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The role of teacher in students' attitudes to and achievement in palaeontology

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Abstract

This study investigated the attitudes and achievements 13/14-year-old pupils' in palaeontology with respect to school type, gender and pupils' perception of palaeontology teacher. Palaeontology provides important evidence to support t he theory of evolution thus it is important for science educator to understand the attitudes held by their pupils in this science topic. A factor analysis applied to a 23 Likert-type palaeontology attitude questionnaire extracted five independent factors that represent pupils' school and out of school attitudes, attitudes to future career in palaeontology and perception of teacher's involvement in palaeontology. A spider type concept map was designed to examine pupils' understanding of prehistoric life in the main geological eras. It was found that grammar school pupils palaeontology and also had better achievement when compared to elementary school pupils. Perception of a teacher were shown to exert showed only a weak effect on pupils' attitudes, but the same variable, teacher attitude, strongly influenced pupils' achievement. Differences caused according to the gender of the showed a weak tendency for a better score in attitudes and better score in achievement for females. These results imply that the greater the teacher's involvement in science the more positively influenced is the pupils' learning outcomes and the stronger the link between teacher and pupils' interest results in a positive influences on pupils' attitudes.

Keywords: Palaeontology; Attitudes; Biology; Students; Teachers

1. Introduction

On the voyage of the Beagle Charles Darwin took with him the first volume of Lyell's Principles of Geology [1]. The succeeding two companion volumes were sent to him as they were published. In this first book, Lyell suggested that the emergence of new species, and extinction of hitherto existing species, was a natural, not a miraculous, event. Biographers of

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Darwin considers it likely that this opinion was the basis on which Darwin began to formulate his ideas, which were developed though his observations of natural variation in the geographical distribution of species. He concluded that the only possible means in which such difference as between species was through descent, with changes in form and function, from a common ancestor [2].

An understanding of Darwin's ideas is complimented day and understanding of palaeontology and the evidence derived from rocks of geological epochs and the fossils which they contain. Such phenomena are evidence in support of the theory of evolution. Such knowledge is increasingly pertinent at the present time with the increasing debate and raising of public awareness soft the ideas of Creationism and intelligent design to explain the variety of life past and present.

Evidence put forward by the defense in the Dover School Board trial in the USA was given by scientists and consisted of information bagmen d form the study of palaeontology. Hence, helping and encouraging student suit understand the scientific viewpoint and to evaluate the amount of evidence e available to support this view is an important part, not only of the education of scientist, but of future citizens.

The quality of science education depends on the quality of instruction that students receive [3]. George and Kaplan [4] showed that a teacher influences students' attitudes toward science through the experiments and science activities they provide for their pupils. The importance of students' positive views of science lies in the significant impact of science on our everyday lives [5]. Furthermore, positive attitudes result in increased enrolment in science courses and interest in scientific careers [4, 6-8]. Moreover, several research works showed at least moderate correlation between attitudes and achievement to science [9-13]. Student achievement in science is, together with attitudes, the most important indicator, or predictor, of the science education outcome [4, 6, 14].

Current research shows that attitudes to science are viewed more or less negatively [15]. For instance, the ROSE project [16] has surveyed students' attitudes to school science across more than 40 countries. In all developed countries, school science was found to be less popular than other school subjects [16, 17]. In general, boys show more positive attitudes toward science than girls [16, 18-20] and older students show less positive attitudes than younger ones [21].

Palaeontology in Slovakia is taught as part of geology in 8th grade (age 13/14). At the undergraduate level, student teachers experience palaeontology and geology as courses integrated to in biology education programs. Current reports from Slovakian pupils aged 10 – 15 years show that attitudes toward biology as distinct school subject taught separately form other science courses become more negative especially in older students [22]; [23]. Furthermore, Prokop, Tuncer and Chudá [22];, in two independent survey's focused on pupils' attitudes to biology of pupils currently learning zoology (grade 6) found attitudes to be significantly more positive than those currently learning geology and palaeontology (grade 8). In addition, 8th grade pupils showed lowed mean attitudes score toward biology comparing with other pupils attending grade 5 – 9. There are at least two explanations for this phenomenon that are not mutually exclusive.

First, because attitude scores showed non-linear decrease on mean scores as pupils' age increased [22, 23] there is a possibility that it is not age, but rather the nature of geology and palaeontology that negatively influences pupils' attitudes to geology and palaeontology. Learning about soil sciences can be simply boring [24], in comparison with life sciences such as zoology or human biology perhaps because of the absence of movement patterns of nonliving things [25]. There is also a greater physiological relationship between humans and animals which might influence and create more positive attitudes toward zoology in comparison with other science subjects [26]. Second, our unpublished results based on interviews and surveys with teachers suggest that biology teachers (all have specialization for both biology and soil sciences in Slovakia) do not like teaching geology, because they are personally more interested in other courses like zoology, botany and human biology. The latter argument is reasonable considering that undergraduate students of biology education in Slovakia are experienced mainly with biology courses and their enrolment in undergraduate courses depends on their biology, but not soil sciences knowledge. This means that biology teachers are probably more motivated to study biology comparing with geology or palaeontology.

In the model developed by Haladyna and Shaugnessy [11], pupils' attitudes to science are determined by three independent constructs: the student, the teacher and the learning environment. These authors also distinguished between exogenous and endogenous variables. The former include student gender and socio-economic status, which are located outside the institution of the school and are not under the direct influence of the school process.

The endogenous teacher and learning environment variables are important because they have the greatest influence on attitudes and they are also easily manipulated to bring about changes in attitudes [11].

Further research supported Haladyna and Shaugnessy's model. Druva and Anderson [27] found that student outcomes were related to the science training of teachers. Several researchers found that secondary students' pupils' perception that a teacher finds the subject matter interesting may enhance pupils' interest and their later decisions about future course selection [28]; [29]; [30]. George and Kaplan [4] showed that students' attitudes are influenced by science experiments and activities that are related to teacher professional preparation.

In the present study, we investigated Slovakian 13/14 year old (8th grade in elementary school or 4th grade in grammar school) students' attitudes toward palaeontology with respect to students' perception of their palaeontology (=biology) teacher especially in dimension of teacher's interest toward palaeontology, type of school and gender. In agreement with Huang (2006) we consider that perceptions might be criticized as lacking objectivity, but measuring perceptions is likely to be a more realistic and informative approach. We have chosen palaeontology either because there are no reports on student's attitudes toward this discipline and because attitudes toward geology and palaeontology in Slovakian 8th graders have been currently found to be most negative comparing with attitudes of students from other grades [23]; [22]. Moreover, because there are only limited reports on students' understanding of palaeontology focused mainly on geological time [31]; [32]; [33]; [34]; we also investigated a relationship between student' attitudes and achievement in palaeontology measured by 'spider concept maps'. In general, students recognize geological eras simply such as "extremely ancient" and "less ancient" [34]. This results in various misunderstandings of geological time. For example, seventeen year-old British students demonstrated some fundamental misconceptions of geological time: they confused the Big Bang with asteroid impacts; they conflated the recent Ice Age with general climatic cooling; and they connected dinosaur extinction with the Ice Age [34]. The significance of gender was also involved in the research, reported here, because there are reports considers ones gender differences in soil sciences, but not in palaeontology [35].

The research was conducted both in grammar schools and elementary schools students. The former group represents selection students who decided to study in grammar schools when 10 years old (grade 5) and their study take 8 years. The latter group is represented by students from "traditional" school system which consists from a study in elementary schools from grade 1 to 9. The former group represents selected students (based on their knowledge score) with interest to study both humanities and natural history sciences. Teaching palaeontology in these two types of educational systems differs with respect to the content. Grammar school students use a translated textbook from English. This text has three illustrated appendices containing information about prehistoric time, the phylogeny of organisms, including human, as well as several meaningful tasks for pupils. In contrast, the textbook for elementary schools lacks some basic palaeontology concepts. They do not have a detailed illustrated appendix. For example, the Lohicer is included in the text used by grammar school students. In addition, several tasks for pupils in this book possess any problem solving exercises. However, despite these differences, the content of the palaeontology chapters in both two textbooks is very similar and both two types of schools are teaching palaeontology with the same time allocation.

1. 1. Research questions

Our research on students' attitudes toward palaeontology was focused on the followed questions:

1. What are Slovakian students' attitudes toward palaeontology?
2. Is there any relationship between achievement in palaeontology measured by spider concept maps drawn by students and attitudes toward palaeontology?
3. Does students' perception of their palaeontology teacher influence their attitudes and achievement in studying palaeontology?
4. Are there any differences in achievement and attitudes between elementary and grammar school students?
5. Are there any differences in attitudes and achievement with respect to the gender of students?

2. Materials and methods

A total of 285 students (146 females and 139 males) from three elementary schools (n = 124), and five grammar schools (n = 161) in western Slovakia participated in the study. The age of participants ranged from 13 – 15 years (M = 13.96, SE = .03), only one student was 16 year old. All students were familiar with palaeontology as a school subject. This is taught in 8th grade. The selection of participating schools was random all teachers asked to participate agreed to administer the questionnaires during normal lessons.

2. 1. Construction of Palaeontology Attitude Questionnaire (PAQ)

The construction of palaeontology attitude questionnaire (PAQ) followed suggestions described by Likert [36] and current research of science attitudes [9]; [8]; [12], [22]; [23]. The questionnaire contains 28 items that were scored by participants from "strongly disagree" (1) to "strongly agree" (5). Half of items (n = 14) represented negative attitude and were coded in a reverse order. Wording of categories was developed following original categories previously used in examining students' attitudes toward chemistry [12] and science [9]. However, several items that related more closely to palaeontology and students' attitudes toward palaeontology teachers were newly developed by ones authors of this paper.

2. 2. Validity and reliability of Palaeontology Attitude Questionnaire (PAQ)

Validity of PAQ was maintained by two ways. First, a panel of three biology teachers and two biology educators at university level, independently and separately reviewed the PAQ items. Firstly, they were asked which items clearly indicated favourable and unfavourable attitudes towards palaeontology. Secondly, results of a pilot study, in which 80 students of the same age category participated, were carefully reviewed. Five items that did not correlate with other items at the level of Pearson correlation r = 0.2 and more were excluded [12]. The final version of the questionnaire in which all items that were considered inappropriate by the panel of expert and/or that did not correlated were thus deleted, was administered to the other 285 students. Data from the pilot study were omitted from future analyses.

Final data obtained from 285 students were subjected to factor analysis with Varimax rotation in order to examine dimensions of students' attitudes toward palaeontology. Factor analysis resulted in seven common factors with eigen values > 1.0, which all together explain 54.5 % of variance. After examination of scree – plot and deleting all items with factor loadings < 0.45 or items that loaded with more than one factor [37], we decided to use five of these factors explaining 47.3 % of the variance. The full version of PAQ with factor loadings is shown in Table 1.

A reliability of the whole PAQ with remaining 23 items, indicated appropriate reliability (Cronbach's alpha α = .87), because tests with alpha values > 7.0 are generally considered reliable [38]. Cronbach's alpha values for each dimension separately are provided in Table 1. Alpha values are comparable with those of Fraser [39], Francis and Greer [18], and Dhindsa and Chung [9].

Table 1. Factor structure of students' attitudes toward palaeontology. Numbers represent values with greatest factor loadings.

Items	School interest α = 0.87	Teacher α = 0.75	Out-of-school interest α = 0.77	Career α = 0.52	Science discipline α = 0.61
I would be happy if we would have palaeontology more frequently	0.79				
I find the palaeontology courses more interesting than other courses	0.76				
Learning palaeontology in the school is loss of my time	0.58				
I find the palaeontology courses very interesting	0.74				
During palaeontology courses, I am bored	0.59				
Palaeontology is one of the most fascinating chapters in geology	0.56				
I hate palaeontology courses	0.54				
My biology teacher study palaeontology in his free time		0.75			

My biology teacher has great knowledge about palaeontology		0.72			
My biology teacher does not have interest about palaeontology		0.65			
My biology teacher is very interested about dinosaurs and fossils		0.77			
I would like to visit a places with dinosaur' fossils			0.59		
I like watching films about the origin of earth			0.67		
I am very interested if there is a site with prehistoric organisms somewhere around my home			0.53		
I would like to visit a museum with prehistoric fossils and skeletons			0.58		
Palaeontology is less important in comparison with other sciences			0.71		
I am not planning to study palaeontology in the future				0.45	
Palaeontology knowledge is not important for my future career				0.66	
I would like to be a palaeontologist				0.60	
Thanks to a paleontology, we can know more about the history of earth					0.64
Palaeontology is out of date science					0.51
I solve palaeontology exercises easily					0.46
Palaeontology significantly contributes to the development of other science disciplines such as zoology and botany					0.71
Eigen value	8.3	2.6	2.1	1.4	1.2

These authors reported alpha values for item subscales (dimensions) .58 and higher. In our case, only Career dimension showed relatively lower reliability, probably due to a limited number of items that loaded in this dimension. However, because this factor, which explains a minor rate of variance (4.31 %), the low alpha could be still considered satisfactory ([12]).

The values of discriminant validity, the mean of correlation values of a sub-scale with other scales, ranged from .1 to .42. Dhindsa and Chung [9] reported values of discriminant validity from .12 to .22. Thus, values of Cronbach's alpha and discriminant validity suggest that our research instrument is internally consistent and reliable for interpreting the data reported in the study.

2. 3. Concept maps

We used a 'spider' concept maps, a modified version of Novak and Gowin's [40] maps, to measure students' knowledge of four main geological periods (Palaeozoic, Mesozoic, Cainozoic and Post-tertiary era). The 'spider' concept map is organized by placing the central theme or unifying factor in the centre of the map. Outwardly radiating sub-themes surround the centre of the map. Our central themes were four geological periods and sub-themes were 16 basic concepts belonging to these four geological periods. These concepts were identified after independent discussions with two biology teachers. All concepts were used after careful review of the palaeontology curricula of both grammar and elementary schools. Palaeontology curriculum in both the grammar and elementary types of schools contains basic facts about the phylogeny of organisms and geological evolution from the Achaean to Post-Tertiary era. Detailed description of concepts is provided in the Results. Students were instructed to review all concepts placed in the margin as first and read to all four geological periods placed in the centre of a sheet of paper (A4 format). The instruction given to students was 'assign four concepts to each geological period to create a meaningful concept map of integrated knowledge.' Students were assured that the questionnaire was not a test, and exhorted not to copy from each other during completing their questionnaires. Concept maps were given after the PAQ on a single occasion. Students were not given a time constraint.

3. Results

3. 1. What are students' attitudes toward palaeontology?

Figure 1 shows means of five palaeontology attitude dimensions. Means > 3.0 indicate positive attitudes and means < 3.0 indicate rather negative attitudes. Values close to 3.0 could be considered neutral. Students showed relatively positive attitudes toward paleontological science and out-of-school palaeontology interest. Attitudes toward the palaeontology teacher were considered neutral. Interest towards palaeontology in school, and attitudes toward a possible future career in palaeontology was rather negative.

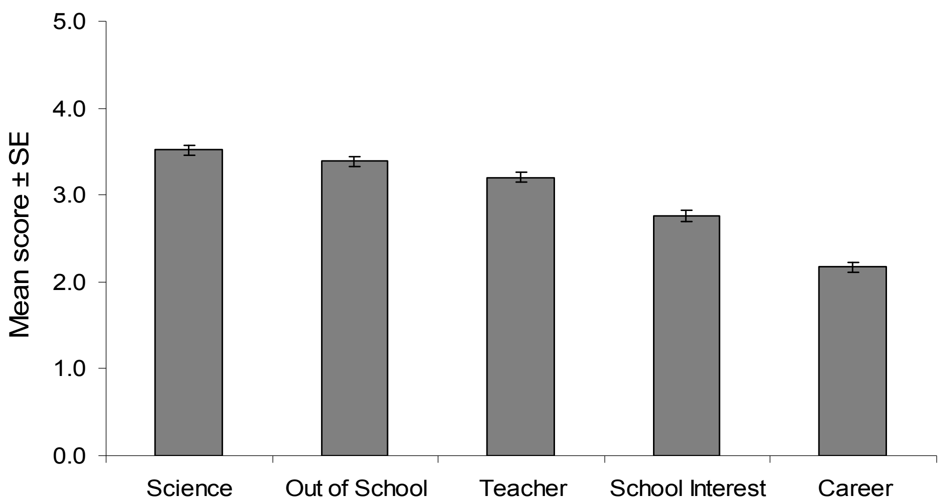

Fig. 1. Means of the five Palaeontology Attitude Questionnaire (PAQ) dimensions.

3. 2. Associations between pupils' palaeontology attitudes dimensions

A series of correlations (Pearson) between attitude scores show that the Teacher dimension correlated just with school and out of school interests, but these correlation coefficients were small (Table 2). This finding that the effect of teachers on their students was somewhat weak. In contrast, school and out of school interests showed highest correlation. There were also several positive relationships between school and out of school interests and attitudes to career and palaeontology science.

Table 2. Relationships between five attitude dimensions measured by Pearson correlation coefficients. Asterisks denote statistically significant differences. * p < .05, ** p < .01, *** p < .001. Unmarked values are not significant with others.

	Teacher	Out of School Interest	Career	ScienceDiscipline
School Interest	0.18**	0.60***	0.47***	0.46***
Teacher		0.15*	0.04	0.09
Out of School Interest			0.34***	0.48***
Career				0.14*

3. 3. What factors influence students' attitudes toward palaeontology?

We used a multivariate analysis of variance (MANCOVA) for further examination of potential factors that could influence students' attitudes toward palaeontology. In order to use a most objective approach for examining the effect of teacher on students' attitudes, we could not use only a teachers identity as a factor, because its' effect can be alternatively explained as a result of effects of different schools, not as an effect of a teacher. We therefore used residuals from teacher dimension (controlled for the teacher identity) as a covariate. Gender and the type of school were defined as categorical predictors (factors) and score from remaining four attitude dimensions were defined as dependent variables. Results are shown in Table 1.

The gender of the teacher did not show a significant effect on students' PAQ score. However, differences attributed to school type showed statistically significant differences in mean scores. The multivariate $\eta 2$ value of .07 indicated 7 % of multivariate variance of the dependent variables was associated with the effect of school type. Other effects were smaller than 5 % (Table 3).

One additional ANOVA on the perception of teachers by students with respect to school type, revealed that grammar school teachers were perceived more positively than were elementary school teachers ($F(1,281) = 12.92$, $p = .0004$). However, but there was not an effect of gender ($F(1,281) = .16$, $p = .69$) or an interaction between school and gender ($F(1,281) = .01$, $p = .92$). These findings suggests that elementary teachers were perceived more negatively than grammar school teachers by their pupils (Mean ± SE, 2.97 ± .08 and 3.38 ± .07, n1 = 124, n2 = 161).

Table 3. Results of a multivariate analysis of variance (MANCOVA) examining effects of selected factors on four palaeontology attitude dimensions.

Factor	Wilks' λ	*F*	Df Effect	Df Error	*p*	η^2
Teacher dimension	.98	1.20	4.00	277.00	.31	.02
School	.93	5.05	4.00	277.00	<.001	.07
Gender	.98	.33	4.00	277.00	.26	.02
Gender × School	.96	2.70	4.00	277.00	.03	.04

A detailed analysis of univariate results revealed that the school type statistically significantly influenced the mean score from each dimension, except for the Career dimension (F(1,280) = 2.64, p = .11). The most significant effects were found in the dimension of Out of school interest (F(1,280) = 16.2, p < .0001), then School interest (F(1,280) = 14.7, p = .0002), and Science discipline (F(1,280) = 8.7, p = .0004) (Fig. 2). The teacher effect influence showed only a weak effect on School interest (F(1,280) = 4.1, p = .044), but all other variables remained non-significant (all p – values > .24).

Although gender showed no significant effect on multivariate results, univariate ANOVA revealed that females were interested in palaeontology science more than were males (F(1,280) = 4.2, p = .04). Other variables were not influenced by gender (all p – values > 0.42).

Inspection of the gender × school interaction revealed that this effect was statistically significant only in the Out of School dimension (F(1,280) = 4.29, p = .039). A Tukey post-hoc comparison of means showed that grammar school females had higher mean score than elementary school pupils.

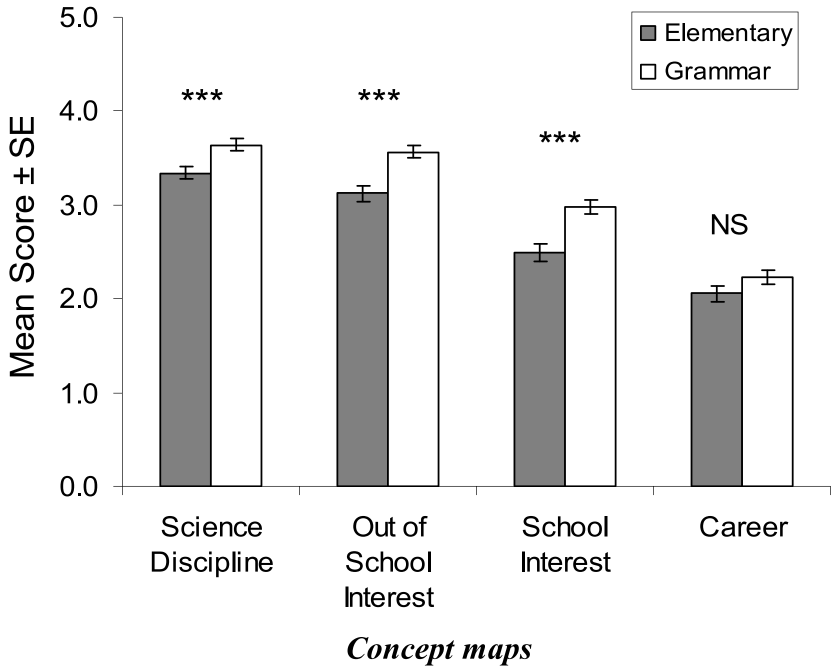

Fig. 2. Differences in attitudes toward palaeontology between elementary (n = 124) and grammar school pupils (n = 161) controlled for the effect of teacher. Asterisks (***) denote statistically significant difference (p < .001), NS = not statistically significant.

3. 4. Descriptive characteristic of main results

It is inappropriate to label any concept map 'typical' or 'characteristic' of a larger population of participants, but such maps do suggest some trends which are apparently related to the educational level of the individuals who construct the maps [41]. However, the 'spider' map used here is restricted in terms of the number of concepts and their relationships, typical examples therefore can be given. We present an example of a concept map with a high score (score 14/16, 87.5 %) drawn by Peter (pseudonym), an 8th grade student attending grammar school.

Palaeozoic organisms (trilobites, fish, and horsetail) and one of most important abiotic factor available in the panel of concepts (oxygen) were correctly included in the first concept map. Similarly, the sun, ammonites, coniferous trees and brontosaurs were correctly included in the Mesozoic concept map. However, although birds, nummulities and thermal oscillation were correct for the Cainozoic concept map, Peter, the boy who constructed this map, also included bears instead of rhododendrons to a third concept maps. The same error occurred in the Post-tertiary concept map, in which besides Neanderthal man, mammoth and iceberg, the rhododendron was placed instead of a bear.

In general, students frequently placed the sun instead of oxygen on the Palaeozoic concept map. Fish were also considered relatively less as Palaeozoic organisms. Most errors were found in the Mesozoic and Cainozoic concept maps (see below). Birds, fish and horsetail were frequently placed within Mesozoic fauna and flora. In the Cainozoic era, coniferous trees, iceberg, bears and brontosaurs were the categories most often shown incorrectly. Such a result indicates that Cainozoic era is viewed as a mixed result of previous and forthcoming geological periods. The Post-tertiary era was best understood (see below) compared with others so, just showing rhododendrons and thermal oscillations as part of this era can be considered as a relatively common misunderstanding of the participants in this study.

3. 5. Factors influencing pupils' achievement in palaeontology

A multivariate analysis of variance was used to examine how gender, teacher (measured as Teacher dimension controlled for the teacher identity) and school type (between – subject effect factors) influences scored from the concept maps constructed by students. The mean score from four geological periods was used as within – subject effect variables which allowed us to examine differences between periods.

As shown in Table 4, the effect of teacher, school and gender significantly influenced the score achieved by students from concept maps. The more positive attitude toward the teacher resulted in a higher score from concept maps. Females gained a higher score from the constructed concept maps compared with males. However, grammar school pupils showed a better knowledge than did elementary school pupils. The effect of the teacher accounted for 6 % of total variance, but other factors explained less than 5 % of variability of multivariate variance of dependent variables.

A detailed analysis of (within effect) variables showed that student' concepts from the Post-tertiary and Palaeozoic era were relatively better developed than their concepts about the Mesozoic and Cainozoic era (Fig. 3). All $\eta 2$ – values of interactive effects of between subjects factors were lower than .01 and therefore explained less than 1 % of variance of multivariate variance of pupils' knowledge. Therefore, the effect of geological periods with η2 = .21 should be considered a most important variable, because it explains 21 % of multivariate variance of four dependent variables.

Table 4. Multivariate analysis of variance (MANOVA) of students' knowledge from palaeontology.

Between – subject effects	SS	DF	MS	F	p	η2
Teacher dimension	4447.74	1	4447.74	2420.14	< .0001	.02
School	12.94	1	12.94	7.04	.008	.06
Gender	31.90	1	31.90	17.36	< .0001	.008
Gender × School	4.03	1	4.03	2.19	.14	.001
Error	.93	1	.93	.50	.48	
Within – subject effects	514.58	280	1.84			
Geological periods (GP)	111.89	3	37.30	72.85	< .0001	.21
GP × Teacher dimension	5.82	3	1.94	3.79	.01	.01
GP × School	1.84	3	.61	1.2	.31	.001
GP × Gender	.87	3	.29	.57	.64	.004
GP × School × Gender	1.03	3	.34	.67	.57	.002
Error	430.07	840	.51			

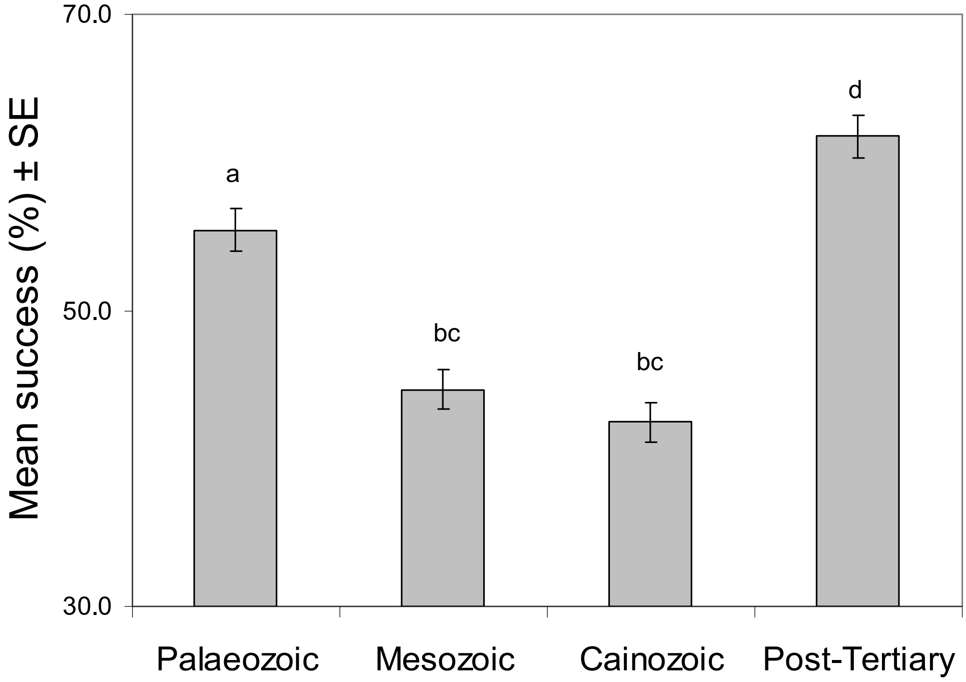

Fig. 3. The mean score from four geological periods obtained from concept maps. Letters 'a – d' denote differences in means based on Tukey post-hoc tests (a vs. others and d vs. others, p < .01, bc vs. bc = not significantly different).

3. 6. Is there a relationship between attitude and knowledge?

Further analysis of data was conducted on the data to determine whether attitudes are related to knowledge measured by concept maps. Students' attitudes regarding school and out-of-school interest, teacher (controlled for teacher identity), palaeontology science and career were chosen as predictor variables. The concept maps total score [40], controlled for the effect of school (elementary or grammar school), was defined as the dependent variable. Using the stepwise method of multiple regression, a significant model emerged in which the Teacher dimension entered a model ($F(1,283) = 7.11$, $p = .008$, $R2 = 0.025$). Effects of school interest ($\beta = .002$, $p = .97$), out of school interest ($\beta = .057$, $p = .34$), career ($\beta = -.07$, $p = .24$), and science discipline ($\beta = .01$, $p = .08$) were not significant. The model remained unchanged even after controlling all variables for the effect of school type.

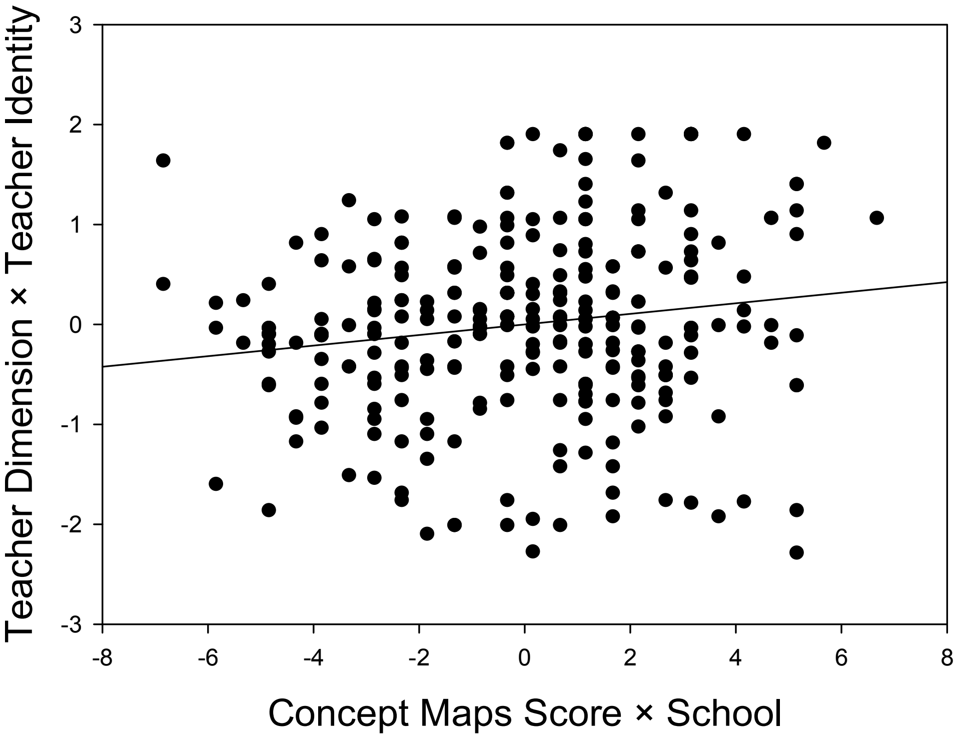

Fig. 4. Relationship between concept maps score and attitudes to palaeontology (biology) teacher ($n = 285$, $p = .008$).

4. Discussion

The results of this study show that the attitudes of Slovakian pupils' toward palaeontology are multidimensional and greatly depend on the effect type of school at which they are studying. The effect of the teacher and the differences caused by gender of pupils revealed only a weak influence on the pupils' attitudes. Paleontological knowledge, examined by spider concept maps, was influenced mostly by the teacher, school type and gender. Interestingly, the Palaeozoic and Post – Tertiary era were better understood comparing with Mesozoic and Cainozoic era. These results might contribute to better understanding of the role of teacher in the development of pupils' attitudes to science.

Attitudes to paleontological science and out of school interests were more positive than school attitudes and career in palaeontology. Negative attitudes to future career in this area is similar to pupils' lack of interest in a career in biology in Slovakia [23]; [8]; [22]. Unlike to showing an interest in biology career, females showed no greater interest in a paleontological career than did males. This finding suggests that palaeontology, unlike to biology, is viewed in the same way by both boys and girls. This finding contradicts result the Dawson's [35] report that males show greater preferences for soil sciences on one hand, but this confirms previous reports which showed that there are no gender differences among 8th graders [23]; [22].

Although the effect of the teacher on pupils' attitudes towards palaeontology was weak, it is important to note that teachers significantly influenced pupils' school interest. Unfortunately, there is no effect of teacher on other dimensions of attitudes. Considering that school and out of school interests in science are related [42;46] the link between teacher influences and pupils' attitudes toward palaeontology should be strengthened by closer relationship between pupils' perception of a teacher and school interest toward science. Current evidences revealed that teachers' influences might lead through enhancing pupils' interests by practical works and experiments in science lessons [4]; [10]. Furthermore, considering that there is up to one hour of practical work in palaeontology in the Slovakian biology curriculum, it is not surprising that pupils' school interest in this discipline is low. In addition, there is minimal financial support for science education equipment in Slovakian schools. This fact may make practical works unusual and ineffective. Fortunately, there are relatively positive attitudes to palaeontology science which should be embraced by the teacher to improve pupils' school interests.

Elementary pupils' perception of a teacher was more negative compared with grammar school pupils. This phenomenon can be discussed from the perspective of three main components that influence attitudes to science [11].

First, it can be argued that teacher's professional competences could be responsible for more positive perception of grammar school teachers [28]; [4]; [29]. In fact, undergraduate preparation of elementary and grammar school teachers differs with respect to the number and/or content of science courses. However, this applies only to teachers who teach 15 – 18 year old pupils. The professional preparation experience by teachers which could result in greater interest in palaeontology in the present study, did not differ. Therefore this factor could not cause differences in pupils' attitudes toward their biology teacher.

Secondly, the learning environment could be responsible for differences in pupils' attitudes [39]. Considering possible school type environment differences, which could influence pupils' attitudes and knowledge to palaeontology, we cannot provide detailed descriptions of all possible effects because this was not the primary aim of our study. However, the third component, selection of pupils' (probably more motivated to study science) to grammar schools, would be most responsible for differences in attitudes toward palaeontology. Moreover, at this stage it is very hard to distinguish between pupil' and environment variables considering that selection of pupils to grammar school is non random, but generally more talented pupils enter high school more frequently (unpublished data). Quek, Wong and Fraser [43] showed that the gifted students perceived the actual and preferred chemistry laboratory environment and their chemistry teacher more favourably than the non-gifted. Although these authors did not investigate teacher's involvement to chemistry explicitly, it is clear that Slovakian grammar school students perceive their teacher more favourably comparing with elementary school children and this attitude can be linked with their higher order thinking skills. This area however requires further research.

The link between attitude and achievement as measured by concept maps on this study corroborate findings of other works e.g. [11-13]. Importantly, we failed to find a statistically significant effect of attitude dimensions on pupils' achievement, with the exception of the Teacher dimension. Moreover, because these results were almost identically significant even after controlling than analysis for the effect of the school type, it can be suggested that the perception of pupils of the interest of their teacher in palaeontology positively influenced the achievement of these pupils. This understanding of pupils of selected geological events, as examined by spider concept maps, confirms Trend's [34] findings that pupils recognize few (two or three) geology eras. This is because researchers have established that, the level of understanding that exceeds 50 % success in tests has been found only with respect to knowledge of the Palaeozoic and the Post Tertiary era. In contrast, the Mesozoic and Cainozoic era were poorly understood by pupils.

The difference in pupils' achievement of pupils caused by their school type are probably linked either with favorable perception of the teacher (as discussed above) and probably with other variables, such as the learning environment and the interest of the pupils to science and their thinking skills. Deeper understandings of these variables could be explored in further work for the benefit of education in this aspect of science [44-56].

5. Conclusions and educational implications

This was the first study conducted into attitudes and achievement in palaeontology in Slovakian elementary and grammar schools. Thus, the findings of the study provide useful information for the teachers of palaeontology, about effects of their knowledge and enthusiasm for palaeontology on both the achievement and attitudes of their pupils. Additionally, these findings are important for planning future strategies in the teaching of palaeontology, which could take into consideration the pupils' inconsistent understanding of the main geology eras. With the continued emphasis on effective practices in teaching and learning in the educational community the findings of this study provide a better understanding of the type of school and the teacher-student perceptions that could help the elementary as well as the grammar school pupils to learn better are applicable to other countries.

In terms of teacher preparation, the findings obtained from the PAQ indicate a need for universities to prepare teachers who are teach palaeontology who are positively influence pupils' learning outcomes in palaeontology. It would be helpful to know more about teachers' own views of palaeontology and variables that influence their interest in this area.

In terms of practical implications, teachers should try to encourage more positive attitudes toward palaeontology through increasing the school interest of pupils in school. This positively correlates with other attitude dimensions. Both teachers and pupils could benefit from better equipped classrooms or science laboratories which could contain palaeontological collections. This would improve pupils' views of palaeontology science and interest in the future career in this area. The teachers could both, incorporate more real-life investigative work into laboratory activities, field trips and adopt a more creative teaching and learning approach. Curriculum developers should plan more practical work in the palaeontology because curriculum influences pupils' attitudes to this science in a positive way.

A further implication would be that palaeontology textbooks for both elementary and grammar school pupils, should be evaluated critically and only the more useful textbook in terms of the graphical presentation, palaeontology concepts, size or quality of tasks, should be recommended for teaching.

Palaeontology is a critical part of the Science curriculum and present climate of various evolutional and creational theories. Part of child's right to education (European Human Rights) is to have balanced education and our aim as science teacher is to provide our students with the skills and knowledge to evaluate the various theories presented in the Darwin celebration year.

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