each identified. This combined data set was used in the next step. *2) Joint brainstorming:* Together, we analysed the table going through each text and comparing the alternative conceptions each of us identified. Instances of disagreement were resolved by going back to the original text and discussing any different significance we might have about it. In the end, all discrepancies were resolved and a new table was produced. *3) Categorization:* The data summarized in the new table was first coded in three categories: alternative conceptions about basic notions of evolution, about natural selection and about human evolution. We then coded the alternative conceptions within each category by identifying the key concept behind student's words. We considered an alternative conception to be related to basic notions about evolution whenever we identified erroneous notions related to basic knowledge, such as when a student explains evolution from a single individual that transforms into another species. As natural selection we grouped the alternative conceptions related to the action of the selective process over a characteristic such as texts stating that organisms feel the need to change to adapt to the environment. Texts with alternative conceptions related to humans, such as statements that humans descend from monkeys, were clustered in the human evolution group. Finally, we confronted our data with previously published work and looked for similarities between our results and published ones. Results are summarized in Table 1.

RESULTS

We analysed 64 texts and identified alternative conceptions in 89.06% of them; 57.81% of the texts had more than one alternative conception.

Table 1.
Categorization of the alternative conceptions identified in the analysed texts

Category	*Alternative conceptions*	*Meaning*	*N (%)*	*In other work*
Basics evolution	Darwin and Lamarck	Both Darwin and Lamarck's ideas are equally accepted to explain evolution	11 (17,19)	Tidon y Lewontin, 2004
	Common ancestral	Species only had one common ancestral, which is the most recent node in their phylogeny	9 (14,06)	
	Unit of evolution	The whole species or individuals can evolve	4 (6,25)	Gregory, 2009
	Transformation	Species derive from one or more species	9 (14,06)	Gregory, 2009
Natural selection	Evolution = natural selection	Evolution always occur to produce an adaptation	9 (14,06)	
	Directed evolution	Variation arises due to environmental or selection pressure	19 (29,69)	Crivellaro y Sperduti, 2014
	Wilful thinking	Organisms wilfully change their traits or the traits of their offspring and beneficial traits arise to supply a necessity	25 (39,06)	Abraham et al., 2009
	Progress	Evolution works on a progressive, linear, scale to produce better organisms	17 (26,56)	http://evolution.berkeley.edu
	The fittest will reproduce	Carrying a beneficial trait means that you will reproduce	7 (10,94)	
	The fittest	The fittest organisms is perfectly adapted to his habitat and only those survive	14 (21,88)	Gregory, 2009
Human evolution	Humans descend from monkeys	Humans are direct descends of monkeys	3 (4,69)	
	Humans are the intelligent species	Humans are the only intelligent species	6 (9,38)	

Alternative conceptions related with basic notions about evolution

Most students used history of science to contextualize the texts. However, 17.19% of the students did that using the arguments of Lamarck and Darwin as equivalent and equally accepted as valid explanations. One example is the text by student E3 that started to explain the evolution of penguins from a Lamarckian perspective: *"According to Lamarckism, the ancestral would have been a terrestrial bird; all these birds wouldn't have the need to go to the sea. (…) Thus, their wings atrophied, becoming smaller and playing the role of fins"*. In a different part of the text the same student uses Darwin's theory to explain the same thus leading us to conclude that both theories can be equally used to understand the evolution of species: *"On the other hand, Darwinism defends that the ancestral population would have been terrestrial. (…) With the need to feed in the sea the penguins with wings that were atrophied and served as fins had an advantage over the others because they would easily feed*

and escape from predators". These texts reveal that students understand the basic differences between Lamarck and Darwin's ideas. However, they seem to accept that evolution could be equally explained by either theory without considering the incoherence in the co-existence of both ideas. Other studies revealed that most students are able to differentiate the theories by Lamarck and Darwin (Pazza et al., 2010) but our work shows that this doesn't necessary mean that they understand the basic concepts of evolution.

When referring to common ancestry, 14.06% of the texts show a rather naïve vision, presenting the common ancestral as a distant parent from the extant species without an understanding of the dimension and the complexity of the phylogenetic scale. This is further perceived in other conceptions such as when students state that a single individual or the entire species evolves (6.25%) or that a species transforms into another species (14.06%) as can be identified in the text by student E33: *"to be able to cope with the environment the ancestors of the horses had several changes. The teeth that used to chew were projected to the front so that they could eat grass. The neck became larger to make feeding easier, the paws gain size to facilitate running away from predators and feet were adapted to harder terrains"*. This result is in agreement with other studies that showed that 15% of students hold the idea that evolutionary change occurs within a generation and that 20% think that the change occurs inside the population (Abraham et al., 2009). Gregory (2009) suggests that this naïve and transformist vision is related with an essentialist philosophy that emerges in childhood but remains in adults, where populations are considered uniform and transforms by an adaptive process.

Alternative conceptions related with natural selection

Most texts had alternative conceptions about natural selection. If students don't know the foundations of natural selection they will have more difficulties to understand how this mechanism promotes evolutionary change (Gregory, 2009). In over 10% of the texts we found the notion that evolution is a synonymous of natural selection and almost 30% of the texts state that evolution is directly related with adaptation, that evolution occurs due to the selective pressure impose by the environment. The text written by student E34 illustrates this: *"The environment is constantly changing and this consequently leads to an adaptation by the species. This adaptation will lead to the existence of a higher variability and diversity creating unique species and consequently lead to the beauty that planet Earth has"*. In other study, 45% of students hold the conceptions that selective pressure or environmental pressures are the cause for the genetic variation in a population (Abraham et al., 2009). Moreover, students suggest that without environmental changes organisms would not have the need to change. These results are in agreement with our findings. In 40% of the texts we identified the notion that organism can proposedly change the genetic features, of their own or of their offspring, and that the genetic characteristics arise to suppress a need. An example is given by student E24 when explaining the origin of bipedalism in humans: *"Initially this common ancestral moved using their four legs but through time he faced diverse difficulties (…). It was thus necessary an adaptation by the individuals and it occurred in the changing of the gene pool of the population, through mutations and genetic recombination, as it can be seen with biochemical analysis of the species"*. Here we can see that beside the conception that organisms changed because of a need the student also hold the idea that this common ancestral become bipedal in a very short geological time scale. The same notion that evolutionary change occurs in a single individual or population is present in other studies (e.g. Crivellaro y Sperduti, 2014).

In about 26% of the texts we identified the idea that evolution is linear and always lead to the best, as if all new variations are beneficial. This alternative conception might be related to the essentialist philosophy previously discussed which can also explain the conceptions that the fittest individuals are

perfectly adapted to the environment and are the only one that survives. And because they have those characteristics they are also the ones that reproduce. This naïve vision can be identified in the text by student E28: *"survival is the privilege of the strongest, the ones that have a capacity to adapt to environmental adversities that is higher than their similar or other species that co-exist in their habitat. A proof of that is that organisms that are more adapted are fit to reproduce more and better than the others which is important to the transmission of their genetic material to offspring."*

Alternative conceptions related with human evolution

In the 17 texts about human evolution we identified alternative conceptions described above but here we discuss only those specific to humans such as the notion that humans arises directly from a monkey and that humans are the only intelligent species. These conceptions are well illustrated in the text by student E7: *"it says that species, according to their needs, will change, modify through time. Then there was the hypothesis than man is a direct descendant of the monkey and has great proximity with this animal"*. Here the student reveals not only the conception that man directly descends from monkey but also that change happens because of a necessity. The conception that humans are the only intelligent species was identified in 9.38% of the texts. The paragraph from student E12 illustrates this: *"several Homo species that evolved went extinct, leaving only the species Homo sapiens, a species with intelligent individuals."*

CONCLUSION

The alternative conceptions identified here reinforce the probable link between the development and persistence of such conceptions and absence of an evolutionary framework until later years in school. We thus support the need to an early teaching of evolution and recommend teachers to be particularly alert to this problem, directing a class discussion towards the identification and clarification of the misconception hold by the students before and during lessons about evolution.

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