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The Impact of Evolutionary Education on Knowledge and Understanding the Evolution

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Abstract: Evolution is one of the most difficult and controversial topics. Scientific knowledge of evolution should belong to general knowledge of people, it should be the part of their natural science knowledge or biological education because it is the basis for accepting or refusing of other important topics such as genetical modification, global climatic change and others. Our aim was to analyse the inclusion of evolution in the teaching process in Slovakia in the subjects of history and biology and the associated potential threats to the formation of misconceptions. We measured the level of knowledge and understanding of evolution and evolutionary processes among high school graduates (N = 200). In doing so, we hypothesized that graduating high school students who have received evolutionary education achieve higher levels of both knowledge and understanding of evolutionary processes compared to those who have not received such education. We hypothesized that interest in science and acceptance of evolution would also positively influence levels of knowledge about evolutionary phenomena and understanding of evolutionary processes. Having used research, we claimed the impact of interest in natural science. We suggest to include the evolution as a main topic of biology into education through exploration- oriented teaching.

Keywords: *Acceptance evolution, education, knowledge, misconception, understanding.*

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Introduction

Evolution as a concept is one of the most discussed concepts in the history of biology. Each question "why" can be answered in biology from evolutionary point of view (Mayr, 2004). Evolutionary thinking in history was mainly influenced by formulation of theory of evolution conceived independently by Charles Darwin and Alfred Wallace during 1842-1853 (Belejkanič, 2002). Many authors nowadays present different definitions of evolution concept. Nowadays, the definition of the evolutionary synthesis period is accepted: "Evolution is the change of local populations and organisms withing period of time" (Mayr, 2004, p. 33), while the unit of evolution is signed the population for which the changes are typical (Peterková et al., 2006). The differences among individuals in population are caused by mutations on genes that influence particular features and signs. Mutations are thus marked as elementary units of variability or elementary evolutionary material (Jablokov & Jusufov, 1985).

One of the essential mechanisms supplying evolutionary change and development of adaptive functions has been since the period of evolutionary synthesis until present days considered natural selection. Knowledge and understanding of natural selection enable to understand why and what way living organism reached their variety and complexity. Nowadays the studies (Gregory, 2009) show that in general, natural selection is understood incorrectly even among students of post-secondary biological education. Failure to understand fundamental concept leads students to misconceptions.

Education of evolution in Slovakia has been involved into teaching process of several subjects. Innovated state curriculum valid since 1st September 2015 includes evolution into subject biology (in topic *"Man and Nature"*) and topic *"Man and Society"* into subject History. In the content of History in category of primary schools in grades 5.-7. is the problem of evolution included in topics *"Images of ancient world"* for 5th grade, *"Images of ancient and medieval world"* in 6th grade and *"Ancestors of Slovak in Carpathian Valley"* in 7th grade of primary schools. Reality shows that in

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the school books there is only simple scratch of human ancestors whilst the concepts of evolution, adaptation mutation does not occur. In higher educational process of secondary education (ISCED3) the state curriculum programme focuses on political, industrial and social matters of human history. The evolution is not included in the subjects, neither in national standards (National Institute for Education in Slovak Republic, 2014).

Studies of Dvořáková and Absolonová (2016) which compare national standards and school textbooks for particular grades in Czech and Slovak Republic showed that evolution and history are involved in study plans in Czech Republic in the topic *"The beginning of human history"* in 5th and 6th grade of primary school and 1st grade of secondary school while this particular topic precedes teaching of evolution in science subjects. Even Czech textbooks shows possible misconceptions, the problem of evolution in included in History much more than in Slovakia.

In biology studies it is possible to include evolution within lower secondary education (ISCED2) into topic *"Vertebrate Body Structure"* in 7th grade, into topic *"Genetics and Variability of Organisms"* in 8th grade and topic *"History of the Earth"* in 9th grade. According to closer focus on educational standards and textbooks used in primary schools in Slovakia it has been found out that evolution problem is not included in curriculum neither the notion of evolution itself is not explained.

The first time ever, according to curriculum, the notion of evolution is mentioned in the 7th grade. Performance standard of 7th grade focuses on (in relation to evolution) explaining the adjusting of vertebrates' body structure, their respiratory, circulatory and support structure in relation to their living conditions and environment. It focuses also on the impact of heredity on human health.

In 8th grade, students (in relation to evolution) deal with heredity, diversion and variability of organisms while students are supposed to solve particular problems of living organisms variations, adjustment of organisms to environment, to differ between hereditary and non hereditary of variability, comparison of particular organism demands on particular environmental factors and reasoning of biological balance disruption.

Studies in the 9th grade include the overview on nature development, according to performance standards referring to evolution problem, it includes the definition of the notion fossil and its formation, the importance of fossils, the ways of rocks identifying, naming and evaluating the importance of geological processes running in particular Earth development era, naming the examples of leading fossils in primordial mountains, mesozoic, tertiary mountains and quarters, naming the meaning of particular proterozoic ferns and equisetidaes in present days, explaining the influence of geological processes on Earth surface formation and organisms life, naming the proofs of human being ancestors and description of human being evolution in geological eras of tertiary mountains and quarters. In category of higher secondary education (ISCED3) there is a possibility to teach evolution within topic dealing with interactions between organisms and environment in *"Organism and environment"* in 1st grade, or in topic *"World of animals"* which deals with evolutional differences between vertebrates and invertebrates.

In the 2nd grade the evolution is included in an extensive chapter *"Genetics"*. The studies (Dvořáková & Absolonová, 2016; Mokrá, 2016) point out that such a large variety of information is taught that is almost impossible to include the evolution into topic of 1st grade. In the 2nd grade the lessons are used to make students understand and practise of genetic rules. Even the evolution could have been included into previous above mentioned topics, teachers do not use this option to develop the understanding of evolution within students.

Inspite of the importance to explain the notions which characterize evolution processes and enable to understand the evolution (e. g. evolution, natural choice, fitness…) the frequency of their occurrence in biology textbooks is very low. In Slovak textbooks it is only 13% while in Czech textbooks the number is 38%. Besides low frequency of evolution occurence in books, the notion evolution is not properly included, but only mentioned in teaching process (Mokrá, 2016).

Many authors (Catley & Novick, 2008; Dvořáková & Absolonová, 2016; Mokrá, 2016; Müllerová, 2015) researching evolution occurance in textbooks found out that the evolution is not only included a little, but there are many confusing inacuracies which might be misleading in understanding of evolution processes. The example of these inaccuracies is linear development of species or naming human as an evolutionary top of creation, which might signify that evolution is not progressing anymore.

If evolution is explained in textbooks, generally it is by diagrams – tree and ladder cladograms, dendrograms, phylograms, phylogenetic trees, spiral diagrams, time clocks or evolutionary diagrams (Mokrá, 2015). Comparisons of Mokrá (2015) show that textbooks for primary schools include only spiral diagram and Earth time clock, either of them being potential sources of misconceptions. The first organism shown in spiral diagram is a trilobite from cambrium age but it is not mentioned that life on the Earth had existed long time ago in simpler forms.

The organisms hierarchy on spiral has potential for misconception that organisms transform into each other. With time clock the worst negative is unexplained counting geological age into 12 hours - pupils lose time horizon of particular organism evolution and on the basis of time clock they have no chance to find out. Many diagrams explaining evolution might be confusing and lead to misconception (Catley & Novick, 2008). Textbooks for secondary schools usually contain linear diagrams, hominid and taxon evolution diagrams, tree diagrams, spiral diagrams and phylogenetic trees. From formal point of view the diagrams are not potential sources of misconception (like diagrams in primary textbooks) but their inclusion into educational process is very low (Mokrá, 2015). Therefore, our research also focuses on observing the impact of evolutionary learning on the knowledge and understanding of students in secondary schools.

Methodology

Research Design

The study describes quantitative research in which we used a questionnaire to investigate respondents' knowledge and understanding of evolution, evolutionary phenomena and principles, as well as their acceptance of these phenomena. The sample size also allowed us to conduct a qualitative assessment of students' responses. The questionnaire used focused on other variables such as the degree of religious belief in relation to understanding and acceptance of evolution, but these are not part of our study. Respondents (n = 200, 84% women) who participated in our research were pre-service teachers studying in various study branches at the Faculty of Education, Trnava University in Trnava. The sample was chosen on purpose, because these students hadn´t had subject dealing with evolution yet. The average age of respondents was 20. A total of 12% (24) of all students studied biology as their subject at University, 88% (176) studied other subjects, not including biology.

Data Collection & Research Instrument

The questionnaire as a research tool was used, focused on understanding and acceptation of evolution. The questionnaire was taken and translated from German partners, made by Institute for biology didactics in Justus – Liebig Universitat Giessen in Germany, being the part of a larger study entitled European research of understanding and acceptation of evolution. The instrument was based on Beniermann's Evolution Education Questionnaire (EEQ) (Beniermann et al., 2021). Questions in the questionnaire were focused on the knowledge about evolutionary processes but they as well dealt with the students ´attitudes and range of acceptation of evolution.

The questionnaire consists of 41 questions divided into three parts. The first part deals with personal data of respondents being used for statistics purposes (age, sex, field of study, interest in biological science, religion, experience with evolution in previous studies). The second part deals with searching and judging respondents´ knowledge and understanding of process and development of evolutionary processes. This part includes two kinds of questions, first one asks about the facts how described adaptation happened, where students were supposed to choose one statement stated or one of four suggested situations. The statements focus mainly on evolutionary assimilation to various living conditions, the way of life of particular units, or fitness of organism. The second kind of question explore how respondents imagine themselves evolutionary process, some questions include mutations. Respondents were supposed to decide if the statements were the truth. This part of questionnaire was evaluated according to correct answers of the students.

The third part of the questionnaire include questions referring to students' attitudes to evolution as itself as well as the questions focused on religiosity level. In this part of questionnaire students responded by Likert scale from 1 (absolute agreement) to 5 (absolute disagreement). Selected results of knowledge and understanding of evolution was analysed and divided into three various dimensions: first dimension called "Evolution knowledge" deals with knowledge of evolutionary processes learned in previous studies. The second dimension deals with knowledge of mutations, that is why it is called "Mutations". The third dimension called "Situations" refers to situations where students deal with the origin of particular adaptations and express their understanding to evolutionary processes.

Analyzing of Data

We verified the reliability of the research instrument using Cronbach's alpha. We chose this method because the items in the questionnaire were homogeneous. The resulting value of 0.83 demonstrates the high reliability of the research instrument. To analyse data multivariate analysis of covariance (MANCOVA) where researched dimensions (situations, evolution knowledge, mutations) were used as dependent variables, previous studying experience with evolution as categorical variable and religiosity, acceptation of evolution and interest in biological science as continuous variable. We chose this statistical method because the population had a normal distribution, as demonstrated by the Shapiro-Wilks normality test.

Results

We analyzed the results of students' knowledge and understanding of evolution along three different dimensions: dimension "Situations" dealt with situations in which students reflected on the emergence of specific adaptations. It included questions in the questionnaire labelled A1 to A8; students could score 8 points for this dimension. Dimension "Evolution knowledge", dealt with acquired knowledge about evolutionary processes (questions B1 to B7), and dimension, "Mutations" (individual statements for question B8), dealt with knowledge specifically about mutations. In dimension "Evolution knowledge" students could achieve a maximum score of 7 points, while in dimension "Mutations" it was possible to score 11 points. Generally, the summary of students in the questionnaire was low; from maximum 26 points no student reached more than 14 points.

Students who participated in evolutionary education got higher score than students who did not participated in evolutionary education. Positive impact of interest in biological science and acceptation of evolution was approved (Table 1).

Table 1. Results MANCOVA on Dependent Variable Situations, Knowledge and Mutations – Summary.

	Nonbio (N 176)	**Bio (N 24)**				
	Mean score	**Mean score**	**Wilks λ**	**F**	**df**	**p**
Interest in biological science	2,75	3,82	0.95	3.18	3.19	0.025
Religious faith	3,33	4,09	0.98	1.40	3, 19	0.24
Acceptation of evolution	3,34	3,73	0.93	4.62	3, 20	0.003
Evolutionary education	4,12	4,29	0.93	4.80	3, 20	0.003

In dimension „Knowledge of Evolution" statistically important difference between respondents who had taken part in evolutionary education in previous studies and those who had not ($F = 9.41$, $P = 0.002$, figure 1).

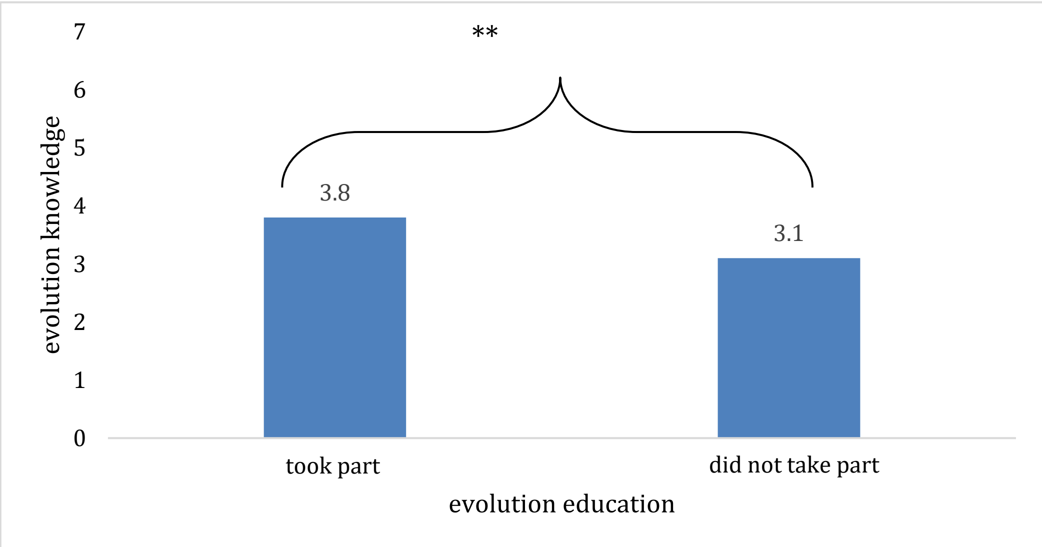

Figure 1. Comparison of Evolutionary Knowledge between Respondents Who had / had not Studied Evolutionary Education in Previous Studies

Using univariate results positive impact of previous evolutionary studies on students' knowledge of mutations was significant ($F = 7.53$, $P = 0.01$, figure 2).

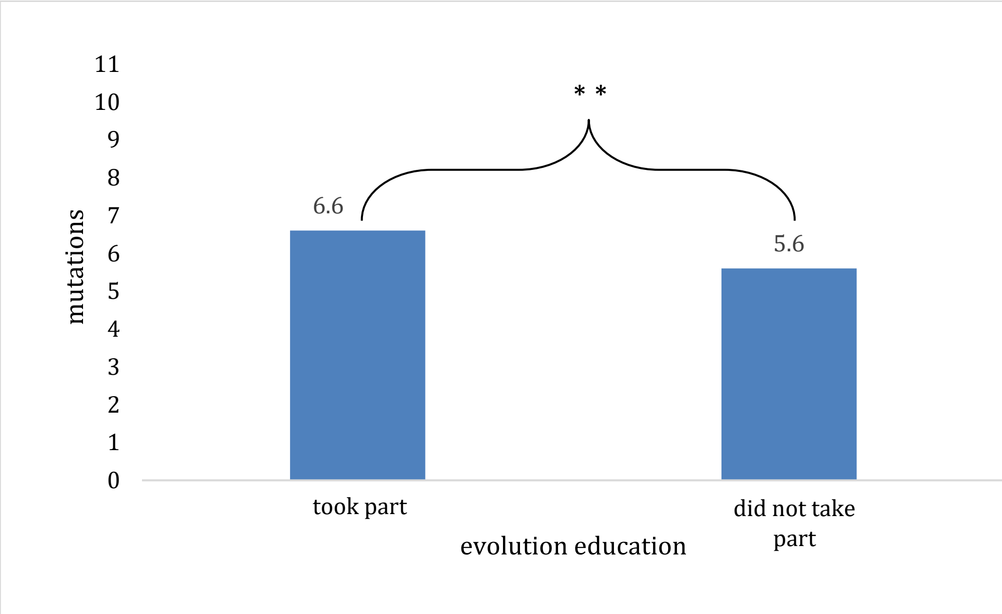

Figure 2. Comparison of Knowledge in Dimension "Mutations" between Respondents who had / had not Studied Evolutionary Education in Previous Studies.

In dimension "Situations" there was no significant difference between students who had evolutionary education and those who had not, where previous evolutionary education did not have an impact on researched dimension. (F = 0.26, P = 0.61). Positive impact on this dimension showed the interest of students in biological science (F = 3.64, P = 0.05, figure 3).

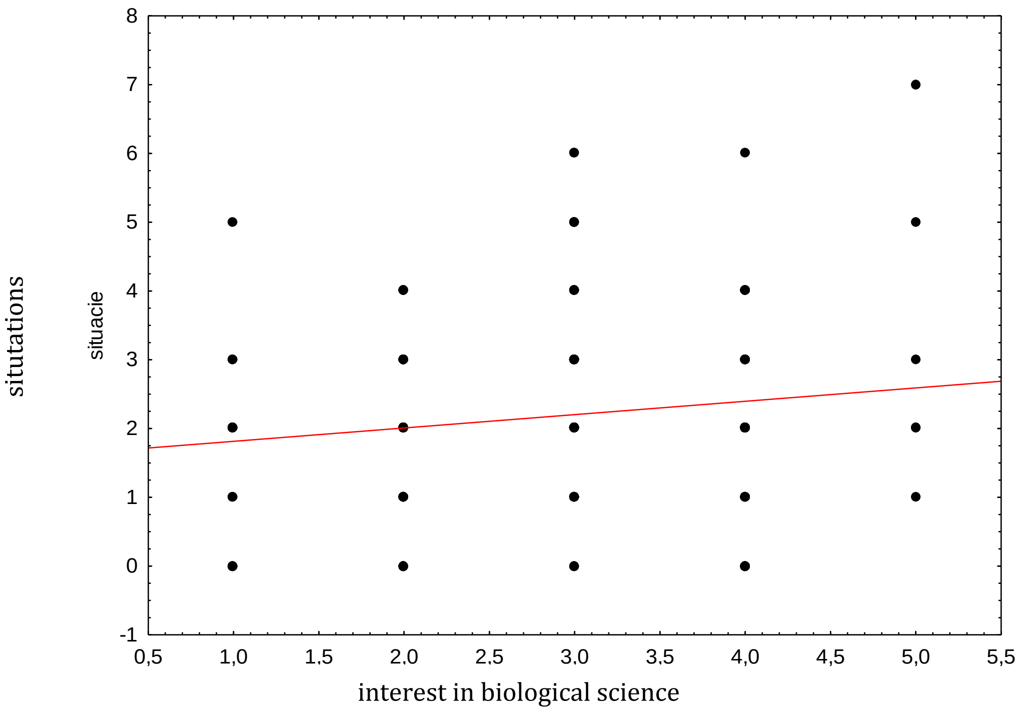

Figure 3. Correlation between Interest in Biological Science and Understanding of Evolutionary Phenomenon in Dimension "Situations".

The lowest mean score was achieved in the "Situations" dimension, so we looked at students' responses in this area. In this domain, they answered questions related to their understanding of evolutionary phenomena, specifically how certain adaptations occurred. Based on the low success rates of students in each response (Figure 4), we decided to qualitatively assess students' responses in this dimension focusing on the most frequently occurring wrong answers.

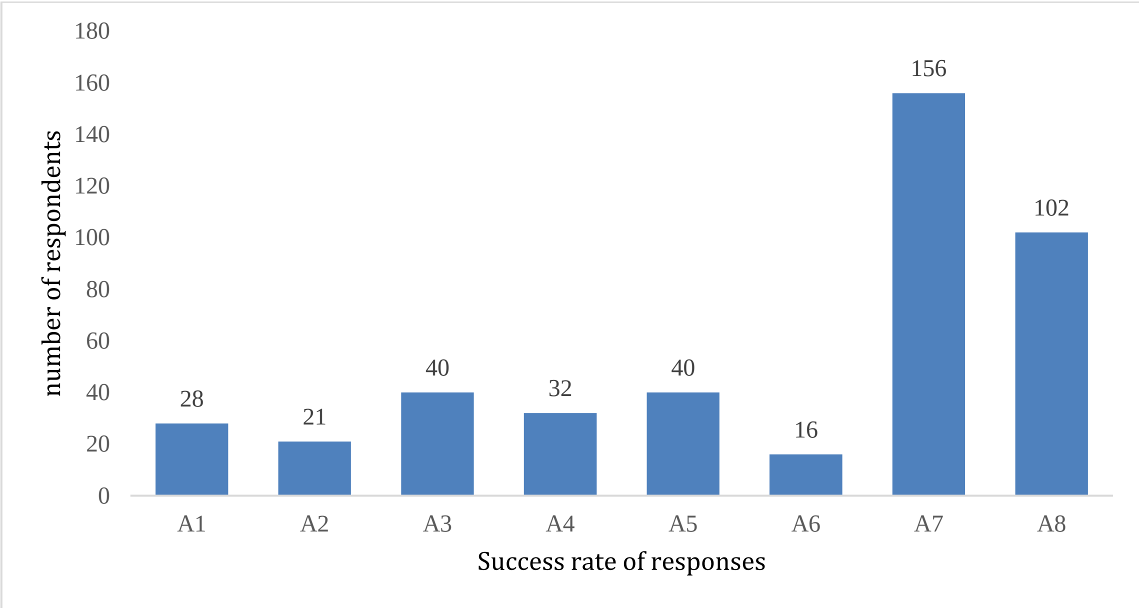

Figure 4. Comparison of the Scores Achieved by Respondents in the "Situation" Dimension.

Question A1 dealt with the adaptation of flycatchers to life on nutrient-deficient soil. The correct answer is that *"Some flycatchers had randomly formed leaves to trap insects and, in addition, were able to consume insects on nutrient-deficient soil. Therefore, flycatchers with this type of leaves were able to grow and reproduce"*. The correct answer was given by 28 respondents (14%). The most common incorrect answer in this case was *"To grow better, flycatchers adapted to nutrient-deficient soil"*.

Question A2 discussed the concept of fitness. Four fictitious characteristics of lions were created in a table that included their size, weight, number of years lived, number of cubs sired, number of cubs that lived to adulthood, and a characteristic comment for each. The students had to determine which of those listed had the highest fitness, fitness. The correct answer included the response that of the 20 cubs sired, 19 lived to adulthood (the most of any of the lions listed), although the lion itself lived to be 9 years old, the fewest compared to the others. Students most often identified the correct answer as the one that was able to move to a new area and change its dietary habits after the devastation of its original territory. There were also responses where they identified the most difficult individual or the individual who lived the most years. The correct answer was marked by 21 respondents (10.5%).

In question A3, the authors focused on speed in cheetahs. The most common incorrect answer given by students was *"Some cheetah ancestors recognized that they could not catch enough prey. Because of this, they increased their speed. As a result of this, they were able to catch more prey and survive more easily"*. Correct answer: *"Some cheetahs were accidentally faster and were able to catch more prey. Therefore, the faster cheetahs were able to survive and reproduce"* was given by exactly 40 respondents (20%).

Situation A4 described two groups of lizards that originally lived in one habitat, but after the earthquake it was split into two separate habitats. The students' task was to indicate the future direction of the groups after a few thousand years. The answer *"The two groups evolved in different directions - it is easy to tell them apart"*, which was also the correct answer, was marked by 32 students (16%). The most common answers were *"It is impossible to predict how the two groups evolved'* and *'The two groups evolved in the same direction - it is impossible to tell them apart"*.

In question A5, we asked respondents about the different colouration (lighter) of the shells of striped snails as protection from predators. 40 respondents (20%) answered that *"Some snails were randomly lighter coloured and were not as easily spotted by thrushes. And so the light coloured snails were able to survive and reproduce"*. However, many times students marked the answer *"Some dark coloured snails recognised that they should change their colouration to be better camouflaged. Therefore, they changed their coloration. As a result they were less consumed and were able to survive more easily"*.

Situation A6 contained a description of the adaptation of cacti to extremely hot conditions with little water. The most frequent misconception of the students was *"Some cacti recognized that they were losing too much water. Therefore, they shortened their leaves. As a result, they lost less water and were able to survive more easily"*, with the correct answer being *"Some cacti happened to have small leaves and lost less water in the desert. As a result, more cacti with smaller leaves were able to survive and reproduce"* was marked by only 16 students (8%).

The last two situations offered built on each other. They dealt with August Wiesmann's experiment in the 19th century, in which he cut off the tails of mice and monitored subsequent generations. For question A7, what the offspring would look like, as many as 156 respondents (78%) answered correctly that *"Cutting off the tails would not affect the tail* *length of the offspring"*. They may have encountered this situation in a genetics class in primary or secondary school, as the success rate for this question was, compared to other situations, exceedingly high. The second part of the question, labeled A8, dealt with what the 21st generation of mice would look like if all previous 20th generations had their tails cut off. This question already required an understanding of the process of evolution. The correct answer*, "Cutting off the tails would have no effect on the tail length of the offspring,"* was given by only 102 respondents (51%). Thus, knowledge gained about a particular evolutionary phenomenon does not imply an understanding of the evolutionary process.

Based on the above analyses of incorrect answers, we found that students consider evolution as a direct response of an organism (e.g., increase in speed, change in color, change in eating habits, etc.) to a specific external change (lack of light, less water, nutrient deficiency...) Thus, we found that many students fail to understand the fact that new traits in a population appear randomly, which we consider as a misunderstanding of the evolutionary process.

Discussion

Our research deals with the impact of previous studies on evolutionary education not only on knowledge but also on understanding of evolutionary processes among students. Students who had dealt with evolution studies in previous education reached higher score in all three dimensions comparing with students who had not studied evolution before. These students also reached higher summary in overall questionnaire. Previous studies (Bishop & Anderson, 1990; Johnson & Peeples, 1987; Nehm & Reilly, 2016) claim that taking part in basic courses of evolutionary processes during university studies lead to statistically important increase in knowledge of evolution even with misconception in evolutionary processes. By analysing the state curriculum, we found that evolution is included in the school system of the Slovak Republic in a marginal way, often not at all, although the potential for inclusion in individual thematic units is considerable. However, even in those cases where it can be found in textbooks, it is often controversial in terms of the formation of misconceptions among pupils. The same findings about the inadequacy of teaching evolution or the existing problems in teaching evolution were reached by Kuschmierz et al. (2021), who call for the naming of problematic or under-represented teaching of evolutionary phenomena in the subject of biology, across 26 European countries. Paradoxically, on a pan-European scale, students in apprenticeship programmes with biology performed better in knowledge about evolution (Kuschmierz et al., 2021), but this was not confirmed in the context of the Slovak Republic - students in combination with biology did not perform better than students in other apprenticeship programmes in terms of knowledge about evolution.

Thus, differences in knowledge between countries do not seem to reflect either the number of textbooks on evolution in the respective school curricula or the number of hours of the proportion of pupils studying biology, at least not for the national samples included in the analysis. However, the study does not mention how evolution is incorporated into the school curriculum, nor does it examine the quality of the content taught. The authors therefore recommend a deeper examination of the content of national curricula and the particular topics in which evolution could be taught in order to strengthen its place in the teaching of science subjects. This could have an impact on students' further knowledge of the subject. Kuschmierz et al. (2021) adds that the sheer number of lessons related to the topic of evolution says nothing about the quality and effectiveness of teaching, and is therefore not a decisive factor for improving students' knowledge of evolution.

Until evolution is not included as a compulsory part of school education or does not personally influence an interest of pupils or student, those are not motivated to search for relevant information about the topic. They do not build up knowledge, adequate in higher grades of education (Fančovičová, 2016). Statistically important difference was submitted only in dimensions referring to knowledge (dimension "Mutations" and "Evolution knowledge") not in dimensions referring to understanding (dimension "Situations"). We conclude that those have not come across with the development of particular evolutionary processes in their previous studies. Understanding itself is on a low level, even after students are no able to applicate it into concrete situations which leads to continuous misconception. Analogical results were reached by authors Nehm and Reilly (2016) who had found out that even students after studying natural selection at university continue to keep misconceptions in conceptual understanding of natural selection and evolutionary processes. However, Kuschmierz et al. (2021, p. 3) does not distinguish these two dimensions ("knowledge" and "understanding") from each other because they "decided to survey content knowledge". They refer to the fact that they worked with a large sample of respondents (students from 26 European countries), whereas our sample consisted of 200 students, and so (given the other parts of the questionnaire) it was also possible to focus on understanding.

Regarding the misconceptions in each dimension, the most frequent was in the "Situations" dimension. Many of the questions from the "Situations" dimension related to the development of adaptations, with students indicated answers such as "the adaptation has evolved because the part was more used/not used". Although this theory has long been outdated in scientific terms, we can see that it is still entrenched in the eyes of the general public and students. This was confirmed by Brumby (1984) and Bishop and Anderson (1990) during a study with students identified as the most successful science students in Australia, many of whom identified the correct answers as being those that were along the lines of Lamarck's theory. The same results were reached in their research by Crawford et al. (2005), in which a sample of prospective biology teachers reported transformationalist responses in explaining the origin of adaptations (eye loss) in salamanders and newts as described by Lamarck many years ago. This has been confirmed by Mayr (1982), who argues that the theory of use, disuse, or acclimatization in the environment is more comprehensible, conceptually convincing, and applicable to students than natural selection as described by Darwin. This type of naive or alternative conceptions is held not only by undergraduate students in biology, but also in other related fields (Ferrari & Chi, 1998).

According to Cunningham and Wescott (2009), the first step towards conceptual change in the meaning structures of not only university students but also students at other grade levels is to understand the nature of misconceptions. The results of their study show that students have general misconceptions about the importance of population size or in changes in the evolution of species, Lamarckian explanations, and also ideas that animals want to evolve towards perfection, adaptability. The vast majority of students in this study indicated that they recognize that survival and reproduction are critical in evolution. However, many of them fail to grasp the fact that new traits in a population appear randomly. Moreover, many of them identified as correct the statement that acquired traits are passed from parents to offspring. Many respondents also indicated answers phrased in terms of 'nature has refined a given adaptation to make the individual capable of survival'.

The teacher's relationship to evolution also contributes to conceptual change in this topic. Around the world of the world, teachers do not feel confident to teach such a controversial topic as evolution. Emotional support from society, as well as appropriate coursework and professional development, could influence teachers' positive attitudes towards evolution, their acceptance of evolution and therefore the knowledge and understanding they give to pupils. Low acceptance of evolution remains an obstacle to quality biology instruction. Acceptance of evolution is not only a factor on the part of the students, but also on the part of the teachers who teach evolution (Romine et al., 2021).

The highest summative scores were achieved by students in the “Mutations” dimension. We conclude that this is also the most frequently discussed topic of evolution in genetics education. Relatively high scores were also achieved in the dimension statements about evolution (which was part of “Evolution Knowledge”), which presented knowledge about evolutionary phenomena that are part of the teaching process or common evolutionary knowledge. The lowest summary scores were shown in the dimension "Situations", in which we were particularly interested in the students' answers. In this domain, they answered questions related to understanding of adaptations, specifically how certain adaptations occurred. The issue is not addressed by bringing up specific situations and students are not encouraged to think critically and reflect and specific adaptations. As a result of this absence, misconceptions persist. Such strong persistence of misconceptions about natural selection in students despite taking evolution classes has also been confirmed by Brumby (1984) in medical biology students, Kim et al. (2009) in biology teachers, and Nehm and Reilly (2016) in biology students, suggesting a lack of understanding of the knowledge learned.

However, there is an interesting thing in interest in biological science: students who are more interested in biological science reached higher score in only of researched dimension – in “Situations” that deals with understanding of evolutionary phenomenon. This means that students with higher interest in biological science showed stronger interest in process of origin and development of particular adaption and reached higher scores in questions that are not common in studying process.

Conclusion

By analysing the state curriculum, we found that evolution is included in the school system of the Slovak Republic in a marginal way, often not at all, although the potential for inclusion in individual thematic units is considerable. However, even in those cases where it can be found in textbooks, it is often controversial in terms of the formation of misconceptions among pupils.

According to understanding of content, evolution belongs to the most difficult field of biological science. It is a process which takes within million years and it is not possible to understand it using simple observation process as it is for instance observing the process of sprouting years. The problem should be the part of educational process so students would be able to identify their pre-concepts, and thus understand principles in process of evolution using constructivist methods that enable students to get into contradiction with already existing images and conceptions. Thanks to this, they can reach scientific conceptions and apply them into explanations of various situations which leads to better understanding of processes. (Jensen & Finley, 1996; Palmer, 2003). Understanding evolution enable them to learn many scientific concepts, to understand the work of scientists, to reach abilities of scientific work and introduce scientific attitude. Fančovičová (2016) adds that the most important thing is to include evolution into curriculum as the key point of biological education.

Recommendations

This research could be conducted again as a post-test with graduating university students in education programs, and we could observe the specific differences of different fields of study, as some (especially in combinations with science subjects) will encounter evolution during their studies. In this way, we would be able to analyse differences in knowledge and understanding of evolutionary processes across studies, while comparing students who have undergone such education with those who have arrived at this understanding through logical reasoning coupled with their cognitive development during their studies.

There are a number of specific fields of education that were not included in this study, such as the fields of genetics, medicine, theology, and others, where novice students' knowledge, understanding, and acceptance of evolution could be explored. Therefore, future research can take into consideration the results and research instrument of this study.

Strengthening interest in science education in the earlier years of education also appears to be a recommendation for educational practice, as these appear to be essential to ensure that students do not lose interest in science later on. Both acceptance of evolution and knowledge in this area are directly correlated with interest in science. It is therefore necessary to provide pupils and students with as many opportunities as possible to encounter evolution and natural science. For a better understanding of evolutionary processes, classroom activities (as described by Sá-Pinto et al., 2021) or an active pedagogical approach to teaching evolution (as described by Buckberry & Burke de Silva, 2012) could be helpful.

Limitations

Our research focused on linking the level of knowledge and understanding of evolution and evolutionary processes and principles among high school graduates with positive effects on evolution knowledge and acceptance. Due to the deliberate choice of the research sample, it is not possible to generalize this research to the whole group of prospective teachers or high school graduates; however, our research highlights a small sample of student prospective teachers across Slovakia. Our sample, may indicate differences in knowledge and understandings of evolution among students in different fields of study.

The biggest limit in the development of evolutionary education in Slovak schools is the fact that since 2008 (when the Education Act no. 245/2008, also called the "School Act" came into force) there has not been such a change in the content standard of the state curricula that would significantly affect education in this area, but also the fact that the teaching materials used in schools contain examples that have the potential for distorting the understanding of concepts and phenomena or directly for the emergence of misconceptions. It is surprising that evolution and evolution education in the context of Slovak education covers only a tiny part (in the subjects of Biology and History).

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Authorship Contribution Statement

Martincová: Conceptualization, design, data acquisition, data analysis, interpretation, drafting manuscript, writing. Fančovičová: Editing/reviewing, supervision, critical revision of manuscript, statistical analysis. Iľko: Securing funding, admin, technical support, critical revision of manuscript. Peterková: Editing/reviewing, supervision, critical revision of manuscript, final approval.

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