ABS

Original Research

The effectiveness of teaching human evolution to 14- to 15-year-olds in Slovenia

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Abstract

In Slovenia, human evolution is first taught in biology classes to 14–15-year-old students. For many, this will be the only contact with this topic at school. The objective was to determine how much knowledge students acquired about human evolution. Data were collected with a questionnaire using a 5-point Likert scale. The participants were 13–14-year-olds who had not yet learned about human evolution (the control group) and 15–16-year-olds who had learned about human evolution one year earlier in biology classes (the experimental group). The results show that students significantly improved their knowledge of human evolution with small to medium effect sizes. Students knew very well that modern humans are the only species of humans today and that they did not live at the same time as dinosaurs. The achievements were low on the following topics: modern humans lived at the same time as Neanderthals and mammoths, and modern humans did not evolve from Neanderthals. To the problematic topics, attention should be paid to teacher education and the biology curriculum. Few correlations were found between the knowledge of human evolution, acceptance of evolution, religiosity, and attitudes toward biology.

Keywords

knowledge of human evolution; acceptance of evolution; religiosity; attitudes toward biology; primary school

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Učinkovitost poučevanja evolucije človeka pri 14-do 15-letnikih v Sloveniji

Izvleček

V Sloveniji se pri biologiji evolucijo človeka prvič učijo 14- do 15-letniki. Za mnoge od njih bo to v šoli edini stik s to temo. Cilj raziskave je bil ugotoviti, koliko znanja evolucije človeka so učenci usvojili. Podatke smo zbrali z vprašalnikom s petstopenjsko Likertovo lestvico. Udeleženci so bili 13- do 14-letniki, ki se še niso učili evolucije človeka (kontrolna skupina) in 15- do 16-letniki, ki so se evolucijo človeka učili pri biologiji eno leto pred tem (poskusna skupina). Resultati kažejo, da so učenci signifikantno izboljšali svoje znanje evolucije človeka, in sicer z majhno do srednjo velikostjo učinka. Učenci so dobro vedeli, da je moderni človek danes edina vrsta človeka in da ni živel sočasno z dinozavri. Dosežki pa so bili nizki pri naslednjih temah: moderni človek je živel sočasno z neandertalcem in mamutom, moderni človek se ni razvil iz neandertalca. Problematičnim temam je treba posvetiti pozornost v izobraževanju učiteljev in osnovnošolskem učnem načrtu. Med znanjem evolucije človeka, sprejemanjem evolucije, vernostjo in odnosom do biologije je bilo malo korelacij.

Ključne besede

znanje evolucije človeka; sprejemanje evolucije; vernost; odnos do biologije; osnovna šola

Introduction

Human evolution is a topic that students can quickly lose interest in, especially if the teacher distracts them with too much theory and data that make no sense to them (Flammer, 2006). Motivation to learn about evolution is influenced by many factors, one of which is prior knowledge. Bloom and Weisberg (2007) claim that students' prior knowledge is the main reason for not accepting evolution, as misconceptions and beliefs can hinder the process of accepting new knowledge (Wescott & Cunningham, 2005; Smith, 2010; Yates & Marek, 2014). If the prior knowledge is good, the student can add new knowledge to the already existing one. However, if the student has misconceptions, motivation decreases, as it is extremely difficult to change entrenched misconceptions with classical teaching methods.

Slovenia ranks above average in the PISA survey. In the latest survey, which was conducted in 2022, Slovenian 15-year-olds ranked above average in scientific literacy. From these results, we can conclude that science literacy among primary and secondary school students in Slovenia is good, and it is also stable according to prior PISA surveys (Strgar, 2010; Štraus et al., 2016).

In a survey about the acceptance of the theory of evolution (Miller et al., 2006), Slovenia ranked in 16th place among 34 countries. University students in Slovenia think that understanding evolutionary concepts is a necessary part of solid general education, but there is also evidence that their actual understanding of evolution is not satisfactory. Surprisingly, they also think that alternative nonscientific theories of evolution should be presented in schools (Šorgo et al., 2014).

According to Pinxten et al. (2020), most of the population in many countries has a very limited formal introduction to the understanding of evolutionary theory. However, in most countries, there are national regulations that demand scientific teaching of evolutionary theory (Borgerding et al., 2016; Tavares & Bobrowski, 2018). In Slovenia, the theory of evolution was first introduced in school in 1945 (Vesel, 1977). According to the current national curriculum (Učni načrt. Program osnovna šola. Biologija, 2011), 14- to 15-year-old students learn about biological evolution in biology classes for the first time. However, some evolutionary concepts are already included in the curriculum for history that is taught to younger students (Učni načrt. Program osnovna šola. Zgodovina, 2011).

At the age of 14 to 15, students in Slovenia finish their compulsory primary education. Biological evolution is introduced to them in the final year (Učni načrt. Program osnovna šola. Biologija, 2011). There is one single national curriculum for all students up to this age. Afterwards, the students attend different secondary schools according to their career choices. These schools vary in the amount of biology courses that they offer. This means that some

of the students continue their education at secondary schools, which have no evolution as part of their curriculum. Into their adult life, these students take with them only the knowledge of evolution they had learned in primary school. Therefore, it is important to know what level of understanding of evolution the Slovenian school system provides during obligatory primary education.

In the Slovenian national curriculum for 14 to 15-year-olds, there are 18 objectives concerning evolution and only one objective regarding human evolution, namely, "Students can explain the origin of humans and primates and the kinship of humans with other primates" (Učni načrt. Program osnovna šola. Biologija, 2011, p. 17).

Published research shows that understanding evolution is challenging for students at all levels of education for a variety of reasons. Surroundings and socio-economic factors also influence students and take part in structuring students' preconceptions about evolution and their attitudes toward evolution (da Silva Oliveira et al., 2022). The problem, therefore, is how much students can learn at that age, specifically, how well they can understand evolutionary concepts and what contextual factors shape students' knowledge. Many studies (Miller et al., 2006; Hermann, 2013; Mantelas & Mavrikaki, 2020; da Silva et al., 2022; Salazar-Enriquez et al., 2023) confirmed a negative correlation between acceptance of evolution and religiosity. It differed depending on the country and cultural background of the people tested. For Slovenia, this problem was addressed in studies by Šorgo et al. (2014), Kralj et al. (2018), and Torkar and Šorgo (2020).

This research aimed to establish how much knowledge about human evolution students had before they learned about this topic in formal education and how much new knowledge about human evolution they acquired during formal education. Therefore, the aim was to determine how effective were the lessons on human evolution, which, according to the national curriculum for biology (Učni načrt. Program osnovna šola. Biologija, 2011), were attended by students aged 14 to 15 years. The point of interest was also whether contextual factors, such as attitudes toward biology, acceptance of evolution, and religiosity, were connected with students' knowledge of human evolution. The outcome could help make changes in the current national curriculum as well as be guidance for teacher educators and teachers themselves (Salazar-Enriquez et al., 2023). The following research questions were formulated:

RQ1: How effective are lessons about human evolution in Slovenia taught to 14–15-year-old students?

RQ2: Are the chosen contextual factors (students' acceptance of evolution, attitudes toward biology, and religiosity) connected with students' achievements on the knowledge test about human evolution?

Materials and Methods

General Background

The data were gathered in the 2021/22 and 2022/23 school years. The survey was anonymous; all the parents of the students signed an agreement to allow their children to participate. No benefits were offered to the participants. According to Slovenian legislation, such a survey does not need the approval of an ethics committee or similar body.

Sample

Our sample consisted of 593 students. The national curriculum for biology in Slovenia (Učni načrt. Program osnovna šola. Biologija, 2011) mandates for evolution to be taught to 14- to 15-year-olds. Students of this age were not part of the sample. In the survey, there were one year younger students (13- to 14-year-olds; a control group; n = 364).) who had not yet learned about human evolution. The experimental group (15- to 16-year-olds; n = 229) was represented by the students who had learned about human evolution in biology classes in the previous school year. In the sample, there was a slightly higher percentage (53.5%) of females compared to males.

Instrument and Procedures

Data were collected using a questionnaire. In the beginning, there were two demographic questions (gender and grade). These were followed by 59 statements that assessed students' knowledge of human evolution, their acceptance of evolution, attitudes toward biology, and religiosity. This part of the questionnaire used a 5-point Likert scale, ranging from strongly disagree (1) to strongly agree (5). Eleven items were originally worded in such a way that disagreement was required as a correct answer; these items were re-coded for statistical analysis. The questionnaire was compiled from statements used in several prior studies. The religiosity of participants was tested

with ten statements using the PERF scale, which was created by Beniermann (2019) and translated into the Slovenian language and used by Torkar and Šorgo (2020) on the Slovenian population. Eight statements that explored students' attitudes toward biology were adapted from The Relevance of Science Education study (Sjøberg & Schreiner, 2019). Seventeen statements that tested students' acceptance of evolution were taken from the MATE questionnaire (Rutledge & Sadler, 2007), and ten were adapted from the questionnaire used by Miller et al. (2006). The remaining 14 statements that tested students' knowledge about human evolution were partly adapted from the study by Miller et al. (2006) and partly designed in line with the curriculum and the textbooks that the participants of this study used when learning about evolution. Face validity of these 14 statements was ensured by the author and the three biology teachers who judged and revised them.

The questionnaire was administered during students' regular biology classes. Students completed it in approximately 15 minutes.

Data analysis

Data were tested for normal distribution with the Kolmogorov-Smirnov test; because the distribution of data was not normal ($ps < 0.001$), non-parametric testing was used. The statistical significance of differences in knowledge about human evolution between the control and the experimental groups was established by a Mann-Whitney U test. Effect size r was calculated using the equation $r = Z/\sqrt{N}$.

On 14 statements of the knowledge test about human evolution, descriptive statistics (mean, standard deviation) were used. On 45 statements assessing acceptance of evolution, attitudes toward biology, and religiosity, principal component analysis (PCA) was conducted using the orthogonal rotation (varimax) method with Kaiser normalization (Table S1). The value of the Kaiser-Meyer-Olkin measure of sampling adequacy was .925, which means that the sample size was adequate for PCA. Bartlett's test of sphericity was highly significant ($\chi2 = 11253.468$, $df = 990$, $p < .001$), indicating that correlations between statements were sufficiently large for PCA. According to the scree plot, retaining five components was justified. Following this, three statements were removed from the analysis. Thirteen statements loaded onto component 1 (religiosity); 14 statements loaded onto component 2 (acceptance of evolution – the theory); eight statements loaded onto component 3 (attitudes toward biology); four statements loaded onto component 4 (acceptance of evolution – the theory is (not) scientific), and three statements loaded onto component 5 (acceptance of evolution – organisms do (not) evolve). Cronbach's alphas for three components were highly reliable (from .85 to .91), while for two components, they were relatively less reliable (.53 and .68). These five components explained 55.926% of the variance. Cronbach's alpha for all 42 statements was .83. Additional results are available as supplementary material accompanying the online article.

Correlations between the knowledge of human evolution, acceptance of evolution, religiosity, and attitudes toward biology were analyzed using Spearman's correlation coefficient (rs). Comparisons of these correlations were then calculated to establish if the differences between correlations of the two students' age groups were statistically significant. For this, the following equation was used: $Zdifference = (zr1-zr2)/\sqrt{[1/(N1-3)]+[1/(N2+3)]}$ (Field, 2009, p. 191).

Results

Students' Achievements on the Knowledge Test about Human Evolution

Students' knowledge of human evolution was tested with 14 statements. Results show that all students showed the least knowledge ($M = 2.41$-2.57) in statements rE1 (Modern humans did not evolve from Neanderthals.), E2 (Modern humans lived in today's Slovenia at the same time as mammoths), and E36 (Modern humans and Neanderthals lived on Earth at the same time) (Tab. 1). In nine statements, they showed an average knowledge ($M = 3.03$-3.43). The highest knowledge ($M = 3.63$-4.13) was achieved on the following two statements: E3 (Today, all human species are extinct, except for our species, modern humans), rE38 (Modern humans did not live in today's Slovenia at the same time as dinosaurs.).

Differences among Students' Achievements on the Knowledge Test about Human Evolution by Age

On 12 out of 14 statements about the knowledge of human evolution, 13-14-year-olds answered significantly differently than 15-16-year-olds (Tab. 1). On one of those 12

statements (rE33 Modern humans did not evolve less than 15,000 years ago.), 13–14-year-olds showed more knowledge. On the remaining 11 statements, 15–16-year-olds had more knowledge. The effect sizes of differences in knowledge between 13–14-year-olds and 15–16-year-olds were mostly small (on 8 out of 14 statements) to medium (6 statements).

Correlations between Students' Achievements on the Knowledge Test about Human Evolution and Contextual Factors

Correlations for the subsample of 13–14-year-olds and the subsample of 15–16-year-olds were established, respectively. The variables were the average achievement on

Table 1. Differences in the students' knowledge of human evolution and effect sizes of differences.

Tabela 1. Razlike v znanju učencev o evoluciji človeka in velikost učinka razlik.

	Age (years)									
	All students (*N* = 589)		13-14 (*n* = 360)		15-16 (*n* = 229)		Mann-Whitney U test			Effect Size
Statement	**M**	**SD**	**M**	**SD**	**M**	**SD**	**U**	**Z**	***p***	**r**
rE1 Modern humans did not evolve from Neanderthals.*	2.41	1.229	2.29	1.183	2.60	1.276	35473.500	-2.742	.006	-.11
E2 Modern humans lived in today's Slovenia at the same time as mammoths.	2.51	1.237	2.44	1.248	2.62	1.215	36871.000	1.780	.075	.07
E36 Modern humans and Neanderthals lived on Earth at the same time.	2.57	1.348	2.43	1.267	2.79	1.441	33830.000	-2.933	.003	-.12
rE33 Modern humans did not evolve less than 15,000 years ago.*	2.99	1.045	3.06	1.060	2.89	1.015	36477.000	-2.108	.035	-.09
E34 Modern humans evolved in Africa.	3.03	1.086	2.78	1.084	3.43	.964	27174.500	-7.220	<.001	-.30
rE35 Humans did not evolve from chimpanzees.	3.08	1.183	2.81	1.102	3.49	1.185	28028.000	-6.466	<.001	-.27
E4 Neanderthals and modern humans share 99.7% of their genes.	3.14	.967	3.03	.924	3.32	1.008	33892.500	-3.532	<.001	-.15
E19 Neanderthals lived in Europe, Asia, and the Middle East.	3.30	.921	3.22	.962	3.41	.843	35868.500	-2.478	.013	-.10
E37 Humans's three closest relatives in terms of evolutionary development are gorillas, orangutans, and chimpanzees.	3.38	1.073	3.36	1.092	3.42	1.043	38414.500	-.774	.439	-.03
rE26 Humans today do not have more or less the same shape as we have always had.*	3.40	1.052	3.21	1.016	3.70	1.040	30096.500	-5.518	<.001	-.23
E41 Humans and chimpanzees evolved from a common ancestor.	3.42	1.089	3.22	1.060	3.74	1.062	29122.000	-6.138	<.001	-.25
rE5 The common ancestor of humans and chimpanzees does not live in Africa anymore.*	3.43	1.107	3.34	1.093	3.57	1.116	35846.000	-2.333	.020	-.10
E3 Today, all human species are extinct, except for our species, modern humans.	3.63	1.198	3.41	1.179	3.99	1.141	28594.500	-6.177	<.001	-.26
rE38 Modern humans did not live in today's Slovenia at the same time as dinosaurs.*	4.13	1.174	3.86	1.282	4.54	.823	28347.500	-6.678	<.001	-.28

*reversed statement

the knowledge test about human evolution and five components extracted by PCA: religiosity (F1), attitudes toward biology (F3), acceptance of evolution – the theory (F2), acceptance of evolution – the theory is (not) scientific (F4), and acceptance of evolution - organisms do (not) evolve (F5). There were six significant correlations altogether (Tab. 2, Tab. 3). Acceptance of evolution – the theory is (not) scientific (F4) was significantly correlated with religiosity (F1) in both subsamples and also with acceptance of evolution – the theory (F2) in 15–16-year-olds. Acceptance of evolution - organisms do (not) evolve (F5) was significantly correlated with attitudes toward biology (F3) in 15–16-year-olds. Knowledge of human evolution was significantly correlated with acceptance of evolution – the theory (F2) and attitudes toward biology (F3) in the group of 13–14-year-olds. All correlations were small (.13 < rs < .21).

Comparison of Correlations between the Control Group and the Experimental Group

A comparison of correlations between the control and the experimental group of students was calculated. The correlations between the knowledge of human evolution and the five components obtained by PCA in the group that had not yet learned about evolution (13–14-year-olds) were mostly significantly different (ps < .01) from the correlations in the group that had already learned about human evolution (15–16-year-olds). Only the correlation between acceptance of evolution (i.e., the theory is (not) scientific (F4) and acceptance of evolution - organisms do (not) evolve (F5)) was similar in both age groups (p = .223).

Discussion

The first research question dealt with whether teaching about human evolution to 14–15-year-old students in Slovenia is effective and whether it attains the standards set in the national curriculum for biology.

Overall, the average achievements on the knowledge test of human evolution ranged from very poor (M = 2.41) to very good (M = 4.31). In summary, Slovenian students knew very well that modern humans did not live at the same time as dinosaurs (rE38) and that modern humans are the

Table 2. Correlations between Students' Achievements on the Knowledge Test about Human Evolution and Contextual Factors (13–14-year-olds).
Tabela 2. Korelacije med dosežki učencev na testu znanja o evoluciji človeka in ozadenjskimi dejavniki (13-do 14-letniki).

Name of the Wetlands, (Blocks).	F1	F2	F3	F4	F5
F1 Religiosity	1.00				
F2 Acceptance of evolution – the theory	.06	1.00			
F3 Attitudes toward biology	.07	.00	1.00		
F4 Acceptance of evolution - the theory is (not) scientific	.16*	-.07	-.00	1.00	
F5 Acceptance of evolution - organisms do (not) evolve	.12	-.05	-.13	-.05	1.00
Knowledge of human evolution	-.08	.13*	-.18**	-.00	.03

* p < .05, ** p < .01

Table 3. Correlations between Students' Achievements on the Knowledge Test about Human Evolution and Contextual Factors (15–16-year-olds).
Tabela 3. Korelacije med dosežki učencev na testu znanja o evoluciji človeka in ozadenjskimi dejavniki (15-do 16-letniki).

Name of the Wetlands, (Blocks).	F1	F2	F3	F4	F5
F1 Religiosity	1.00				
F2 Acceptance of evolution – the theory	.04	1.00			
F3 Attitudes toward biology	-.05	-.07	1.00		
F4 Acceptance of evolution - the theory is (not) scientific	-.15*	.21**	.07	1.00	
F5 Acceptance of evolution - organisms do (not) evolve	.04	-.04	.20**	-.07	1.00
Knowledge of human evolution	-.07	-.04	.09	-.02	.02

* p < .05, ** p < .01

only species of humans today (E3). They also knew above averagely well that humans had changed their shape over time (rE26), that humans and chimpanzees evolved from a common ancestor (E41) that no longer lives (rE5), and that gorillas, orangutans and chimpanzees are humans' closest relatives (E37).

Students knew averagely well that modern humans evolved in Africa (E34), that they evolved more than 15,000 years ago (rE33), and that humans did not evolve from chimpanzees (rE35). In two of these statements, the knowledge improved significantly after the biology lessons in the ninth grade.

Students knew beyond average that modern humans and Neanderthals lived at the same time (E36), that modern humans lived at the same time as mammoths (E2), and that modern humans did not evolve from Neanderthals (rE1). For two of these statements, the biology lesson slightly improved knowledge.

In contrast, students were unsure what proportion of genes Neanderthals and modern humans share (E4) and where Neanderthals lived (E19), although knowledge improved significantly after the biology lessons in the ninth grade of primary school.

The fact that even the younger students had above-average achievements in seven out of 14 statements suggested that they might have gained some of this knowledge in history classes one year earlier (Učni načrt. Program osnovna šola. Zgodovina, 2011), through popular media (Modell & Wenderoth, 2005), digital and print media (Garibi et al., 2021), or their social surroundings (OECD, 2016; OECD, 2017; Šterman Ivančič & Mlekuž, 2023), especially their parents (Salazar-Enriquez et al., 2023).

The comparison of the knowledge of both groups showed that there were significant differences between students' answers in most of the statements. The experimental group (15–16-year-olds) showed mostly a better knowledge of human evolution than the control group (13–14-year-olds). Interestingly, younger students showed significantly better knowledge of one statement (rE33, Modern humans did not evolve less than 15,000 years ago). No knowledge was gained on the following two statements (E37) Human three closest relatives in terms of evolutionary development are gorillas, orangutans, and chimpanzees, and (E2) modern humans lived in today's Slovenia at the same time as mammoths. This suggested that these three topics were probably not addressed in biology classes. On the remaining 11 statements, older students answered significantly better. Therefore, we can conclude that in Slovenia, the teaching of (at least human) evolution at the primary school level is reasonably good. This is in line with Mead et al. (2017), who found that after classes, students' knowledge of evolution was improved immediately after the lesson and was retained. Some studies in other European countries showed that teaching evolution was not satisfactory and that evolution was taught only after the other topics had been covered (Pinxten et al., 2020). Some teachers also do not have sufficient content knowledge (Borgerding et al., 2015; Hartelt et al., 2022) and pedagogical skills to teach such a demanding topic (Stasinakis & Athanasiou, 2016). However, the fact that the effect sizes of all eleven improvements in knowledge of human evolution in the present study were mostly small or medium suggested that there is room for improvement in the way human evolution is taught. Changes in the curriculum should be made concerning the topics with low achievements. Despite some research not showing any connection between students' knowledge and the quality of the national curriculum (Belin & Kisida, 2015), other studies showed that the structure of the curriculum influences knowledge and acceptance of evolution (Vaughn & Robbins, 2017).

Information gathered in the present study can be applied immediately to improve the curriculum (Salazar-Enriquez et al., 2023), which is currently underway in Slovenia. The results will also be important for pre-service teachers' educational programs because by securing the understanding and acceptance of evolution in teachers, the transfer of these to new generations of students will be more favourable (Balgopal, 2014; Cofre et al., 2017; Torkar & Šorgo, 2020).

The second research question dealt with the chosen contextual factors (students' religiosity, attitudes toward biology, and acceptance of evolution) and their possible correlations with students' achievements on the knowledge test about human evolution. Six significant but small correlations were found.

According to most studies, the knowledge and acceptance of evolution are positively correlated (Carter et al., 2015; Tavares & Bobrowski, 2018; Torkar & Šorgo, 2020; Salazar-Enriquez et al., 2023). Surprisingly, there was no such correlation for 15–16-year-olds in the present study. However, for 13–14-year-olds, the results showed that the better knowledge they possessed, the more they accepted the general statements of the evolutionary theory (F2). This is in line with other studies indicating that the correlation

between knowledge and acceptance of evolution is not strong (Mead et al., 2017).

Most of the research (e.g., Salazar-Enriquez et al., 2023) found that knowledge and acceptance of evolution negatively correlate with religious beliefs. Interestingly, the present study showed no correlation between religiosity and knowledge. However, in both age groups, there was a small negative correlation between religiosity and conviction that evolutionary theory is scientific (F4). The more religious 15–16-year-olds were, the less convinced they were that the evolutionary theory is scientific. At the same time, more religious 13-14-year-old students were also more convinced that the evolutionary theory was scientific. This result is consistent with Mpeta et al. (2015) and Fiedler et al. (2024), who stated that the acceptance of evolution is also related to age, religiosity, and the time that has passed since the first learning about evolution.

A small negative correlation was found between attitudes toward biology (F3) in 13- to 14-year-olds and knowledge of human evolution. This is not surprising—despite a positive attitude toward biology, these students lacked knowledge of human evolution because they had not been formally taught this topic yet. Students 15 to 16 years old with more positive attitudes toward biology (F3) were more convinced that organisms evolved (F5). This could be explained by the findings of Prokop et al. (2007) and Kubiatko et al. (2017), who report that good teaching strategies and a positive teacher personality positively influence students' attitudes toward biology. It might be that students who were taught by such teachers were also more likely to accept the scientific facts presented by these teachers. The only correlation between two aspects of the acceptance of evolution was observed in 15- to 16-year-olds: the more the students accepted the theory of evolution (F2), the more they were convinced that it is scientific (F4).

Correlations calculated for the 13- to 14-year-olds were then compared with the correlations calculated for the 15- to 16-year-olds for statistical significance. Fourteen out of 15 correlations calculated differed significantly between these two groups (ps < .01). The results show that teaching evolution not only significantly improved the students' knowledge of human evolution but also caused changes in the acceptance of the evolutionary theory. This is in line with other studies that found positive correlations between knowledge and acceptance of evolution (Carter et al., 2015; Tavares & Bobrowski, 2018; Torkar & Šorgo, 2020; Salazar-Enriquez et al., 2023). There was no difference (p = .223) only regarding one correlation: in both groups, students who were more convinced that evolutionary theory is scientific (F4) were also more convinced that organisms evolve (F5). The fact that the 13- to 14-year-olds who had not learned evolution yet had the same convictions as the 15- to 16-year-olds was surprising, and it could be the consequence of contextual factors, such as the students' social surroundings (OECD, 2016; OECD, 2017; Šterman Ivančič & Mlekuž, 2023) or parental education level (Salazar-Enriquez et al., 2023).

A limitation of this study was its cross-sectional nature. A longitudinal study would have yielded more reliable results, but it would have been impossible to conduct due to logistical issues.

Conclusions

We can conclude that students in the ninth grade of elementary school improved their knowledge of human evolution. The progress was small to medium. The question is how to eliminate some important misconceptions our students have concerning Neanderthals, specifically that modern humans evolved from Neanderthals (rE1) and that modern humans and Neanderthals did not live on Earth at the same time (E36). The student's knowledge should also be improved on the following topics: modern humans evolved in Africa (E34) more than 15,000 years ago (rE33), they did not evolve from chimpanzees (rE35), and they lived at the same time as mammoths (E2). In these topics, attention should be given to teacher education programs in curricular renewal.

Author Contributions

Conceptualization, J.S.; methodology J.S.; formal analysis, J.S.; investigation, J.S.; data curation, J.S.; writing—original draft preparation, J.S.; writing—review, editing, and paper communication, J.S. All authors have read and agreed to the final version of the manuscript.

Conflicts of Interest

The author declares no conflict of interest.

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