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Research Article

Honors High School Graduates Students' Misconceptions Regarding Evolutionary Theory of Biology

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Abstract: Over the years, there has been a growing emphasis in scientific research on uncovering students' alternative conceptions or interpretations of fundamental concepts and principles within the field of biology. This endeavor has yielded a wealth of valuable international bibliographic data, particularly about the teaching and reception of the theory of evolution among respondents. Specifically, this paper addresses the theory of evolution, investigating alternative perspectives held by honors graduate students from the third Lyceum for Biology, who are enrolled in medical school. Additionally, the study explores how gender influences participants' viewpoints. To achieve these objectives, a comprehensive multiple-choice questionnaire was administered to students, inquiring not only about their background knowledge in biology, including gender, age, and level of interest measured on a Likert scale but also about their understanding of the fundamental tenets of evolutionary theory. A subsequent analysis of the data collected was conducted to determine if there were any correlations between gender and the percentages of correct and incorrect responses, as well as whether these responses were indicative of gender-based patterns or statistical deviations. Ac-cording to the statistical analysis of the collected data, many honors students within our educational framework hold alternative viewpoints about biological concepts. Furthermore, there was no correlation between misconceptions identified in the questionnaire and variables such as grade in the Panhellenic exams, gender, or interest in biology courses. The findings of this study hold implications for the enhancement of science education, curriculum development, and the ongoing professional development of educators in the field.

Keywords: Biology; evolutionary theory; misconceptions; alternative ideas, high school

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1. Introduction

The Natural Sciences, including Physics, Chemistry, Biology, Geology, Astronomy, Meteorology, Seismology, and Environmental Sciences, are dedicated to observing and studying the various phenomena that occur in nature, whether physical or chemical. These sciences aim to determine the underlying principles of these phenomena by conducting experiments and observations (Lederman, 2013). Specifically, physics studies issues of physical phenomena, while chemistry deals with chemical phenomena, and biology considers chemical and biological phenomena that are directly connected to life (Halliday et al., 2013).

As we all know, teaching natural sciences is initiated in primary school as a standalone subject. The primary focus of this education is on developing mental and physical skills and the comprehension of concepts rather than the mere accumulation of dry knowledge (DeBoer, 2019). The current interdisciplinary Unified Curriculum Framework is designed in order to facilitate students' comprehension of the natural world, its governing laws, the physical and chemical phenomena, the organisms, and the processes that cause environmental changes (National Research Council, 2012). Simultaneously, science teaching should

contribute to the following:

- In the development of abilities and cultivation of skills through experimental and laboratory procedures so that the student becomes capable of evaluating scientific applications,
- in the recognition and evaluation of the contribution of the natural sciences towards enhancing the quality of life,
- in the cultivation of teamwork spirit and development of communication, cooperation, and mutual assistance skills,
- in the knowledge of the organization and processes of the environment and acquiring the ability to intervene to solve social problems, making use of the relevant expertise,
- Familiarizing the student with simple scientific terminology can contribute to his general language development.

Therefore, the aim is to encourage curiosity and broaden the spirit of inquiry in students, to help them understand the world around them, to enable them to "learn how to learn," and finally, to understand basic concepts of the natural sciences that will help them build a stepping stone to expand their cognitive horizons later (Noe et al., 2014). However, by the time young students attend primary school, they have already heard from their family and broader social environment several things and possible interpretations about the natural phenomena that occur in their world. Many times, of course, these interpretations need to be corrected, with the result that, as we mentioned above, the students have different perceptions from those that are scientifically acceptable and correct (National Research Council, 2015).

1.2. Literature Review

Exploring Evolutionary Theory: Teaching Approaches in Biology Education

Evolution stands as life's defining feature, serving as the cornerstone for harmonizing biology with an array of scientific disciplines, including medicine, agriculture, and ecology (Laland et al., 2015). Positioned at the heart of biology, the Theory of Evolution emerges as a central and cohesive framework, adept at elucidating both the coherence and divergence within life (Deniz & Borgerding, 2018). In his work titled "Nothing in Biology Makes Sense Except in the Light of Evolution," Dobzhansky eloquently contends, "Biology, when illuminated by the principles of evolution, emerges as among the most awe-inspiring and gratifying of sciences. Absent the illuminating force of evolution, it remains a disjointed compilation of occurrences, some intriguing yet lacking in cohesive narrative" (Dobzhansky, 2013).

The foundations of the Theory of Evolution were laid about 150 years ago by Charles Robert Darwin (1809–1882) with the publication of his book "On the Origin of Species Using Natural Selection, or the Preservation of Favored Races in the Struggle for Life." The Theory of Evolution is one of the fundamental theories that students should be taught, as it is a thorough "explanatory history" of nature and the living world. The National Academy of Sciences (NAS) has described the theory of evolution as "the cornerstone of biology" (Hall, 2012). On June 21, 2006, 67 Academies, including the Academy of Athens and Inter-Academy Panel (IAP) members, signed a joint declaration urging parents and teachers to provide children with the necessary information to develop life on Earth.

However, despite the intervening years and the simultaneous development of evolutionary biology as one of the most dynamic research fields, the general public still needs to understand this theory (Hokayem & Fayad, 2023; Mantelas & Mavrikaki, 2020; Raff, 2012; Wilson, 2019). This is due to theoretical issues, which have to do with the idea itself, and pedagogical ones, which have to do with the teaching approach.

Studies have shown that social (external) and cognitive (internal) factors such as teleology and causality by intention greatly influence the comprehension of the principles encompassed within the Theory of Evolution as well as its acceptance or rejection (Santos & Caballes, 2023; Sober, 2014; Imenda, 2014).

Children and adults tend to believe that natural entities possess an invisible essence, a hidden power that gives them their outward appearance and behavior (Boszormenyi-Nagy, 2013). Teleology is closely related to the reasoning of causality by intention; some intelligent entity with a will can also cause everything that happens for a purpose. A consequence of this was that creationism or intelligent design flourished (Kelemen, 2012). Studies have shown that children believe things in their physical environment exist for a purpose (Berk, 2015; Hart, 2013). For example, they tend to think that "animals have mouths because they need to

eat," "birds have wings to fly," "clouds exist to give rain," and so forth. Also, studies show that children respond that "someone" created the first entity of each class (Kelemen & DiYanni, 2005; Kelemen, 2004).

In addition to cognitive barriers, religious barriers play an essential role in understanding the concepts of the theory of evolution and its acceptance or rejection (Borgerding et al., 2017; Glaze et al., 2015; Hermann, 2011; Winslow et al., 2011) and cultural, ideological views and the alternative ideas that pre-exist (Glaze & Goldston, 2015; Pobiner, 2016). Considerable difficulties in accepting evolutionary theory have been recorded for religious and cultural reasons (Lovejoy, 2017; Mead, 2017).

Several researchers have studied the manner and extent to which religious beliefs influence the Darwin's theory of evolution, accepted or rejected (Schaefer, 2015; Wilson, 2016). Of interest is the 12-year study by Downie & Barron (2000) investigating the perceptions and acceptance or rejection of evolutionary theory among religiously biased Scottish first-year Biology and medicine students. In this study, it was observed that 4-11% and 10% of first-year students of a Biology and Medicine department, respectively, rejected the theory of evolution, and the rejection was linked to their religious positions. The percentage of students who left the approach accepted evolutionary changes in species but did not accept the creation of new species (speciation) (Downie & Barron, 2000).

Dagher and Boujaoude (2005) asked senior college students whether evolutionary theory is scientific. It is worth noting that they needed more training on the structure of scientific theories. Finally, an important role is played by the language used by respondents to interpret evolutionary phenomena and the perceptions created about them (Cotner et al., 2010).

The relationship between understanding and acceptance of evolution is contradictory according to the literature. Some studies suggest that there is a positive correlation between academic performance and acceptance of the theory (Hawley et al., 2011; Scharmann et al., 2005; Shtulman & Calabi, 2012), while others indicate that there is no significant correlation (Ingram & Nelson, 2006; Sinatra et al., 2003). As mentioned above, students derive their knowledge about development from school environments and family, peers, and the media (Bramschreiber, 2013; Moore et al., 2011). Bloom and Weisberg (2007) assert that the fundamental source of student reluctance towards embracing the teaching of evolution stems from their pre-existing knowledge acquired before their introduction to science during elementary school.

2. Materials and Methods

2.1. The Study Population

A total of 316 graduate students from the 3rd Lyceum actively took part in a research study, all of whom were students in their first year of enrollment in the Department of Medicine at the University of Ioannina. Among these participants, 54% identified as male, while 46% identified as female. Greek medical students are renowned for their exceptional academic performance, as admission to medical school is highly competitive, with only a select few students admitted each year. To secure a place, students must demonstrate exceptional performance on university entrance exams, with biology being one of the most crucial subjects requiring meticulous study for academic success.

Furthermore, Greek students must choose between two distinct educational tracks: natural sciences and technology-oriented disciplines, or social sciences and humanities-focused disciplines. Typically, students who opt for the scientific track excel in subjects such as physics, mathematics, biology, and chemistry. Out of the 313 participants in the study, the vast majority pursued a scientific education path at the 3rd Lyceum, while only three opted for a technological orientation. The research was conducted during the initial semester of their academic pursuits.

2.2. Purpose of the Study

The principal aim of this study was to investigate diverse viewpoints regarding the theory of evolution, recognized as a cognitive element within the subject of Biology, among honors students enrolled in the Department of Medicine at the University of Ioannina. Furthermore, the study aimed to investigate any potential correlation between these alternative ideas and the participants' gender.

The study was conducted to examine the following fundamental questions:

1. To what extent do honors students from the 3rd Lyceum maintain consistency between their scientific and alternative understandings of Evolutionary Theory?

2. What level of interest do honors students from the 3rd Lyceum demonstrate towards the Biology course?
3. Does gender have a statistically significant impact on students' performance in their responses?

2.3. Pilot Study

To gather research data, a preliminary pilot study was conducted to assess the effectiveness of questionnaires by implementing trial versions among individuals resembling the eventual sample group. This endeavor yielded several valuable insights: Primarily, it facilitated the identification of words, phrases, or concepts prone to misunderstanding or subject to misinterpretation by the participants. Further, it enabled the evaluation of the perceived level of interest and value attributed to responses to each question. Moreover, it identified questions that posed challenges to subjects or elicited requests for additional information. Additionally, the study assessed the time investment required for participants to complete the questionnaire. Lastly, it involved observing and analyzing subjects' reactions and devising strategies to address and mitigate any challenges or concerns they expressed.

2.4. Instrument

The questionnaire comprises a total of 13 inquiries, with the initial four focusing on demographic information regarding the participants' age and gender. Subsequent questions delve into the participants' background knowledge of the Biology course, encompassing queries about their level of interest in the Biology course on a five-point scale ranging from "1= not at all" to "5= very much," as well as their performance in the Biology course during the Panhellenic entrance exams for Higher Education.

Furthermore, the questionnaire encompasses inquiries regarding the instruction of the theory of evolution and its reception by the participants, alongside an investigation into children's alternative concepts and perspectives concerning evolutionary theory.

It's pertinent to note that, in accordance with the Greek Analytical Program, students in the current study received instruction on the theory of Evolution as part of the General Education Biology 3rd High School course. Notably, this aspect of the curriculum is not evaluated in the Panhellenic Entrance Examinations.

2.5. Main Study

The participating students submitted their responses to the questionnaire items in their respective classrooms, under the direct supervision of the authors, at the beginning of their first lecture at the university. This procedure was meticulously carried out in two consecutive stages. Initially, the study was formally presented to the students, and comprehensive instructions regarding the completion of the questionnaire were provided. Subsequently, following a predefined and standardized protocol for study introduction, trained research assistants facilitated the process. They obtained informed consent from the students, explained the associated assurances, gave detailed instructions for completing the questionnaire, and closely monitored the students throughout the entire process to ensure its smooth and efficient implementation.

2.6. Statistical Analysis of the Data

A comprehensive statistical analysis of the research data was conducted using IBM SPSS Statistics version 29.0 and Microsoft Office Excel spreadsheets. Using Cronbach's alpha coefficient, the second part of the questionnaire was evaluated for internal consistency and reliability, while the third part was assessed using Kuder-Richardson Formula 20 (KR-20). There was binary item coding on the third part of the questionnaire, which distinguished between "incorrect" responses and "correct".

An assessment was conducted to evaluate the overall performance of the "Personal Interest" category in the field of biology. The knowledge section was analyzed in two steps. Firstly, the 12 items were examined to assess their difficulty level, which should be between 0.30 and 0.70. Additionally, the item discrimination index was calculated, and values of 0.20 or higher were expected according to guidelines set by Chu et al. (2012) and Boopathiraj & Chellamani (2013). Secondly, the overall performance across all items was computed.

Specific statistical indicators, including averages, frequencies, and percentages, were computed to analyze the data. These indicators were then visually presented using suitable diagrams and tables. Histograms were employed to evaluate the normality of the data distribution.

Furthermore, the statistical criterion χ^2 test was utilized to assess the relationship

between the two variables under consideration. This test facilitated the determination of whether the observed frequencies significantly differed from the expected frequencies, suggesting a potential relationship between the variables.

3. Results

As mentioned above, the population of the study is 300 excellent students of the 3rd Lyceum, namely 162 boys (percentage 54%) and 138 girls (rate 46%) aged 18-19 years. All participants wrote in the Biology course in the nationwide entrance exams a score ranging from 19.5-20. Interestingly, almost all the participants stated that their interest in the Biology course was "very" great (statement based on a five-point scale of 1=not at all, 2=moderately, 3=enough, 4= much, and 5= very much). Table 1 shows the Biology interest among the participants.

Table 1. Biology interest of the participants

Biology interest	Frequency	Percentage (%)
Not at all	0	0
Moderate	0	0
Enough	0	0
Much	15	5
Very much	285	95
Total	**300**	**100**

Afterward, the participants were asked to answer questions regarding the teaching of the theory of evolution and to what extent they accepted it.

In Question 1: "To what extent do you consider that the deepening of the processes of evolution during the teaching of the course was satisfactory?" 12 % of the respondents answered that they had not been taught this theory "Not at all" well, 57 % "a little," 19% "moderately," 9% "a lot" and 3% "very much" (Figure 1). It is worth noting that a total of 76% of the respondents have been taught a little to moderately the theory of evolution.

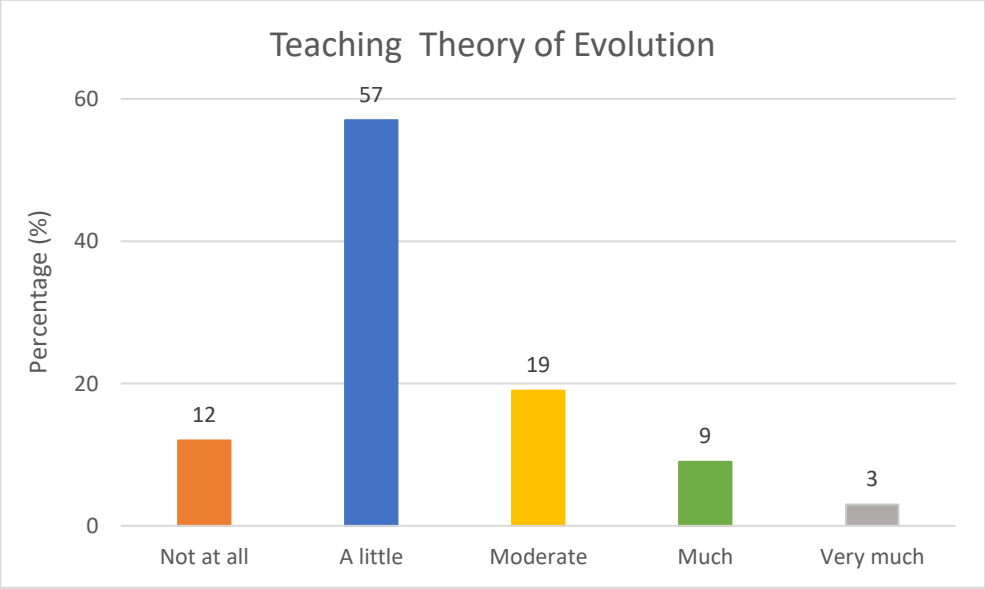

Figure 1. Distribution of participants' responses to the question, "To what extent do you consider that the deepening into the processes of development during the teaching of the course was satisfactory?"

In Question 2: "Based on the following scale, how would you characterize your knowledge of the theory of Evolution?" 6.3% of respondents answered that it is almost non-existent, 50.3% "a little," 38, 3% "moderate," 3.3% "enough" and 1.7% answer that it is very good (Figure 2). It is worth noting that a total of 89 % of the respondents characterize the knowledge of the theory of the evolution of species as little to moderate.

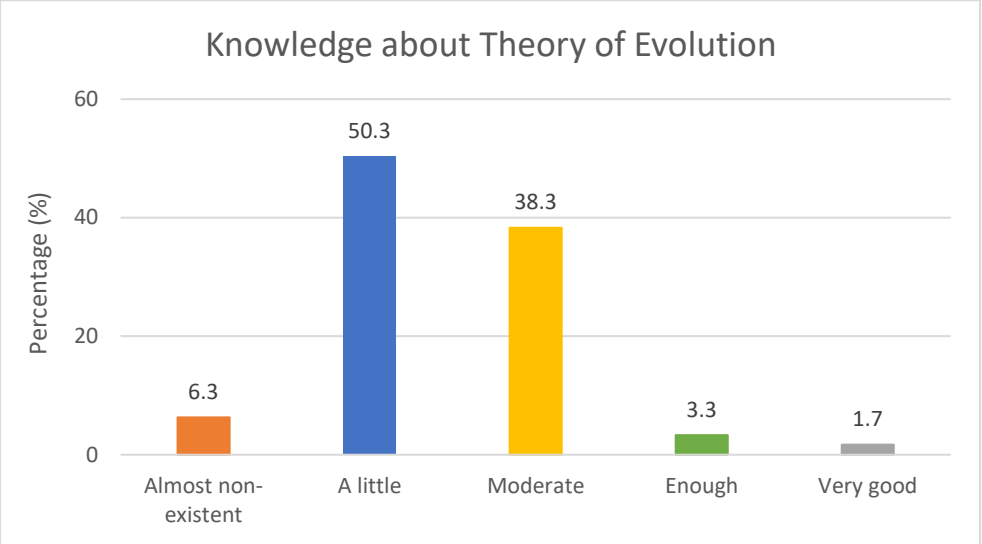

Figure 2. Distribution of participants' responses to the question "Based on the following scale, how you would characterize your knowledge of the theory of Evolution?"

In Question 3: "Would you like to be extensively taught the theory of evolution?" 91.4% of the respondents answered that they would, 3% would not, and 5.6% were not interested in teaching this theory (Figure 3).

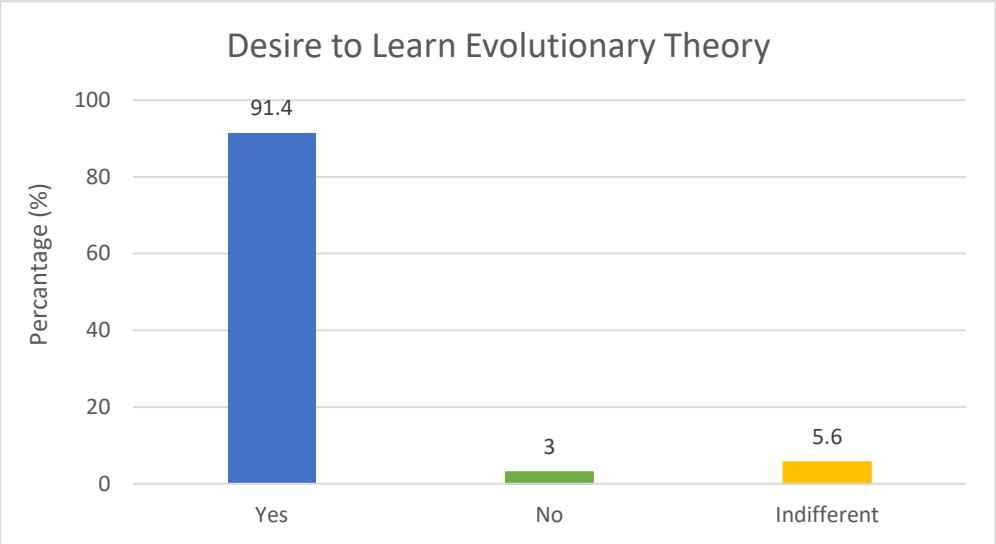

Figure 3. Distribution of participants' responses to the question "Would you like to be taught extensively about the theory of evolution?"

In Question 4: "Which of the following statements most closely approximates your views on evolution..." 68% of respondents answered that evolution is a scientific fact (A). There is evidence to support it; 20% of the scientific community accepts evolution, but I remain "partially convinced," (B) and 12% respond that there is evidence to support evolution (C). However, I believe it "remains only a theory". It is worth noting that none of the respondents answered that the evolutionary theory is untrue (Figure 4).

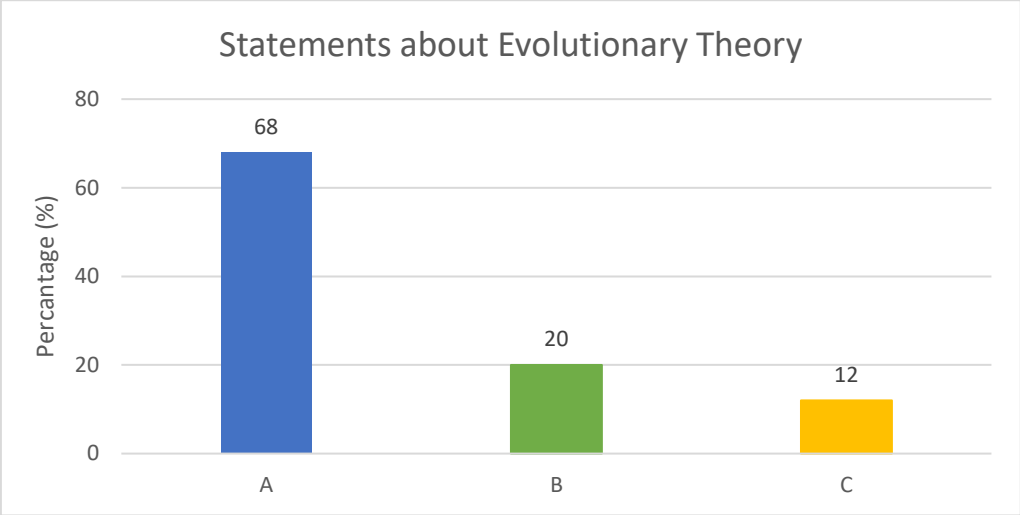

Figure 4. Distribution of participants' responses to the question "Which of the following statements best approximates your views on evolution..."

In Question 5: "Which of the following statements most closely aligns with your views?" 47% of the respondents answered that the creation of a species is the result of random evolutionary processes, implying that evolution takes place through the Mechanism of Natural Selection (A), the creation of species made by God (8%), while 42% answered that there is an organized plan that is controlled by some higher power (Creationist theory, which accepts evolution through natural selection but a higher power controls this process) (C), and last (D) I do not know or do not answer (3%).

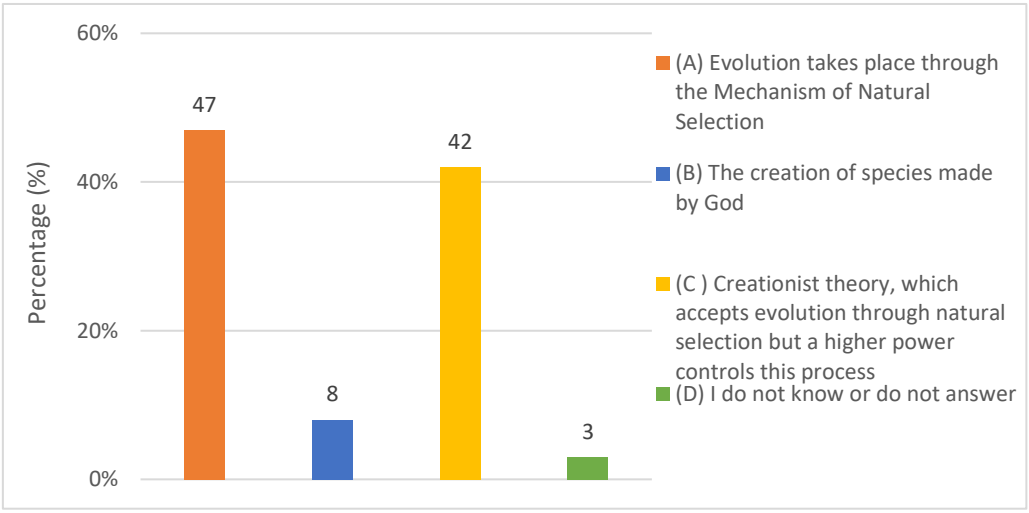

Figure 5. Distribution of participants' responses to the question, "Which of the following statements represents you the most?"

In the last part of the questionnaire, the questions asked of the students were intended to investigate and highlight possible alternative ideas and misconceptions. Despite many students' acceptance of evolutionary theory, the concepts underlying the theory of the evolution of species still need to be fully understood. As described by other research groups, the primary cognitive barriers to teaching development and understanding its concepts are teleology, essentialism, and intentionality.

In Question 6: "Based on the theory of evolution, giraffes are believed to have evolved from an ancestor with a shorter neck. This evolutionary change occurred due to..." as shown in Figure 6: 22% of respondents believe that the animals stretched their necks to reach the highest branches, its length gradually increased, and then this characteristic was inherited by the offspring (Lamarckian perceptions), 63% believe animals with short and long necks are in the giraffe population by chance. Environmental conditions favored animals with long necks, survived and dominated (Darwinian perceptions), 12% believe that giraffes have

always had high necks and, 3% declare that they do not know - do not answer. It is worth noting that this question is an example in the textbook and, therefore, has been taught to students. Nevertheless, only 6 out of 10 respondents gave the correct answer.

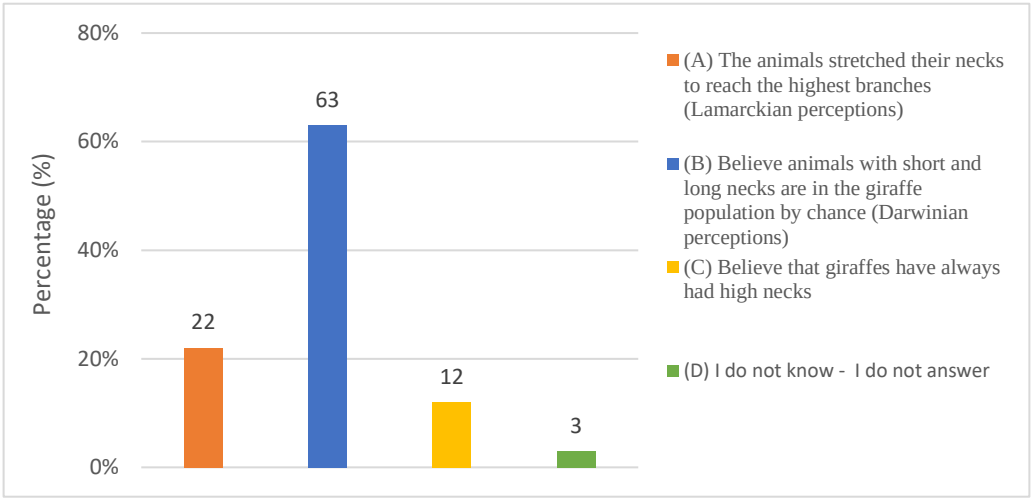

Figure 6. Distribution of participants' responses to the question "According to the theory of evolution, giraffes were descended from an animal with a shorter neck. This happened because..."

In Question 7: "In the newspaper, we read that Scientists have repeatedly warned the medical community about the dangers arising from the increased use of antibiotics, which is often done without reason. Why are scientists worried..." we observe, as shown in Figure 7: 68% of respondents (204/300 respondents) support the Lamarckian view of evolution, which holds that bacteria themselves develop defenses against antibiotics and pass this trait on to their offspring, 26.7% (80/300 respondents) claim that mutations occurred in some bacteria and more resistant strains emerged, which survived, reproduced, and prevailed, 2% (6/300 respondents) answered that some force constantly creates new germs and finally, 3.3% (10/300 respondents) of the respondents do not know - do not answer. It is worth mentioning that the General Education Biology textbook of the 3rd Lyceum they were taught states that "The reckless use of antibiotics results in the creation of strains of bacteria that are resistant to antibiotics."

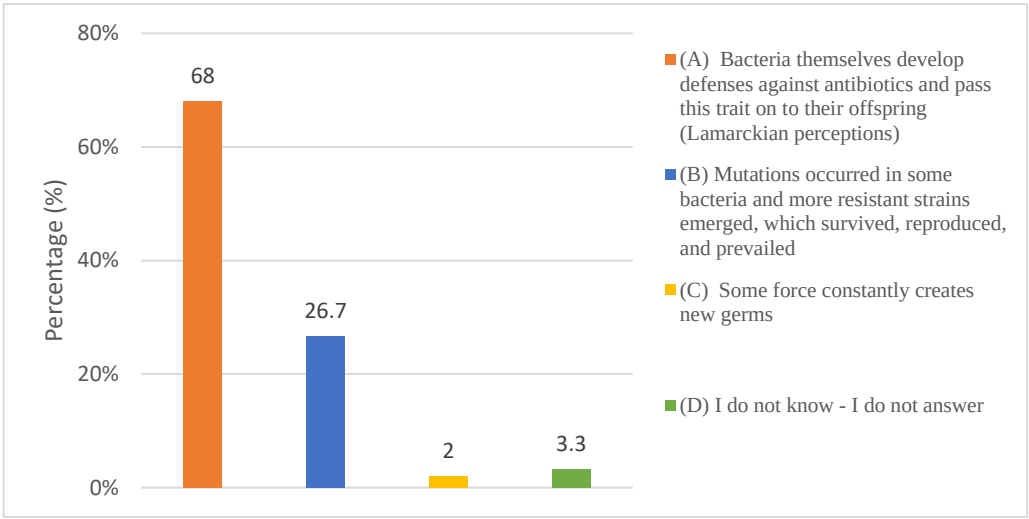

Figure 7. Distribution of participants' responses to the question "In the newspaper, we read that Scientists have repeatedly warned the medical community about the dangers deriving from the increased use of antibiotics, which is often done without reason. Why are scientists worried..."

In Question 8: "In accordance with the theory of evolution, ducks are hypothesized to

have evolved from an ancestor lacking webbing between the toes. This evolutionary transition occurred due to..." we observe, as shown in Figure 8, that: 57% of respondents (171/300 respondents) answered that ancestral animals without membranes gradually developed and increased membranes to swim better (Lamarckian views), 2% of respondents (6/300 respondents) answered that ducks have always had webs between their legs (I am assuming there was no evolution), and 41% of respondents (123/300 respondents) answered that environmental conditions favored animals with webbed feet and gradually evolved into ducks (Darwinian views). There was no "I do not know, I do not answer" option from someone. Only 6 out of 10 respondents gave the correct answer.

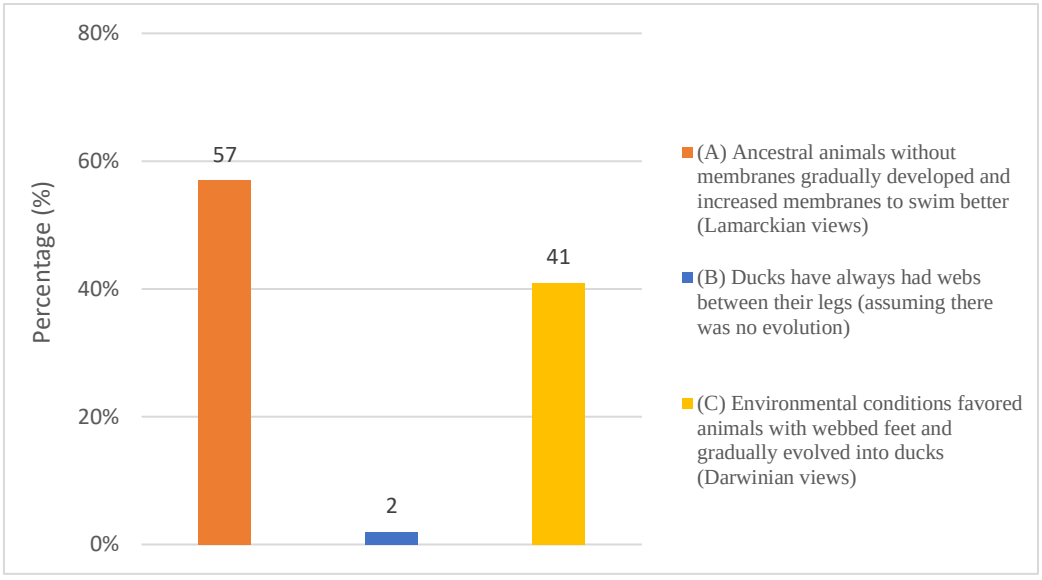

Figure 8. Distribution of participants' responses to the question "According to the theory of evolution, ducks evolved from an animal without webbing between the toes. This happened because..."

Question 9: "Do you think those who exercise on horizontal bar grow taller than the others?" 40% of respondents answered "Yes," (A) an answer indicating Lamarckian perceptions; 30% answered "No," (B) an answer indicating Darwinian perceptions; and finally, 30% chose the answer "I do not know/I do not answer" (C) (Figure 9).

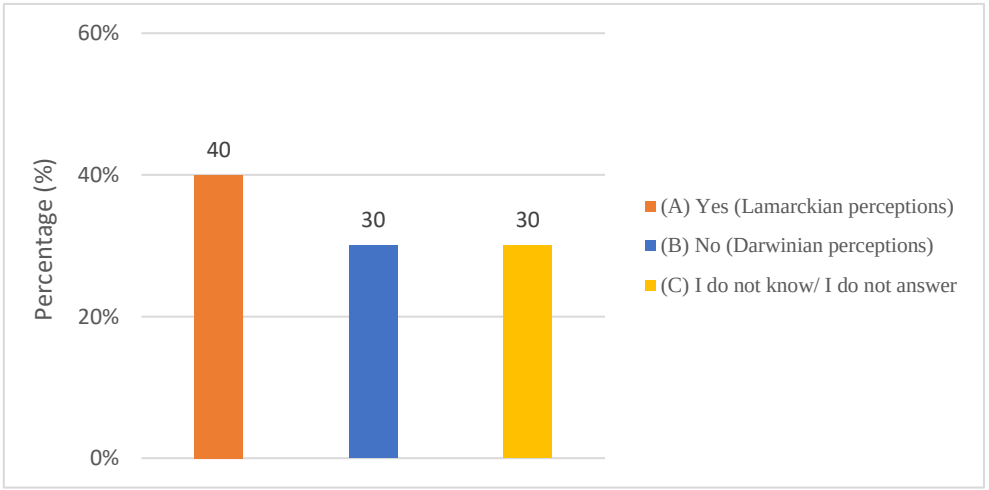

Figure 9. Distribution of participants' responses to the question, "Do you think anyone who does horizontal bar gets taller than the others?

Calculation of the Total Performance (Score)

Based on the data collected, we calculated the percentage of scientifically accurate responses for each question and the overall performance. Table 2 provides a breakdown of these results. According to the table, the overall performance score for the Cognitive Subject

of Biology is 40.17 ± 23.74.

Table 2. Total tally of scientifically correct answers provided by respondents

Biology object	
Questions	**Ratio of scientifically precise responses (%) (Total N = 300)**
Question 1	63.00
Question 2	26.67
Question 3	41.00
Question 4	30.00

Subsequently, an examination was conducted to determine whether the gender of the participants had any impact on the overall performance (Table 3). This difference was statistically significant ($p<0.001$) for the Biology Subject.

Table 3. Total performance of respondents by gender

Score Biology	1.26±0.83	2.01±0.92	**P<0.001**
Score Biology 100 %	31.48±20.77	50.36±23.00	**P<0.001**

4. Discussion

In the present research, the alternative ideas of the honors graduate students of the 3rd Lyceum were investigated in the concepts of natural sciences and, more specifically, in the theory of evolution (the cognitive subject of biology).

Our research population comprised honors students within the educational system, selected due to their distinguished performance in the Panhellenic Entrance Examinations., i.e., excellent responses in advanced subjects of natural sciences and, more specifically, in biology subjects examined in the said research. Hence, it was expected that these students would possess a comprehensive understanding of Biology topics, although to varying degrees.

It is worth noting that when we carried out the present research, the evolutionary theory was taught in the context of the General Education Biology course at the 3rd Lyceum. However, it is not examined in the Panhellenic Examinations. In the first part of the study, students were asked about teaching (extensive teaching, knowledge, and deepening) and acceptance of the theory of evolution. From this research, we found that 76% of the respondents have been taught a little to moderate the theory of evolution, and 89% consider that the knowledge they have acquired in this theory is slight to moderate. Given that the Department of Medicine students participated in the present study, their interest in extensively teaching the theory of evolution would be great. In this specific question, this percentage was found to be 91.4%. A large percentage of students, 68%, accept that the theory of evolution is a scientific fact and that there is evidence to prove it.

All the same, we recorded alternative ideas from many respondents to the theory of evolution. In Question 6, which exists as an example in the General Education C High School Biology textbook, we noticed that only 63% of the respondents interpret the origin of giraffes based on Darwinian concepts. In comparison, 22% of the students interpret it according to Lamarck's views. One in ten students (12%) answered that giraffes have always had high necks; that is, they believe that evolution has not occurred.

Additionally, it is worth commenting that in Questions 7 and 8, most students give interpretations based on Lamarckian concepts (rates of 68 % and 57 %, respectively). The General Education Biology textbook, page 26, states, "Nevertheless, their reckless use results in the creation of strains of bacteria that are resistant to antibiotics". The wording of this sentence in the textbook contributes to the interpretation with the help of Lamarckian concepts. Using the nouns "survival," "predominance," or "selection" instead of "creation" would probably help the student understand more that the reckless use of antibiotics results in the survival of those strains of bacteria that are resistant to them.

5. Conclusions

Evolution is a process in which a causal dependence on specific conditions or events determines the current outcome. To grasp this concept, educators must differentiate between (a) design-based justifications, which pertain to the deliberate intentions of external or internal agents to accomplish a predetermined objective, and (b) non-intentional consequence-based justifications, which are rooted in the Darwinian theory of evolution via natural selection.

Such a distinction requires attention to how evolutionary explanations are described by professors or presented in textbooks (Sober, 2018).

One of the primary conclusions drawn from this study is that strong performance in the Panhellenic exams does not consistently align with a comprehensive grasp of course subjects. The statistical analysis conducted on the collected data indicates that many high-achieving students within our educational system maintain alternative ideas about biology concepts to a considerable extent.

It is also understandable from the results of the present study that several students perceive development as a process with a purpose. It is essential and appropriate to help students move beyond their first intuitive mental representations and support the construction of a new explanatory framework of evolution that will allow them to formulate consistent and stable explanations for evolutionary phenomena (Coley & Tanner, 2012).

They should be led into a situation of cognitive conflict, where the dominant components of their conceptual frameworks will be challenged by themselves and gradually replaced by new ones. In this process, it is necessary to emphasize two concepts wholly opposed to the mental pre-representations of the students that we described earlier: "luck" and "unpredictability." Students must understand that their intuitive teleological explanations contradict the natural course of evolution (Barnes et al., 2017).

To conclude, the answers from high-achieving students within our educational system reflect two discernible characteristics commonly observed in students across all levels of education concerning natural sciences (Kotsis & Panagou, 2022; Panagou et al., 2022; Tsoumanis et al., 2024). Firstly, they lean on intuitive or empirical mental constructs, and secondly, they incorporate scientific knowledge acquired through education, leading to a blend of perplexity regarding these experiences (Kotsis & Panagou, 2022; Kotsis & Panagou, 2023a; 2023b). Nonetheless, as these students have advanced through various educational stages, the predominant characteristic is the latter, suggesting that their perspectives have primarily been influenced by scientific models and knowledge acquired over the course of their schooling (Panagou et al., 2024).

Research Limitations and Further Research

The present study is bounded by certain limitations that warrant consideration and further exploration. Foremost among these constraints is the methodological approach adopted for data collection, which predominantly relies on quantitative measures. While this approach offers valuable insights, it inherently overlooks the nuanced perspectives and subjective interpretations of students regarding the concept of theory of evolution. To enrich our understanding, it is proposed to augment the current methodology with qualitative interviews. This complementary approach promises to yield a more comprehensive and nuanced comprehension of students' perceptions and interpretations.

Moreover, a noteworthy limitation arises from the narrow scope of the sample population, consisting solely of students from a single university in Greece. Consequently, the findings may not be broadly generalizable to encompass the diverse landscape of higher education institutions across the country. To bolster the external validity of future research endeavors, it is advisable to expand the sample criteria to encompass a broader array of institutions, thereby capturing a more representative cross-section of students.

Furthermore, an avenue for potential exploration lies in the implementation of alternative didactic approaches to elucidate any discernible shifts in students' conceptual frameworks regarding density. By introducing varied instructional methods, researchers can ascertain whether divergent pedagogical strategies yield differential outcomes in students' comprehension and interpretation of this fundamental concept. Such explorations hold promise for enriching our understanding of effective instructional practices and enhancing educational outcomes in the domain of science education.

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Data availability: Data generated or analyzed during this study are available from the authors on request.

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