Conceptual Change about Evolution and Origins of Life throughout an Undergraduate Course of Biological Sciences

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Abstract. This research aimed to understand how students at different terms of a Biological Sciences course deal with the themes of evolution and the origin of life. The research instrument was a questionnaire developed within the European project BIOHEAD-CITIZEN applied in several countries aiming at analysing the views of students and teachers about health, environment and evolution. For this study only evolution questions were selected, which were answered by 56 students of the course of Biological Sciences, of the University Centre of Formiga, Minas Gerais (UNIFOR/MG), Brazil. The Qui-square (χ^2) and Pearsons statistical tests were applied to estimate the effect of being enrolled in the course, i.e. applied to the answers of the students attending the 2nd, 4th and 6th terms. Results showed that they accommodate new conceptions about biological evolution and human origin, which often are conflicting between science and religion views. The contradictions observed may be associated to the lack students' definition about dogmatic and scientific views. Comparisons with answers obtained in other Brazil regions and other countries were established. The results obtained at the 2nd, 4th and 6th course terms showed that attending the course leads to students' conceptual changes. It was noticed that the dogmatic views hinder the understanding and acceptance of the new scientific concepts for any students and it was concluded that attending the course makes the future biology teachers modify their conceptions. However, they find it difficult to accommodate the new scientific knowledge with their beliefs. The analysis of how these students in the future, as teachers, will deal with the dichotomy of conceptions linked to science and to religion in their classroom practices is a matter of further investigation. This research was supported by FAPEMIG.

1. Introduction

The origin of life and human evolution are part of the school curriculum in science and biology.

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However, the approach to these topics in the classroom, often cause discomfort in teachers, since there is an imminent risk of confrontation between scientific concepts and the religious beliefs of students. The historically difficult relationship between religion and science, with various moments of intense crisis, makes teachers uneasy to deal with issues related to biological evolution, and in particular, the origin of the human being [1]. Also Brazilian authors [2,3,4] that discuss Biology Education teaching, refer the difficulties in addressing this topic in the classroom, that arise from personal teachers' positioning from their inadequate initial training and the pupils' previous conceptions, among others.

The scarce information on biological evolution at all levels of education is analysed by Souza et al. [5] in an investigation in a large Brazilian university (University State of Londrina/PR) targeting several courses, including Biological Sciences, and focused the topic of biological evolution and acceptance of scientific or dogmatic knowledge. Only 25 % of the Biological Sciences students and 10% of Chemistry students revealed to have confidence in the evidence supporting the theory of evolution. This precariousness of assimilation and acceptance of scientific knowledge can be linked to the possible difficulty for students to understand how to build a scientific theory, confusing hypotheses with theory and ignoring scientific methods [5]. Also the conflict with the one's personal beliefs can explain the difficulties in accepting the Evolution theory [1]. Therefore, biological evolution seems to be a students' and teachers' dilemma hard to solve in their daily lives as they remain faithful to their religious dogmas [6]. Cerqueira [7] states that this is a daily secondary school teacher conflict but the lack of research consensus, including the differences in the methodologies used, make difficulty distinguish whether school evolution learning deficiency is linked to the teachers' compromise with religion or to their unsuitable teaching training. In addition, Cobern [8] has shown that even in social contexts where religion strongly determines the worldview, a religious person can still develop an analysis compatible with science, even though it may not be considered scientific in many respects. In this sense, also El-Hani and Bizzo [9] claim that it is possible to deal with deadlocks that occur when situations of crossing cultural boundaries occur in the classroom, as they consider contradictory beliefs within the cognitive structure can coexist in the same person. In contrast, Mahner and Bunge [10] claim that the person has to decide between religious and scientific perspective, since these would be inconsistent in the synthesis between religion and science. For them religious education can be harmful to science education.

In the context outlined above, the present study aimed to investigate how students of Biological Sciences, University Center of Formiga-MG perceive and conceive the topics related to the origin of life and human evolution and compare with other studies.

2. Methodology

The instrument of data collection used in this study was a part of the questionnaire constructed within the European research project Biohead-Citizen, which aims to study multiculturalism through important and controversial topics such as Evolution, Sex Education, Education for Health, Education environmental and other issues [1]. The length of the questionnaire and the variety of issues (144) allow the spread of responses that enable better represent the students' perception of the proposed themes. It has been applied in several European, African and Middle Eastern countries and in more than one region of Brazil, seeking to understand the impact of creationist ideas in future teachers, so it creates a basis for comparison of considerable analysis [1, 11].

This questionnaire was answered by 56 students of the Biological Sciences bachelor course of the University Center of Formiga-MG, along the 2nd (19) 4th (16) and 6th (21) academic periods. In this article, the six dependent variables A33, A44, A51, A62, A64 and B28 were analysed. To estimate the influence of being attending this course on the acceptance of the theory of evolution along the three periods, the chi-square (χ^2) Pearson test was used. The significance level of 0.05 was

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established.

3. Results and Discussion

The answers modalities to the question A33 ("The emergence of the human species (*Homo sapiens*) was just as improbable as the emergence of any other species"), were 1-"I agree" and 2-"I agree more than disagree" are more associated to the evolutionary conceptions whereas 3-"I disagree more than agree" and 4-"I don't agree" indicate creationists conceptions . Table 1 shows the answers frequencies of all students together, regardless the period they were enrolled in.

Table 1: Frequency of students' answers to question A33

Question			1	2	3	4	
A33.	The emergence of the human species (*Homo sapiens*) was just as improbable as the emergence of any other species.	I agree	**27%**	**16%**	**23%**	**34%**	I don't agree

1 - I agree; 2 - I agree more than disagree; 3 - I disagree more than agree; 4 – I don't agree.

Students' options to the question A33 were mainly "I disagree more than agree" and "I don't agree", with 23% and 34%, respectively. Thus, more than half of these students (57%) do not accept the idea of a chance for the emergence of the human species. To Carneiro [4], students retain concepts that separate them from the science concepts because generally perceive Biological Evolution as development and improvement from an initial creation. It is possible that this is the case for 57% of the participants on this research.

Figure 1 shows the frequencies of responses to the question A33, taking into account the number of students in each 2nd, 4th and 6th academic period of the Biological Sciences course. It was observed that the frequency of the response option "I Agree" increases as students advance through different periods of the course [Figure 1].

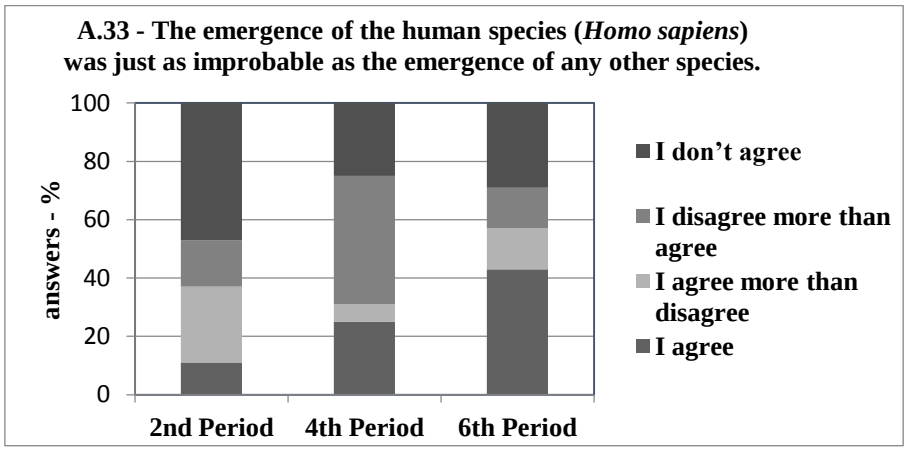

Figure 1: Frequencies of students' answers to Question A33 in each academic period.

The statistical analysis, using the chi-square test to determine significant differences as a function of time of participation in the Biological Sciences course showed significant differences ($p < 0.05$) over the three periods, indicating that the continuity in the course of Biological Sciences (2nd, 4th and 6th periods) promoted effective change to the scientific concepts and thus students increasingly accepted the idea of chance for the emergence of the human species. These data contradict those reported by Souza et al. [5] that have not detected changes in Biological Sciences students' perceptions on the evolution and origin of humans over the years at the Biological Sciences course.

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On the question A44 ("The emergence of the human species (*Homo sapiens*) was the aim of the evolution of living species"), [Table 2] a balance between those who tended to agree (48 % = 18% "I agree" + 30% "I agree more than disagree") and those who tend to disagree (52 % = 16% "I disagree more than agree" + 36 % "I don't agree") was found. This answers balance reveals a profile of students who still have queries about the evolutionary process. It lies between the scientific knowledge acquired at the Biological Sciences course, but touches the need to put humans in a different place in this process, as achieving the highest point of this process of evolution. Sepulveda and El-Hani [6] found that there is a commitment of Biological Sciences students (i.e. prospective science and biology teachers) with their own religious beliefs that clash with the need to present an explanatory model of science.

Table 2: Frequency of students' answers to question A44.

Question			1	2	3	4	
A44.	The emergence of the human species (*Homo sapiens*) was the aim of the evolution of living species.	I agree	**18%**	**30%**	**16%**	**36%**	I don't agree

1 - I agree; 2 - I agree more than disagree; 3 - I disagree more than agree; 4 – I don't agree.

Figure 2 shows the students' frequency responses in four modalities in each period (2nd, 4th and 6th periods), being observed that the sum of the two modalities "I don't agree" and "I disagree more than agree" increases successively with the time in the Biological sciences course, indicating that students increased their scientific conceptions, as confirmed by the statistical chi-square test at $p < 0.05$.

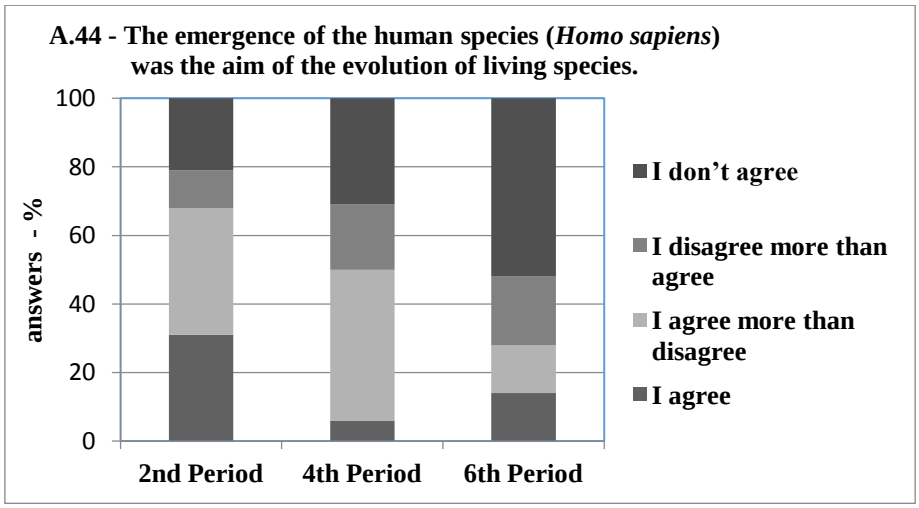

Figure 2: Frequencies of students' answers to Question A.44 in each academic period.

The A51 question puts the controversy about the tension between science and religion with the statement "Science and religion should be separate" [Table 3].

Table 3: Frequency of students' answers to question A51.

Question			1	2	3	4	
A51.	Science and religion should be separated.	I agree	**30%**	**11%**	**21%**	**38%**	I don't agree

1 - I agree; 2 - I agree more than disagree; 3 - I disagree more than agree; 4 – I don't agree.

The majority (59% = 21% "I disagree more than agree" + 38% "I don't agree") believes that science and religion should not be separated. These data, which are in agreement with those obtained by

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Pagan [12], indicate that students believe there should be more integration between science and religion, with either perspective presenting its vision and defending its proposal for reflection.

The analysis of responses to the question A51 at the 2nd, 4th and 6th periods [Figure 3], shows a small tendency of change, especially between the 4th and 6th periods, towards the separation between science and religion ($p < 0.05$).

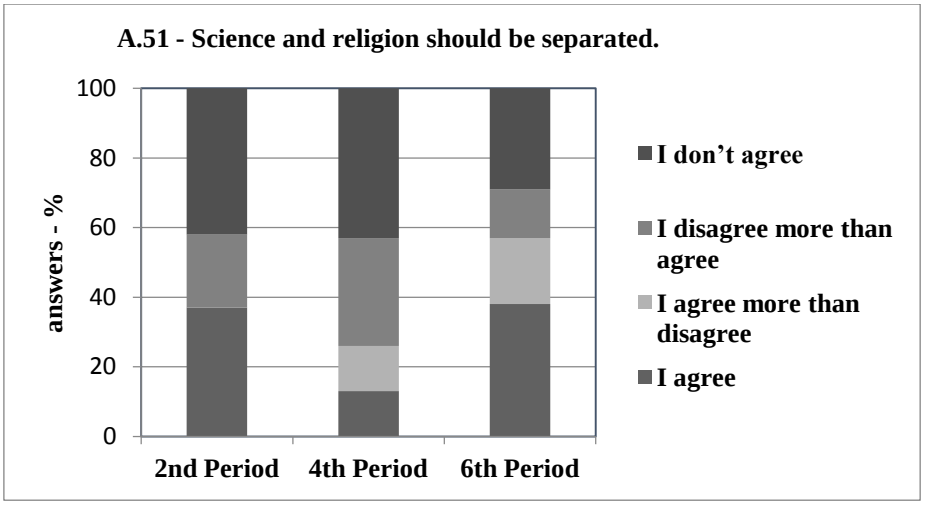

Figure 3: Frequencies of students' answers to Question A.51 in each academic period.

Considering the four categories of Barbour [13] on the students' placement regarding science and religion (conflict, independence, dialogue and integration), the present data showed that for some students the thesis of the conflict would be the most appropriate because science and religion would be mutually exclusive and incompatible infallibly, creating an barrier between science and religion, in which the truth would be only on one side, a thesis shared by radically atheistic scientists and literal biblical creationists. For others, but still within the same line of thinking, the approach should be independent, with high separation between science and religion, because each one, with its own traditions, has different beliefs, thus having little or nothing to say to each other. Indeed, having differentiated methods, themes and languages that do not compete nor overlap, and focusing distinct areas, they should not interfere with each other [14].

The A62 question asks students to indicate the three expressions that are more related to the origin of man, among Evolution, Natural selection, Australopithecus, Adam and Eve, Creation and God [Table 4].

Table 4: Frequency of students' answers to question A62.

Question		Evolution	Natural selection	Australopithecus	Adam and Eve	Creation	God
A62.	In the list below, tick the THREE expressions that you think are the most strongly associated with the origins of humankind.	**24%**	**22%**	**9%**	**7%**	**15%**	**23%**

Data shows that the evolutionary terms were the main choice with 55% (24% Evolution + 22% Natural Selection + 9% Australopithecus), and slightly more prevalent than choices on creationist terms that reach 45% (23% God + 15% Creation + 7% Adam and Eve).

Students tended to assume the requirements relating to the Darwinian theory, evolution, natural selection and Australopithecus over the terms Adam and Eve, Creation and God, showing a decline

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in importance for the Origin of Humanity during the Course of Biological Sciences [Figure 4], revealing a significant change in the conceptions of these students over the three periods ($p < 0.05$).

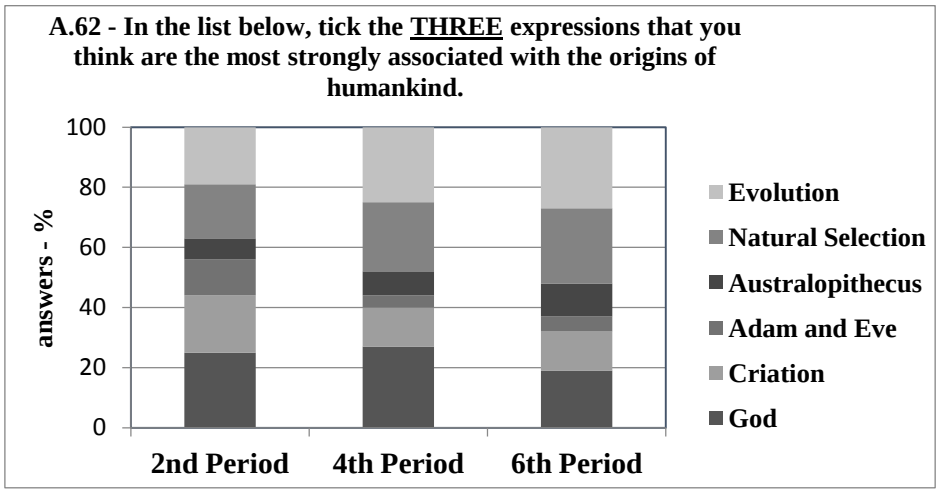

Figure 4: Frequencies of students' answers to Question A.62 in each academic period.

These results are in agreement with those found by Lopes [15] in France, Portugal and Brazil, using the same survey instrument, the questionnaire Biohead-CITIZEN. Thus, these results can be analysed in the light of the evolution of conceptual profile proposed by Mortimer [16] that considers the possible coexistence of two types of antagonistic conceptions, which therefore does not require the need of a conceptual change. However, for others, such as Posner et al. [17], when a new design conflicts with preconceptions there must be a conceptual change to accommodate this new concept, which seems do not have occurred in this case because it was not detected a significant association between the answers given by the students of the three periods [Figure 4]. These findings are consistent with results reported by Souza et al. [5] who found little or no conceptual change about evolution among students in Biological Sciences courses. Sepulveda and El-Hani [6] indicated that, in this context, there may be a conceptual change from a fundamentalist to a more liberal perspective, as if accommodating the evolutionary question, which would provide students with both scientific knowledge and dogmatic views. Mahner and Bunge [10] consider to be a degree of doctrinal incompatibility between religion and science, linked to the literal interpretation of religious doctrines and, in particular, of the holy scriptures, which could explain the positioning of those students who remained with the dogmatic conception, even after being confronted with the scientific approach.

The frequencies of responses to the question A64 ("Which of the following four statements do you agree with the most?" (about the origin of life) are shown in Table 5.

Table 5: Frequency of students' answers to question A64.

Question		Natural Phenomena	Natural Phenomena without God	Natural Phenomena with God	God
A62.	Which of the following four statements do you agree with the most? (tick only ONE answer)	**12%**	**9%**	**59%**	**20%**

Data show that 79% of students gave answers with creationist tendency (59 % Natural Phenomenon with God + 20% God), believing that somehow there is a creator participation in the process of the origin of life. The data are consistent with the proportion of 80 % of students from the state of São Paulo with Creationist conceptions, as detected by Caldeira et al. [11], by using the same question of the same questionnaire Biohead-Citizen [1].

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Figure 5 illustrates how the students of the three periods (2nd, 4th and 6th) of Biological Sciences Course responded to the same question A64, where once again the statistical tests indicate a significant change during the three periods ($p < 0.05$), emphasizing the increased importance given to natural phenomenon as a function of the time enrolled in the course. The students pointed out the "natural phenomenon" and "God" as responsible for the origin of life, suggesting accommodating both possibilities, so that most students opted by the modality linking natural phenomena with God.

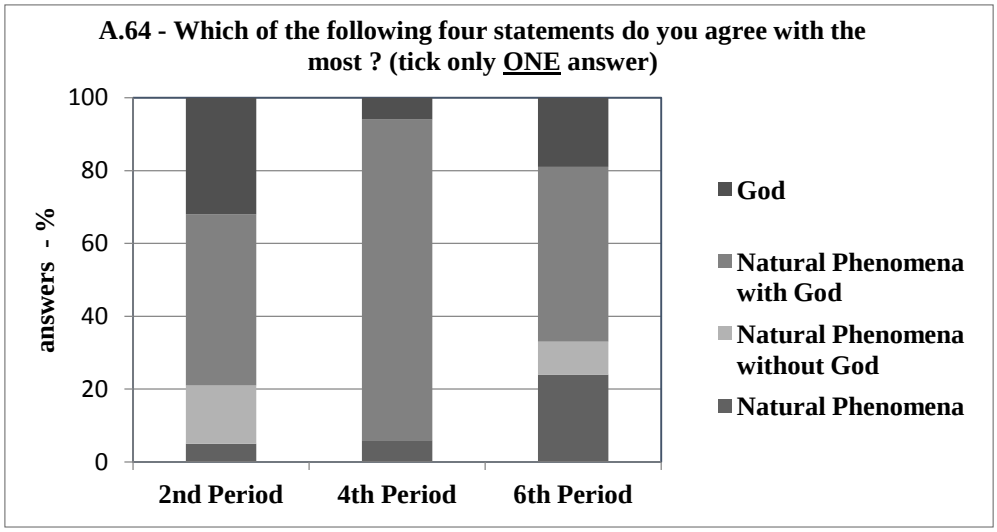

Figure 5: Frequencies of students' answers to Question A.64 in each academic period.

There is the possibility that the processes mediated by the university teachers about the theory of evolution allowed the students to maintain coexistence between previous believes and the acquired Biological Sciences course knowledge [16]. Thus, the goal of the university teachers should not be the extinction of their students' previous knowledge but promote discussion [18]. Another interpretation, anchored by the work of Sepulveda and El-Hani [19], is that this preference of most students for the response on the Natural Phenomenon and God (in question A64) and Evolutionary Processes with God (in question B28) may be because students might be building their vision approaching the hypothesis of the intelligent design model of divine creation coupled with biological evolution, which processes is supposed to be guided by God. This view solves the impasse and tension between religion and science about the human origin. As referred by Coutinho and Silva [14] and Barbour [13] this intermediate position makes a kind of integration, since the idea of God's existence is kept and so the divine participation can coexist with the evolutionary process theory.

Percentages on the question B28 ("With which of the following four statements most agree?") are shown on Table 6:

Table 6: Frequency of students' answers to question B28.

Question		Evolutionary processes	Evolutionary processes without God	Evolutionary processes with God	God
B28.	Which of the following four statements do you agree with most? Select ONLY one sentence:	**21%**	**7%**	**52%**	**20%**

Again these data are in agreement with those obtained by Caldeira et al. [11] with the prevalence of creationist responses as compared to evolutionists. Students seem to have understood the Darwinian evolutionary question, but do not stray from the dogmatic vision and remain believers in the hand of

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a creator, even if participating in biological evolution. Again this response may be pointing to a tendency to accept the hypothesis of Intelligent Design [19] and the integration approach proposed by Barbour [13].

Observing the answers to Question B28 given by the three periods [Figure 6], it appears that the percentage of creationist responses are high in the first periods (2nd and 4th) but low in the last period (6th), with statistically significant differences ($p < 0.05$), indicating the students' conceptual change during the course.

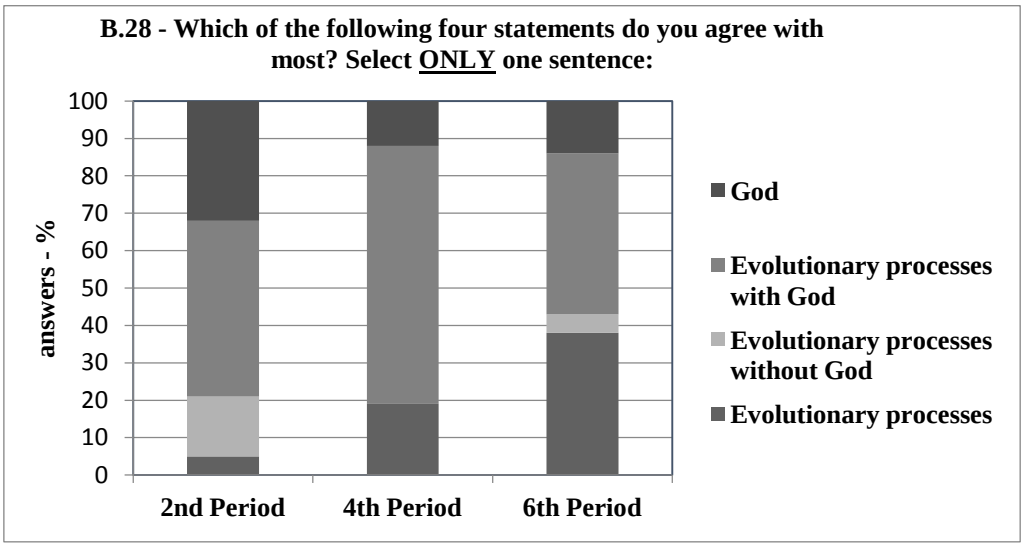

Figure 6: Percentage of students' answers to Question B28 in each academic period.

These data corroborate Oleques et al. [20] as they say that an undergraduate program that aims to train biology teachers should make the students have a greater affinity for the evolutionary theory. There is also the possibility of students being making efforts to manage the coexistence of their religious beliefs and the scientific knowledge acquired throughout the course, and so attempting to merge both conceptions [19]. Moreover, even in the last period (6th) of the Course of Biological Sciences, almost half of the students retained the dogmatic view, possibly because they could not make the reconciliation between the religious beliefs and learnt science, keeping the separation of either field, probably due to methodological, attitudinal and doctrinal differences [10].

4. Final considerations and implications

Results showed that the inquired students learned about evolutionary concepts throughout the course of Biological Sciences, over their initial dogmatic views about the origin of life. The students' answers also suggested distinct forms students cope with the religion and science issues about the origin of life human evolution, leading to accommodation, acceptances or rejections. Contradictions between some responses seem to reveal a lack of definition of students in relation to the scientific perspective and dogmatic views and it seems that students are trying to accommodate both perceptions. Further research is necessary to allow understanding how this process of accommodation is revealed when these students become teachers and are in the classroom working with this dichotomy of religion and science which is of difficult reconciliation in the teaching process.

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