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A CROSS-CULTURAL STUDY ON FRESHMEN'S KNOWLEDGE OF GENETICS, EVOLUTION, AND THE NATURE OF SCIENCE

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Abstract. *The purpose of this study was to measure the freshmen's level of knowledge about genetics, evolution, human evolution, the nature of science, and opinions on evolution and the presence of non-scientific explanations among Czech, Slovakian, Slovenian and Turkish students. Determination of prior knowledge and pre-conceptions about these issues is important because they are filters to learning other related concepts. The results are going to be a starting point for developing teaching strategies concerning Darwinian evolution and preparing prospective science teachers for working with students in national and international contexts. A total of 994 first-year university students from the Czech Republic (276; 27.8%), Slovakia (212, 21.3%), Slovenia (217, 27.3%) and Turkey (235, 23.6%) participated in this study. The findings can be summarized as follows: knowledge especially that of the nature of science at the freshmen level was seriously flawed. Non-scientific explanations were present in high percentages. Both were regarded as barriers towards scientific reasoning and acceptance of general human evolution especially for students expressing orthodox religious beliefs.*
Key words: *evolution, genetics, human evolution, nature of science, non-scientific explanations.*

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Introduction

The world is becoming a global village in almost all aspects of human endeavour and education is affected as well (Suarez-Orozco, 2001; Tikly, 2001; Akar, 2010, Šorgo, & Špernjak, 2012, Fancovicova, Prokop, & Leskova, 2013). Globalisation and internationalisation in education are not only a matter of organisation and culture or language (Balaz, 2010) but are also the first-class curricular and pedagogical issues (Svensson & Wihlborg, 2010). Paralleling the mobility of students and teaching staff, the use of international textbooks, internet and the rising number of immigrant students, the important question becomes whether the same teaching methods and strategies can be used internationally or whether every entity like country or school district or even every school or teacher, should develop these strategies individually (Fuller & Clarke, 1994; Sleeter, 2001; Gerritsen & Lubbers, 2010).

The aim of the present study was to determine the differences in the a) level of knowledge about genetics, evolution, human evolution, and the nature of science; b) opinions on evolution, and c) the presence of non-scientific explanations among Czech, Slovakian, Slovenian and Turkish freshmen students. The identification of prior knowledge and pre-conceptions on an issue are important because prior knowledge and pre-conceptions can be filters to learning other related concepts (Ferrari & Chi, 1998; Shtulman, 2006). The findings will be useful in achieving two goals. The first is to determine the knowledge level and opinions in each of the participating countries in order to improve teaching practices in secondary schools and recommend changes in curricula concerning Darwinian Evolution, paranormal beliefs and the nature of science as central goals of science education. The second one is to

prepare prospective science teachers for working with students on evolution and similar topics, which are often recognized as offensive (Reiss, 2001; Losh & Nzekwe, 2011a, b) in national and international contexts.

Evolution was chosen as a subject because it is the central theory of biology (Dobzhansky, 1973), and if students after years of Biology and science courses do not understand evolutionary concepts it can only mean that the central point of biology teaching was missed (Losh & Nzekwe, 2011a). Additionally, knowledge and skills on evolution teaching gained in pre-service teacher trainings can be extended to other domains of unscientific reasoning such as health, paranormal phenomena and astrology (Losh & Nzekwe, 2011b).

Darwinian evolution is recognized as one of the most controversial and difficult issues to be taught by a science teacher (Moore & Cotner, 2009; Nehm, Kim & Sheppard, 2009; Lac, Hemovich & Himelfarb, 2010; Smith, 2010a; Smith 2010b; Oliveira, Cook & Buck, 2011). Even though the scientific evidence for evolution is strong, research shows that the scientific understanding of biological evolution continues to remain elusive to many people (Mazur, 2004; Scott, 2005; Miller, Scott & Okamoto, 2006). The problem of teaching evolution, not known in the largest part of science education, is that teachers should fight two sources of flawed information. The first is the lack of interest, the formation of misconceptions and forgetfulness; a problem faced when teaching every issue. The second is active rejection of the Darwinian Evolution by students or even by teachers (Irez, Bakanay & Dilek, 2011).

Teachers must be able to recognize the difference between scientific explanations and explanations based on non-scientific reasoning. Additionally, they must understand that religion is a different sort of understanding – one that is rooted in faith and not evidence-based (Reiss, 2008 & 2011; Weissmann, 2006) – in order to explain scientific issues to students. In the case of evolution, teachers must be equipped not only with the knowledge of facts easily learned such as body weight or brain volume of a Hominoid species but also with a detailed understanding of the evolutionary mechanisms. The reason is not only to present evolution to the students in an interesting and intellectually exciting way, but also to withstand well-prepared to the attacks of different anti-evolutionist groups (Lac, Hemovich & Himelfarb, 2010; Peker, Comert & Kence, 2010).

Many studies about the knowledge and opinions of evolution exist in various parts of the world (e.g. Miller et al., 2006; van Dijk, 2009; Hokayem & BouJaoude, 2008; Kose, 2010; Sanders & Ngxola, 2009; Schilders et al., 2009), showing that the results from one study cannot simply be transferred from one country to another. This conclusion leads the authors of the present study, to assess the target population using the same instrument as the first step to devise new international teaching strategies.

Methodology of Research

Survey Participants

The study was carried out in October 2010 in four countries. A total of 994 first-year university students participated in the study: the Czech Republic (276; 27.8%); Slovakia (212, 21.3%), Slovenia (217, 27.3%) and Turkey (235, 23.6%). Of the 994 students, 785 (79%) were female and 209 (21%) were male students. The differences between male and female students, even if there may exist any (Losh & Nzekwe, 2011) were not the scope of the study. The larger number of them (708; 71.2%) were prospective teachers and 286 (28.8%) came from a non-educational background. Differences between these two groups were not the scope of the study. Even though future teachers and the improvement of their university education were one of the main aims of the study, data from students who do not choose educational study track were not discarded. The argument was that at this stage the study searches for their conceptions were not yet influenced by university courses. On the other hand, all participants were students of the same faculties where they can change study tracks. Participants were in their first weeks at the universities, mostly 19 (48.8%) or 20 (20.1%) years old. The primary reason to choose this sample (freshmen students) was that the survey would be performed with participants who had finished secondary schools, but were not yet influenced by the new knowledge gained in university courses.

Questionnaire

The questionnaire was developed in English as a language of conversation between the authors and translated later into the Czech, Slovakian, Slovenian and Turkish languages.

The first section contained questions about the basic demographic data (gender and age). The second section included 15 Likert-scale items. Students answered the items by choosing one of three options: disagree (1), undecided (2) and agree (3). The statements express a range of facts, experiences and opinions on previous teaching. The section was adapted from a previous comparative study on Biology teaching in Turkey and Slovenia (Sorgo, Usak, Aydogdu, Keles, & Ambrozic-Dolinsek, 2011). The questionnaire had five loosely defined groups of statements:

- Religiosity was measured by one statement: *'I would declare myself as a religious person'.*
- Actual school experiences on evolution teaching consisted of 4 items.
- Active personal effort consisted of 4 items.
- Opinions on how evolution should be taught consisted of 3 items.
- Perceived importance of evolution consisted of 3 items.

A 30-item test about knowledge was compiled in five subscales. The subscales were as follows: genetics, evolution, human evolution, nature of science and non-scientific explanations. Each subscale consisted of 6 questions and students had to choose among three options, namely: True, False and I do not know / I am not sure. About half of the items were negatively worded to prevent guessing, and were later recoded to allow for a statistical analysis. Questions in the present study were chosen from a pool of 115 questions used in a preliminary study performed in Slovenia (unpublished data). Based on answers of 204 secondary school students and a procedure proposed by Selwyn (1997) and Lavonen et al. (2004), the final pool of questions was compiled.

Data Collection

Sampling was performed by authors or their teaching assistants at their Universities after classes or laboratory sessions. Participation was voluntary and no extra credits or any other types of rewards were given. Because of the format of the questionnaire (check boxes) it took about 20 minutes to complete.

Statistical Analyses

Kolmogorov-Smirnov test was first run to test the normal distribution. As presented in Table 1, none of the variables related to the differences in students' actual school experiences followed a normal distribution at the level of $p < 0.01$. Chi-square (χ^2) statistics (Kolmogorov-Smirnov non-parametric test) were used to identify the differences in the frequencies of answers between the different groups of respondents. In the second part where sums on subscales were compared between countries (Table 3) the assumption of normality was met so in order to make parallel comparisons of possible differences an F–test was performed. Pearson moment correlation test was used to test correlations among the subscales.

Results of Research

Students should agree, disagree or stay undecided on the statement "I would declare myself as a religious person". The highest agreement was found among Slovakian students (33.2%), followed by the Turkish (26.3%), Slovenian (23.8%) and Czech students (16.7%). Differences were statistically significant ($\chi^2 = 157.11$, df = 6, N = 992, $p < 0.0001$). The highest number of students who clearly disagree with the statement comes from the Czech Republic (43.4%) followed by the Slovenian (22.4%), Turkish (21.3%) and Slovakian (13.0%) students. Remaining students were undecided.

School experiences on evolution teaching, active personal effort in the learning of evolution,

opinions on how evolution should be taught and perceived importance of evolution were measured by the same method with the statements presented in Table 1.

Table 1. Differences in students' actual school experiences on evolution teaching, active personal effort in the learning of evolution, opinions on how evolution should be taught, and perceived importance of evolution among four countries.

	C1	N	Mean	SD	Mean Rank	χ^2	p
We had enough lessons on evolution at school.	1	276	1.63	0.80	470.62	18.34	< 0.001
	2	212	1.57	0.79	449.25		
	3	266	1.83	0.81	542.47		
	4	232	1.72	0.79	505.02		
	Total	986	1.69	0.80			
We had lessons at school where connections between genetics and evolution were clearly explained.	1	276	1.95	0.87	484.09	5.90	0.12
	2	212	1.93	0.90	477.99		
	3	269	1.98	0.79	492.20		
	4	235	2.11	0.83	532.70		
	Total	992	1.99	0.85			
Most of the time the biology teacher talked about evolution and we had to listen.	1	276	1.45	0.73	387.64	151.37	< 0.001
	2	212	1.49	0.74	401.92		
	3	269	2.21	0.84	621.09		
	4	235	2.02	0.84	567.07		
	Total	992	1.80	0.86			
We debated controversial issues during biology lessons.	1	276	1.43	0.72	441.62	33.36	< 0.001
	2	212	1.49	0.76	460.72		
	3	269	1.65	0.71	534.07		
	4	234	1.72	0.79	548.35		
	Total	991	1.57	0.75			
I would like to learn more about evolution.	1	276	2.10	0.83	412.74	61.25	< 0.001
	2	212	2.24	0.81	457.42		
	3	266	2.54	0.69	553.78		
	4	235	2.54	0.72	558.97		
	Total	989	2.35	0.79			
With friends and relatives we talk about genetics and evolution.	1	276	1.43	0.79	478.55	5.77	0.12
	2	212	1.44	0.77	485.40		
	3	271	1.48	0.77	503.88		
	4	235	1.57	0.84	523.32		
	Total	994	1.48	0.79			

	C1	N	Mean	SD	Mean Rank	χ^2	p
Beside the literature prescribed by the school I read books and popular science journals on evolution out of my own interest.	1	276	1.24	0.60	427.79	60.63	< 0.001
	2	212	1.32	0.66	455.76		
	3	270	1.62	0.83	550.06		
	4	234	1.60	0.78	552.65		
	Total	992	1.45	0.74			
I have visited internet pages with evolution as a topic out of my own interest.	1	276	1.22	0.60	431.82	53.45	< 0.001
	2	212	1.31	0.65	464.88		
	3	270	1.60	0.82	553.49		
	4	234	1.54	0.80	535.69		
	Total	992	1.42	0.74			
Beside the Darwinian theory of evolution alternative evolutionary theories should be taught.	1	276	2.53	0.70	556.10	29.75	< 0.001
	2	212	2.42	0.65	502.63		
	3	269	2.24	0.70	436.14		
	4	234	2.38	0.66	487.92		
	Total	991	2.39	0.69			
The Darwinian theory of evolution should be taught only to persons who are not offended by it.	1	276	1.31	0.64	432.60	27.53	< 0.001
	2	212	1.55	0.74	522.61		
	3	270	1.56	0.74	525.98		
	4	235	1.52	0.72	516.23		
	Total	993	1.48	0.72			
Teachers should have the option of teaching only topics which do not interfere with their beliefs and moral system.	1	276	1.38	0.66	461.70	57.27	< 0.001
	2	212	1.84	0.88	596.07		
	3	271	1.32	0.63	442.91		
	4	235	1.58	0.83	513.57		
	Total	994	1.51	0.77			
There is no need for knowledge about evolution to understand the diversity of life.	1	276	1.80	0.87	537.51	38.08	< 0.001
	2	212	1.86	0.87	556.29		
	3	268	1.51	0.75	450.38		
	4	234	1.49	0.76	442.55		
	Total	990	1.66	0.83			
Scientific knowledge on human evolution can be declared as basic knowledge which every person should possess.	1	276	2.74	0.62	543.36	56.05	< 0.001
	2	212	2.74	0.54	532.38		
	3	270	2.40	0.73	412.59		
	4	235	2.67	0.61	507.61		
	Total	993	2.63	0.65			

	C1	N	Mean	SD	Mean Rank	χ^2	p
Evolution is not a fact but an unproven theory.	1	276	1.63	0.71	454.61	13.11	0.004
	2	212	1.74	0.70	500.58		
	3	267	1.84	0.71	535.41		
	4	233	1.70	0.67	489.34		
	Total	988	1.73	0.70			

[1]C = country: 1 = Czech Republic, 2 = Slovakia, 3 = Slovenia, 4 = Turkey.

Knowledge concerning the nature of science (NoS), knowledge on genetics (KoG), knowledge on evolution (KoE), knowledge on human evolution (KHE), and non-scientific explanations (NEX) were measured by answering statements presented in Appendix.

The differences between participating countries in the mean of answers are presented in Table 2.

Table 2. Differences in knowledge between four countries.

	C[1]	N	Mean	SD	F	p
KoG[a]	1	276	3.62	1.298	10.03	< 0.001
	2	212	3.04	1.196		
	3	271	3.64	1.438		
	4	235	3.59	1.509		
	Total	994	3.49	1.388		
NoS[b]	1	276	2.09	1.336	11.64	< 0.001
	2	212	1.94	1.179		
	3	271	1.51	1.092		
	4	235	1.88	1.130		
	Total	994	1.85	1.210		
KoE[c]	1	276	3.13	1.270	10.63	< 0.001
	2	212	2.45	1.263		
	3	271	2.75	1.436		
	4	235	2.88	1.367		
	Total	994	2.82	1.358		
KHE[d]	1	276	3.49	1.275	8.92	< 0.001
	2	212	2.92	1.347		
	3	271	3.16	1.230		
	4	235	3.39	1.346		
	Total	994	3.25	1.311		
NEX[e]	1	276	3.16	1.433	22.50	< 0.001
	2	212	2.27	1.316		
	3	271	3.37	1.572		
	4	235	2.90	1.745		
	Total	994	2.96	1.576		

[1]C = country: 1 = Czech Republic, 2 = Slovakia, 3 = Slovenia, 4 = Turkey.
[a]genetics, [b]nature of science, [c]evolution, [d]human evolution, [e]non-scientific explanations.

Almost all correlations between correct responses were statistically significant ($p < 0.001$, Table 3), however, their power was medium to low.

Table 3. Correlations between the sums of correct answers.

	KoG	NoS	KoE	KHE
KoG[a]	1			
NoS[b]	0.142**	1		
KoE[c]	0.346**	0.122**	1	
KHE[d]	0.288**	0.101**	0.288**	1
NEX[e]	0.315**	-0.012	0.363**	0.233**

**. Correlation is significant at the 0.01 level (2-tailed).

[a]genetics, [b]nature of science, [c]evolution, [d]human evolution, [e]non-scientific explanations.

Discussion

It is well known from literature (Mazur, 2004; Scott, 2005) that religious beliefs can affect the teaching of evolution. The highest percentage of the religious respondents came from Slovakia, the lowest percentage from the Czech Republic and the highest percentage of the undecided ones came from Slovenia. In light of the purposes of the study, it is possible to conclude that the number of religious students exceeds the number of sceptics or non-believers only in Slovakia. Religiosity does not necessarily mean the rejection of evolution (Reiss, 2011; Winslow et al., 2011), because active rejection is more often restricted to the orthodox groups (Wiles, 2011). The answers to the statement "The theory of evolution must be wrong because the holy texts (Bible, Koran) are unmistakable (Appendix)" can be used to identify the number of orthodox believers. The highest number of orthodox believers comes from Slovakia (16.5%), which is followed by Turkey (10.6%), the Czech Republic (5.4%) and Slovenia (3.3%). On the other hand, teachers should count on different kinds of spirituality, not necessarily connected with established religious groups. This approach can be useful, especially when interpreting answers to the statements such as "Humans evolved by the laws of evolution but the spirit was given by a higher being" where agreement is much higher. One cannot conclude from these results that completely different strategies should be used in different countries because of the different number of orthodox believers. One of the initial steps must be a clear distinction between scientific explanations based on evidence and non-scientific explanations based on faith to prevent tensions between believers and non-believers (Edis, 2009; Reiss, 2008, 2011). Students should be exposed to this difference as early as possible in the course (Scharmann, Smith, James, & Jensen, 2005).

It can be observed that the students from all participating countries stay close to the neutral or disagreeing answers about evolution not getting the appropriate level of attention in schools. Teaching evolution in high schools, with the exception of Turkey, seems to be not clearly connected with genetics. The teaching in Slovenia and Turkey is more teacher-centred than it is in the Czech Republic and Slovakia. The similarity in the teaching practice between Slovenia and Turkey was previously reported (Sorgo et al., 2011). Students from all countries disagree with the statement that they debated about controversial issues during their biology classes, leading to a conclusion that students will not internalise their knowledge and if preconceptions exist these will stay untouched. Students in general share the same opinion that they would like to learn more about evolution; however, this opinion is not supported by their personal efforts to fill the gaps. Slovenian and Turkish students are a little bit more enthusiastic in acquiring additional information, but the results are far from being satisfactory. The conclusion of the study can be that if an issue is not a part of the regular school curricula, then students will not search for information about this issue as long as they are not personally affected. Because the knowledge of biological evolution has an important meaning in the understanding of natural processes and has

limited practical implications for solving everyday problems, the probability that someone is going to learn about evolution in out-of-school settings, just to satisfy his/her own interests is small.

The students from all four countries agreed that the alternative evolutionary theories should be taught (Table 1). From the wording in the questionnaire we cannot be sure whether they have the creationism in mind or whether they simply do not recognise that the current evolutionary theory is almost consensually accepted by the scientific community as the only valid theory of the formation of organisms. On the other hand, students mostly disagreed that evolution should be taught only to the persons who are not offended by it. Disagreement with the statement that teachers should have an option of teaching only topics which do not interfere with their personal beliefs, was somewhat better supported by the Slovakian students, probably reflecting the higher levels of religiosity. From the viewpoint of teaching evolution, it can mean that teaching can address all students in a classroom, regardless of nationality. From the teaching point of view, the students mostly agree that scientific knowledge on human evolution can be declared as basic knowledge which every person should possess; that they recognise a connection between the biodiversity and evolution; and for the most part they know that evolution is not an unproven theory. Combining responses from all the subscales, it can be concluded that the associations between these subscales exist, but are generally small/moderate so as to allow the conclusion that completely different teaching cultures should be established.

The knowledge on nature of science after secondary schools is far from satisfactory in all four countries leading to a conclusion that this aspect of science teaching must be improved. The knowledge of nature and philosophy of science can be regarded as the key to the acceptance of evolution (Rutledge and Warden, 2000), because it provides a basis for scientific and evidence-based reasoning. As such, it should be embedded deeply in the teaching of science not only because of evolution but as a basis for acceptance and rejection of many important issues such as genetic modifications, global climate changes, health issues, etc. More emphasis should be given to the understanding of the term theory and what the attributes of a theory are and the way scientific findings are verified, both in preparing a study and later in verifying the results (Scharmann et al., 2005). Additionally, students should be encouraged to read popular and scientific texts, but, at least, in some cases they should be guided to recognise the difference between writings based on evidence and writings based on speculation. Strengthening the understanding of science and scientific methods is, therefore, crucial because when people lack this understanding they choose an informal type of reasoning as a way of solving problems (Sadler & Zeidler, 2005).

The understanding of genetics is regarded by many as a prerequisite to the understanding of evolution (Beilharz et al., 1993) even if the relationships are not very straightforward as presented in Table 4. Students from all participating countries on average showed the highest level of knowledge in the domain of genetics, a finding which can be explained by the coverage of genetics in the secondary school curricula. Differences among Czech, Slovenian and Turkish students were small and Slovakian students obtained the lowest scores (Table 3). One cannot be satisfied with the results because a number of students received zero points out of six (data not shown). Analysing the table answer by answer, it was possible to see that only about three quarters of the students were sure about the determination of sex in humans, or the presence of the DNA in plants and animals. From the low scores achieved by answering the item about modern genetics (it is possible to transfer genes with genetic engineering in bacteria from humans), it can be concluded that students receive information about the classical genetics but are poorly informed about the connections between genetics and biotechnology.

Questions on the knowledge on evolution were best answered by the Czech students and students from all other countries did not exceed the 50% of the scores on average (Table 3). Results can be regarded as alarming because the understanding of evolution is the scientific basis for understanding many topics in biology (Dobzhansky, 1973). Without evolutionary connections, biology can be regarded as an encyclopaedia of unconnected facts. It can be recognised as shocking that only a little more than half of the students knew that fleas cannot develop from dust in a biogenetic way, and only one fifth of them know that the development of an eye can be explained by the laws of evolution. It seems that the teaching of biology is lost in details but important "cover stories" such as biogenesis-abiogenesis and the emergence of life are poorly covered.

Results of the knowledge on human evolution are better than results on the general evolution subscale (Table 3) and only Slovakian students failed to exceed the 50% average. The results can be attributed to the better coverage in all curricula. However, the results are flawed because only about 70% were sure that humans and dinosaurs did not coexist before the extinction of dinosaurs and only 33.9 % knew that humans are not the direct descendants of apes. One can recognise that the knowledge on human evolution is affected by different factors, such as the quality of teaching, religious views and the interest for and the knowledge of general evolution. Human evolution should not be taught as a list of human species and the knowledge of anatomical facts learnt in the process of root learning. Instead, time gaps and connections between human species should be explained by showing that a state when only one of the human species existed at a time was not common but an exception. Additionally, time gaps and anatomic differences between findings do not automatically mean a discontinuity in the evolution but, in fact, a lack of fossils.

Non-scientific explanations are inevitable in human civilisations yet the science classrooms should be a place where they are not welcomed. The highest scores were achieved by Slovenian students and the lowest by the Slovakian students. It was amusing to find out that only about 70% of the students did not believe that accidents were more frequent on Friday the 13th, but the statement "If evolution exists, it is directed by a superior being" was denied by less than half of the students. We can attribute these results to the fact that non-scientific explanations are not seriously confronted during science teaching in schools. It is reported that teachers do not spend enough time on the identification of alternative conceptions or even on their importance (Anderson, Fisher & Norman, 2002; Jensen & Finley, 1996; Lewis & Wood-Robinson, 2000). From correlations (Table 4) it can be observed that the absence of non-scientific explanations is positively correlated with knowledge, but not with the nature of science.

Conclusions

It can be concluded that differences exist among the Czech Republic, Slovakia, Slovenia and Turkey and these differences can influence the teaching of evolution. The understanding of the nature of science in all countries is probably the weakest point, where improvements are immediately necessary. Only an excellent understanding of the differences between scientific and unscientific explanations can help someone to recognise the distinction between them in new contexts. Religion is deeply embedded in a culture and its values make the teaching of science more difficult (Reiss, 2008); however, teaching science can only be based on scientific reasoning. Additionally, the way of scientific reasoning can greatly help in making personal decisions on issues like the use of genetically modified organisms, health and many others. Even if the questionnaire measured only a small fraction of the knowledge, it can be recognised that the knowledge of high school students in the fields of genetics, evolution and human evolution is seriously flawed. There are no excuses that three out of ten do not know for sure that humans and dinosaurs never coexisted. One of the possible explanations is that the teachers and students never debated on self-evident issues (from the point of view of the teachers). In each country there are persons who can be regarded as fundamentalists who reject evolution on this basis. The difference is in the number which is bigger in Slovakia and Turkey than it is in the Czech Republic or Slovenia, but does not exceed the number of non-believers or sceptics. This brings the opportunity to prepare a balanced debate in a classroom setting. From the internationalisation of the university teacher education, it can only mean that there is always a chance to meet a fundamentalist or nonbeliever. Religiosity was found to be a predictor of the rejection of evolution and the lack of related knowledge. When students understand the difference between scientific and unscientific reasoning with regard to such phenomena, it is hardly likely that any fundamentalist group will try to ban the inclusion of the analysis of the predictive values of horoscopes. Thus, this may be a good time to start teaching about the evolution of life to the fundamentalists.

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Appendix:

Frequencies of answers concerning the nature of science (NoS), knowledge on genetics (KoG), knowledge on evolution (KoE), knowledge on human evolution (KHE), and non-scientific explanations (NEX) for the total samples.

	Statements	N	False %	True %	I do not know / I am not sure %
NoS	Scientific theories are not facts but explanations. (T)	986	223 22.6	496 50.3	267 27.1
NoS	Scientific explanations are only temporary. (T)	994	299 30.1	387 38.9	308 31.0
NoS	Every scientific work is based on a hypothesis. (F)	994	152 15.3	674 67.8	168 83.1
NoS	The development of humans by evolution is only one of the possible scientific explanations. (F)	989	270 27.3	424 42.9	295 29.8
NoS	Scientists can accept the existence of particles or phenomena which have never been directly observed. (C)	991	237 23.9	373 37.6	381 38.4
NoS	To be valid every scientific theory must be confirmed by an experiment (F)	994	162 16.3	681 68.5	151 15.2
KoG	Ordinary tomatoes do not have genes, but genetically modified ones do. (F)	989	588 59.5	53 5.4	348 35.2

	Statements	N	False %	True %	I do not know / I am not sure %
KoG	Genetically modified animals are always bigger than original animals. (F)	991	538 54.3	149 15.0	304 30.7
KoG	Cloning is a type of reproduction whereby a new organism is the result of the fusion of an egg-cell and a spermatozoid. (F)	992	680 68.4	198 20.0	114 11.5
KoG	The human sex is determined by females. (F)	992	758 76,4	99 10,0	135 13,6
KoG	All animals and plants possess DNA. (T)	987	168 17.0	686 69.5	133 13.4
KoG	It is possible to transfer genes with genetic engineering in bacteria from humans. (T)	993	206 20.7	223 22.4	564 56.7
KoE	Traits developed during a lifetime are transferred to the offspring. (F)	992	537 54.1	324 32.7	131 13.2
KoE	The universe is less than 1 million years old. (F)	994	725 72.9	52 5.2	217 21.8
KoE	Under good conditions fleas can develop from a particle of dust. (F)	992	528 53.2	111 11.2	353 35.6
KoE	We can explain the development of an eye by evolution only.(T)	988	298 30.2	209 21.2	481 48.7
KoE	Women, who understand the theory of natural selection, are more likely to choose males with good genes. (F)	990	411 41.5	251 25.4	328 33.1
KoE	Evolution does not necessarily lead to the development of more complex traits. (T)	988	215 21.8	312 31.6	461 46.7
KHE	Humans and dinosaurs coexisted before the extinction of dinosaurs. (F)	993	701 70.6	98 9.9	194 19.5
KHE	Neanderthals used fire. (T)	988	129 13.1	708 71.7	151 15.3
KHE	On the Earth there was always only one species of humans at the same time. (F)	989	632 63.9	152 15.4	205 20.7
KHE	Human evolution is a result of natural selection. (T)	989	127 12.8	559 56.5	303 306
KHE	Humans are the direct descendants of apes. (F)	984	334 33.9	449 45.6	201 20.4
KHE	Modern humans are the descendants of Neanderthals. (F)	990	301 30.4	504 50.9	185 18.7
NEX	Humans evolved by the laws of evolution but the spirit was given by a higher being. (F)	992	427 43.0	252 25.4	313 31.6
NEX	The theory of evolution must be wrong because the holy texts (Bible, Koran) are unmistakable. (F)	994	710 71.4	84 8.5	200 20.1
NEX	We can only explain what is happening in nature by natural laws. (T)	994	453 43.8	293 29.5	266 26.8
NEX	On Friday the 13th there are more accidents. (F)	991	695 70.1	148 14.9	148 14.9

	Statements	N	False %	True %	I do not know / I am not sure %
NEX	Without faith human life will be without reason. (F)	993	452 45.5	353 35.5	188 18.9
NEX	If evolution exists, it is directed by a superior being. (F)	985	454 46.1	191 19.4	340 34.5

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