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Effects of keeping animals as pets on children's concepts of vertebrates and invertebrates

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Abstract

Looking after pets provides several benefits in terms of children's social interactions, factual and conceptual knowledge about these animals. In this study we investigated effects of rearing experiences on children's factual knowledge and alternative conceptions about animals. Data obtained from 1541 children and 7705 drawings showed very strong bias towards rearing vertebrates and a general ignorance of invertebrates. Experiences with rearing animals significantly contributed to children's knowledge about animal' internal organs. Children who reported keeping two or more animals acquired better scores in our study than children keeping only one or no animals. Moreover, the misclassification of invertebrates was not influenced by children's experiences of keeping animals. Although girls showed better knowledge about the anatomy of animals and actually kept more animals than did boys, they also more frequently misclassified invertebrates by drawing bones inside the bodies of the animals, hence allocating them to the vertebrates. We propose that science activities with animals should be more focused on rearing invertebrates and improving children's attitudes and knowledge about them.

Introduction

Children's acquisition of biological knowledge has attracted a number of psychologists and educational researchers. Carey (1985) claimed that children before around the age of 10 (i.e. below grade 5 in Slovakia) make predictions and explanations for biological phenomena based on intuitive psychology. This means that young children misunderstand biological phenomena as a psychological one and thus have an undifferentiated psychology and biology theory (Jaakkola & Slaughter, 2002). Carey's approach has been evaluated and criticized (e.g.

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Hatano & Inagaki, 1997) and current experimental works rather suggest that children's biology is constructed through daily experience in the early years (Hatano & Inagaki, 1997). Teixeira (2000), using as an example the human digestive system, they found that children posses biological knowledge as an independent knowledge domain from the age of 4. Jaakkola and Slaughter (2002) proposed the same for 4 – 6 year children for their understanding of body functioning.

The evidence thus suggests that a child's biology experience influences their concepts about living organisms. However, few studies examined this question empirically. Inagaki (1990) investigated 5 year old children's knowledge about goldfish. He found that children who had experienced keeping goldfish acquired a greater amount of both factual and conceptual knowledge about goldfish compared with children who had never raised any goldfish. In addition, the goldfish-raising children could use their knowledge about goldfish as a source in making predictions about the anatomy of an unfamiliar animal (a frog). Inagaki thus concluded, because there were no differences in the two groups in reasonable predictions for humans, that differences in factual and conceptual knowledge between groups were "primarily due to the specific experience of raising goldfish" (Inagaki, 1990, p. 119). Strommen (1995) found that primary children living in a rural habitat (i.e. closely to a forest) had better knowledge about forest inhabitants than did urban children. More frequent visits to the forest by children resulted in a better knowledge amongst those children of the organisms living in the forest. Tunnicliffe and Reiss (1999a) found that basic knowledge about animals is more influenced by information from home and direct observations. However, in contrast they found that books, school or multimedia seemed to be relatively less important sources of knowledge about animals for the children interviewed. Some other researchers (e.g. Shepardson, 2002), investigating children's ideas about insects, did not examine the effect of children's personal experiences on their knowledge about insects explicitly. More currently,

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Tarlowski (2006) found that the effects of direct experiences with nature (examined indirectly by comparing rural vs. urban children) and the biological expertise of parents affected the concepts of humans, mammals and insects held by 4 year old children.

This brief review shows that there are a limited number of works examining the effects of children's direct biology experience on their knowledge about animals. Moreover, the majority of existing work has been carried out mostly on preschool or primary school children and with limited sample sizes, which make generalization of these findings disputable. A very specific problem in this topic is research of children's misconception (i.e. conceptions that differ from those of scientists, see Fisher, 1985) or alternative conception (Trowbridge & Mintzes, 1985, 1988) about animals. While *stable* alternative conceptions develop before and during the early school years and persist relatively unchanged into adulthood, progressive alternative conceptions seem to yield more readily to formal instruction and/or nonschool experiences (Trowbridge & Mintzes, 1988). Yip (1998) distinguished between misconceptions that are generated either through children's life experiences or 'naive' explanations related to more complex or abstract phenomena which are not related to personal experiences. Some misconceptions are formed as a result of a lack of understanding during instruction and other sources of misconceptions come from teachers (Yip, 1998). The present study is focused on concepts about animals in children of various age groups. Thus, concepts of younger children could not be affected by formal instruction and could not be attributed to the results of personal experiences. In contrast, alternative conceptions of animals in older children could be attributed to a lack of understanding during formal instruction in biology. The former group could be named 'naive' concepts (Mintzes, 1984) and the latter group could be named 'misconceptions' (Fisher, 1985). We used only a single term 'alternative conception' (Arnaudin & Mintzes, 1985) for a simple description of concepts that are different from scientific conceptions throughout the text.

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Alternative conceptions in science may be characterized as follows: they are found in males and females of all ages, abilities, social classes, and cultures. Such everyday ideas or alternative conceptions serve a useful function in the everyday lives of people. However, these everyday beliefs are often resistant to conventional teaching approaches and they interact with knowledge presented by teachers, with resultant unintended learning outcomes. These alternative conceptions may resemble the ideas of previous generations of natural philosophers; they are products of direct observation, everyday language, the mass media and peer culture and they are found frequently amongst teachers as well as students (Munson, 1994; Yen, Yao, & Chiu 2004).

Several research reports showed children's alternative conceptions in classifying animals. For example, Bell (1981) found that only 50 % of children knew that frogs are amphibian. Approximately one-third of elementary school children incorrectly thought that a tortoise is an amphibian (Bell, 1981; Braund, 1998; Yen et al., 2004). Similarly, visual absence of limbs in snakes and their movement similar to worms probably is why snakes are frequently misclassified as invertebrates (Braund, 1998; Yen et al., 2004). Also, from the children's point of view, penguins are mammals, because they are flightless and live in the sea (Braund, 1991; Trowbridge & Mintzes, 1985, 1988). Habitat and movement patterns seem to be the most important cues when children classify an animal (Kattmann, 2001). The effect of children's first-hand experiences on their ability to classify animal are poor. Only Braund (1998) noted that those children who visited a zoo or museums or engaged in bird-watching and fishing were more successful in animal classification than other children. However, his conclusion is based on a limited sample size (115 children from 6 age groups) without providing any statistical evidence.

Purpose

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This cross-age study was focused on the effects of keeping various animals themselves on children's knowledge and alternative conceptions about the internal structure of animals. The ideas and knowledge of children about the internal structure of animals was selected for study because this is an integral part of biology. Children's interest in biology correlates with their out-of-school experiences (Uitto, Juuti, Lavonen, & Meisalo, 2006), thus it is reasonable to test whether any relationship between the experiences had in keeping animals and knowledge about animals (in terms of animal internal structure) exists. Moreover, previous research on children's ideas about internal skeletons of animals (Tunnicliffe & Reiss, 1999b) did not examine children's biology experiences on their knowledge about skeletons.

This paper explores the following questions: 1. What is Slovakian children's knowledge about internal structure of vertebrates and invertebrates? 2. How much does children's concepts about vertebrates and invertebrates change from first to ninth grade (from age 6 to age 15)? 3. Does the keeping of animals have any effect on children's concepts of internal structure of vertebrates and invertebrates? 4. Does keeping animals have any effect on children's conceptions in classification of invertebrates?

Methods

A total of 1544 children (6 – 15 years old) from six randomly selected Slovak elementary schools participated in the study. These schools had between 400 – 1000 children on the roll of the school. After teachers agreed to participate in our research, one of us visited the school and administered a questionnaire with tasks (see below). Initially, each child was given a

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sheet of paper with the questionnaire which asked for several details that could potentially affect their knowledge about animal anatomy. The children were asked 1) for their age/grade, 2) sex, 3) if they kept any animals as pets, and, if yes, 4) what animal species they kept themselves as pets. A few children also included hens that can be classified as farm animals rather than pets. We included these children in the analyses, because even after removing them, it did not qualitatively change the results of the study. We also controlled for the effect of parents' education level that could influence children's attitudes toward science (George & Kaplan, 1998). From this demographic data we indirectly inferred about the socioeconomic background of the children (McLoyd, 1998) as follows: completion of only elementary school by parents was classified as Level 1, high school as Level 2 and university as Level 3. Because mothers' and fathers' educational level significantly correlated ($r = 0.53$, $p < .001$, $n = 1541$), we used the mean level of both parents educational level in the analyses.

Both taxidermically prepared invertebrates (the Stag beetle *Lucanus cervus* and the crawfish *Astacus astacus*) and vertebrates (fish *Scardinius erythrophthalmus*, the European starling *Sturnus vulgaris*, and rat *Rattus norvegicus*) were shown to all children each on a single occasion making a total of 5 visits to the school in all. The order of presenting animals to children was random. The animals used were chosen because of their potential familiarity with Slovakian children. All of the species are relatively common in Slovakia.

After filling in the demographic data, the children were asked to draw what they thought was inside each animal specimen when the animals were alive. We recognised and scored separately the organ systems in each drawing to a seven point scale first designed and used by Tunnicliffe and Reiss (1999c, 2001) (Table 1, see Figure 1 for an example). Two of us separately and independently scored the drawings. In the few cases where our scorings differed we discussed the drawing until we agreed on the level to be awarded. The presence of an internal skeleton inside invertebrates was scored separately (see Figure 2 for an example),

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because its presence refers about misclassification of invertebrates with vertebrates. Three participants failed to provide details about their sex or age and were not included in statistical analyses. Thus, data from 7705 drawings obtained from 788 boys and 753 girls were included in analyses and were used as dependent variables in the statistical tests.

Insert Figs 1 and 2 somewhere here

Insert Table 1 somewhere here

Results

General patterns of children's ideas about what is inside animals

Scores of drawn vertebrates and invertebrates were submitted to the principal component analysis (PCA) which extracted only one factor and explained 76.5 % of total variance (eigenvalue = 3.78). This means that the children's drawings showed very consistent patterns and were internally related. Reliability analysis (Cronbach's alpha = 0.92) and high internal correlation between scores ($r = 0.7$) also confirmed this suggestion (Nunnaly, 1978). In order to maintain an objective approach when scoring children's drawings, one independent researcher unfamiliar with our previous ratings scored drawings of 100 randomly selected children from various age classes following the same criteria of the scoring system (Tunnicliffe & Reiss, 2001). We then examined the relationships between scores from the independent researcher and our original data obtained from the same 100 children by the use of Pearson correlation coefficient. We found highly significant correlations ranged 0.93 – 0.96

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(all p< 0.001) for score from each animal being drawn. These results also confirmed that our scoring system was reliable.

The most frequently organ drawn by approximately 2/3 of all children was the heart. Lungs, stomach, brain, intestines and liver were also drawn relatively often. In contrast, the endocrine, reproductive organs and muscles were drawn least frequently.

A comprehensive representation of the two or three major systems (level 6; 2.7 % of all drawings) or four or more organ systems (level 7; 0.05 % of all drawings) was relatively rare. Drawings of one (level 3; 30 % of all drawings) or more internal organs (level 4; 35 % of all drawings) in appropriate position were most frequent. A total of 942 drawings (12 %) contained one or more organs placed at random (level 2) and other drawings contained only silhouettes without internal organs.

The significance of animal being drawn

Figure 3 shows the mean level of drawings per each animal species that was drawn by each child (n = 1541). One-way analysis of variance (ANOVA) with a score per each animal species as the dependent variable and animal species as the factor revealed significant differences in the level of drawings between species ($F_{4,\,7700} = 25.406$, $p < 0.001$). A Tukey comparison of group means showed that the internal structure of crawfish did significantly differ from all other animals ($p < 0.001$). The stag beetle was drawn relatively better than the crawfish, but the mean level for the bird was significantly greater ($p = 0.003$) and the level for the mammal also tended to differ significantly from the stag beetle ($p = 0.07$). Fish tended to be drawn on somewhat lower mean level than the bird ($p = 0.06$) and the bird and mammal were drawn at a similar level ($p = 0.87$).

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A typical feature of misunderstanding of internal organs in invertebrates was drawing of a gaseous exchange system. Virtually all drawings of the stag beetle (35 % of children) included the respiratory system in drawings of the stag beetle and in drawings of crawfish 48 % of children included the respiratory system in drawings. These drawings showed a typical higher vetrebrate lung and did not contain breathing tubes (in case of stag beetle) or the plume-like gills that are located in gill chambers on each side of the body (in case of crawfish). These results could be attributed to lack of knowledge for children up to age 11. However, older children should recognise between vertebrate and invertebrate respiratory system, but we failed to find evidences for such a tendency.

Insert Fig. 3 somewhere here

The effect of age

As could be predicted, the mean level of drawings significantly increased as children became older (Fig. 4). More detailed data with respect to age differences are shown in Table 2.

Insert Table 2 somewhere here

This trend was consistent for drawings of all animal species. The lowest score was found among youngest children aged 6 – 8. After grade 3 (i.e. around age 9) the mean score rapidly increased. The former group of children typically drew one or more organs placed at random position inside an animal (level 2 – 3). These patterns correspond with Slovak biology curriculum. Children from grade 1 are unfamiliar with animal anatomy from being taught in a formal learning process. Children from grade 2 learn about basic morphology, but not about

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the anatomy of the honey bee, *Apis mellifera*. Even so, children in the end of grade 3 should be aware of basic facts of human anatomy. Thus, increasing scores slightly exceeding that of level 3 in children gained by grade 4 and 5 children could be attributed to their ability to make analogies between human and animal anatomy. Although 6th graders (age 11/12) should be aware about the internal organs of animals and reach relatively better scores than younger children, mean scores per each animal being drawn (around 3.5) indicate that these children drew up to two internal organs in appropriate position. Children from grade 9 (age 14/15) drew more than one organ in an appropriate position, but usually without deeper relationships between them (level 4). However, these children should have comprehensive knowledge about anatomy of animals (from grade 6) and human (from grade 7 and 9). It is interesting to note that the mean score of 7th graders who were currently learning human anatomy unexpectedly decreased relative to that of the 6th and 8th graders. This trend was consistent for all species, but the cause of this phenomenon remains unclear.

Insert Fig. 4 somewhere here

Keeping animals

A total of 1252 children reported experiences with looking after 2438 animals as pets. The types of animal kept were categorised into 16 animal taxa. The mean number of reported animals per children was 1.51 with a range of 0 – 12. Looking after a single animal was reported by 40 % of all children, about 20 % not looking after an animal, 17 % reported keeping 2, 11 % reported keeping 3 and 8 % cared for 4 animals. Keeping more than 4 animals was reported by the remaining 4 % of participants. The most frequently cited animals

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with respect to age are listed in Table 3. Dog, cat and hamster were reported by the majority of children. Although the distribution of the types of animal kept as pets across all age groups was rather equal, it must be noted that hamster and "other animals" were reported among older children more frequently. Vertebrates were cited more frequently than invertebrates as pets. Just 3 children reported keeping tarantulas (*Brachypelma* sp.) 1 reported ants of unknown species and other 6 children reported keeping unspecified insects. No further reports on invertebrates were found.

Insert Table 3 somewhere here

Although the proportion of boys and girls keeping animals was similar (631 of 788 boys, 80% and 621 of 753 girls, 82.5%), the mean number of kept animals per girl was significantly greater than that for boys (1.36 ± 0.05 vs 1.68 ± 0.05, $t = -4.8$, df = 1542, $p < 0.0001$) even after controlling for the effect of age.

Effect of raising animals on children's knowledge of vertebrates and invertebrates

Children were categorized according to their experiences with rearing animals into three groups: 1) No keepers (N = 327), 2) Children who reported keeping 1 animal (N = 633) and 3) Children who reported to keep two and more animals (N = 581). This categorization indirectly refers to experiences with keeping animals. One would predict that keeping more than one animal may be a result in greater personal experiences than keeping just one or no animal. Multivariate analysis of covariance (MANCOVA) with score per each animal drawn (dependent variables), category of the number of rearing animals (factor) and gender (factor) was controlled for the effect of the child's age. Parents' educational level (covariates) was

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used to test the effects of selected factors on children's knowledge about animal internal organs. The use of covariates yields tests uncontaminated by individual differences in age and parents' educational level.

The results showed a significant effect of animal rearing on the mean score of organ system from drawings ($F_{10, 3030} = 1.89$, $p < 0.05$). Gender (Girls > Boys, $F_{5,1515} = 2.55$, $p < 0.05$) and both two covariates (each $p < 0.001$) showed also significant effect. When the child reared two or more animals, the mean level of drawing were significantly higher than if they did not keep any animal or keep just one animal (Fig. 5). A Tukey post-hoc test for univariate results showed that mentioned differences were statistically significant ($p < 0.001$) for all animals. The effect of gender was significant for all animals except for the fish ($p = 0.15$) which suggests that girls have better knowledge about animal internal organs than did boys. Unfortunately, the extremely low number of children that reported keeping invertebrates (see above) did not allow us to examine whether children keeping invertebrates have also a better understanding of the internal organs of invertebrates than do other children.

Insert Fig. 5 somewhere here

Alternative conception of invertebrates

A substantial number of children's drawings of internal structures of invertebrates contained bones (Fig. 4). Bones more likely occurred in drawings of the Stag beetle (373 of 1541, 24.2 %) relative to crawfish (248 of 1541, 16.1 %) ($\chi^2 = 18.12$, $p < 0.001$).

Potential factors that could influence children's alternative conception of invertebrates were examined by multiple logistic regression which allows us to test multiple independent variables on a dependent variable which is binomially distributed (i.e. the presence or absence

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of bones inside invertebrates). The results are very consistent and show that age and differences caused by gender may explain the children's misunderstandings of internal structures of both crawfish and the stag beetle (Table 3). In both cases, age showed negative correlations with the presence of internal skeleton inside crawfish (Spearman rank correlation r_s = -0.22) and the Stag beetle (r_s = -0.19) ($p < 0.001$, respectively). Rapid decrease of incorrect drawings can be found out of grade 6 (age 11) where children are learning zoology in school (Figure 5). The most frequent occurrence of drawings with alternative conception was found among 2nd graders (age 7), but more than 10 % of older children (grade 8, 9 ages 13 - 15) still showed they held scientifically incorrect ideas about the internal structure of the two invertebrates (Fig. 5). Girls showed significantly greater number of drawings with alternative concepts relative to boys (Fig. 6).

Insert Fig. 6 somewhere here

Other factors remain non significant (Table 3). It is important to note that children who reported keeping at least one animal (1252 of 1541) also had parents with a higher educational level (ANCOVA controlled for the effect of age, $F_{1, 1526} = 14.69$, $p \leq 0.0001$), but neither keeping animals, nor parents' educational level influenced children's alternative conceptions *per se* (Table 4).

Insert Table 4 somewhere here

Insert Fig. 7 somewhere here

Discussion

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Our study provided an empirical evidence for the significance of keeping animals on children's factual knowledge about the anatomy of animals. Children with greater experience of looking after animals as pets showed a better knowledge when drawing internal organs of several animal species compared to children that did not report keeping any animal.

Effects of keeping pets and age of children

Keeping pets has been reported elsewhere to provide benefits in children's factual and conceptual knowledge about animals (Inagaki, 1990) and a positive attitude, better social interactions with friends and leisure activities (Paul & Serpell, 1996) and better health (Serpell, 1991) relative to non-keepers. Moreover, some researchers propose that pet keeping in childhood may have important effects on children's self-esteem, social skills and empathy (Covert, Whiren, Keith, & Nelson, 1985; Poresky & Hendrix, 1990). Thus, putting these evidences together, Slovakian elementary school children benefit from their keeping of animals in that their factual knowledge about the animal's internal anatomy is greater. The positive effect of children's age on their knowledge of anatomy is predictable. A similar effect was reported for children's understanding of animal skeletons (Tunnicliffe & Reiss, 1999b) or human (Reiss & Tunnicliffe, 2001) or animals' internal organs (Tunnicliffe & Reiss, 2001).

The significance of gender

More surprisingly, gender differences failed to play significant role in the above mentioned studies. We found that girls kept more animal that did boys, which is consistent with Lindemann-Matthies's (2005) finding from Switzerland. Girls' preferences for having pets can be explained by the higher interest toward wild animals shown by boys relative to 'traditional' domestic pets (Lindemann-Matthies, 2005). Better knowledge of the animal' anatomy and greater interest toward keeping pets seems to positively influence factual

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knowledge about internal organs of animals in girls, because girls scored better in drawings of internal organs than did boys. In contrast, girls expressed significantly more alternative conceptions about invertebrates than did boys which seem to contradict with girls' better score from internal organs of vertebrates and invertebrates. We suggest that these contradictory results may result from different attitudes of boys toward biology and consequently from their personal experiences with live organisms. Millett and Lock (1992) found that boys show a higher willingness for carry out experiments with live organisms. Unlike girls, boys also express a higher interest in wild animals (Strommen, 1995; Lindemann-Matthies, 2005). Thus, boys would have greater personal experiences with invertebrates from the field and consequently better concepts about the presence or absence of internal skeleton in the bodies of invertebrates.

Alternative conceptions about animals

Children are probably able to make analogies to unfamiliar animals (Inagaki, 1990), which was confirmed by a better score from drawings of invertebrates obtained by those children who kept animals (mostly vertebrates) regardless of their poor experiences with invertebrates. In contrast, however, the respiratory system of invertebrates is very different from those of higher vertebrates and possible 'making analogies' resulted in incorrect drawings of crawfish and stab beetle's respiratory systems. Incorrect drawings of younger children (up to grade 6) are perhaps reasonable, because they could be a simple result of their poor knowledge about respiratory system of invertebrates. However, the resistance to change the model of vertebrate to invertebrate respiratory system in children from grade 6 and older fit the criteria of alternative conceptions that are hard to change through the formal learning process (e.g. Munson, 1994).

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It must be noted that our analysis of children's drawings failed to find an expected level of knowledge about animal anatomy in Slovakian children. In Slovakian schools, biology is taught separately from other science subjects. Children aged 8/9 year (grade 3) are taught basic facts of human anatomy, such as position and function of major organs in the human body. Thus, the least expected level of organ systems is 2 or 3 (one or more organs placed at random), because children do not learn animal anatomy explicitly till this age group. These results are corroborated by our study. Then, older children learn more precise anatomy of vertebrates and invertebrates 11/12 (grade 6) and human anatomy 12/13 (grade 7). This means that children older than 11/12 year should have developed comprehensive concepts about placement and functions of particular organs and organ systems of various animals including both vertebrates and invertebrates. Ninth graders (age 14/15) have mixed model biology teaching which includes ecology, general zoology and human biology. Most of these topics serve as a final recapitulation and synthesis of children's previous biology knowledge. The mean score of these children should vary between 5 and 7 (i.e. at least one or more organ systems indicated). However, we show that the mean score of each animal being drawn did not exceed 4.5, which suggests that children drew mostly organs placed in appropriate position but without connections with other organs, thus showing no understanding of systems. Because no data from other, simultaneously used research method were obtained, we cannot be sure if Slovakian children's understanding of animal organs is poor or if there are serious problems with how children understand animal anatomy. Further research in this area is therefore necessary.

A significant proportion of children showed misunderstandings of internal organs of invertebrates and ascribed an internal skeleton to them in their drawings. This drawing of bones inside invertebrates was mostly among younger children (up to age of 10). This finding is in agreement with the rapid increase of children's biology knowledge in this age category

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(e.g. Carey, 1985; Teixeira, 2000; Jaakkola & Slaughter, 2002), but it also correlates with the Slovakian biology curriculum. Children aged 11 (grade 6) start to learn zoology which includes both the biology of invertebrates and vertebrates. Thus, the positive effect of school may be a significant predictor in elimination of children's misunderstanding of animal classification. Despite this, up to 20 % of children older that 11 still thought that crawfish or the Stag beetle has an internal skeleton. A very similar proportion of North Carolina elementary and junior school children classified a crab (comparable crustacean with crawfish) as vertebrate (Trowbridge & Mintzes, 1985). Trowbridge and Mintzes (1988) in their follow up study showed that crawfish was misclassified as a vertebrate by about 31 – 42 % of elementary and high school students. Interestingly, about 5 % of college biology majors expressed the same alternative conception. The spider was misclassified significantly less frequently (1 – 10 % of all participants) relative to crawfish which suggest that classification of crawfish is more problematic than classification of other invertebrates, perhaps due to large size that is typical mostly for vertebrates. In fact, classification of smaller invertebrates such as ants or spiders seems to be less problematic, because nearly all 8 – 10 year old children identified spider and ant correctly as invertebrates (Braund, 1998). Typical beetles are also correctly classified as insects virtually by all the 12 – 15/16 year old children (Braund, 1991). Our data confirm the current knowledge that alternative conceptions are present in other cultures (Wandersee, Mintzes, & Novak, 1994). The higher proportion of stag beetles drawn with internal skeleton is puzzling, but perhaps children's experiences with crawfish as food can explain this difference. During eating crawfish, children could see that no internal skeleton is present.

The role of interest in children's ideas about animals

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We cannot be sure if previous interest toward animals resulted in keeping pets and then activities e.g. reading books/watching films about animals, could influence girls' better knowledge, because our data have empirical, not experimental character. Girls' more positive attitudes toward biology have been shown by several researchers (Jones, Howe, & Rua, 2000; Keeves & Kotte, 1992; Osborne, 2003) which indirectly support the idea that owning pets together with interest in biology could result in higher factual knowledge about animal' anatomies. Girls are additionally more interested in human biology than boys (Baram-Tsabari & Yarden, 2005; Dawson, 2000; Uitto et al., 2006) and drawings of human anatomy is related to animal anatomy in children's drawings (Tunnicliffe & Reiss, 1999b; Tunnicliffe & Reiss, 2001). Therefore, girls' knowledge about human biology could be applied to animals.

Another significant problem identified in our study was a general ignorance of children about keeping and caring for invertebrates. Just a few children reported keeping spiders, ants, and some other invertebrates and this finding was probably a cause of relatively lower knowledge about crawfish and the stag beetle amongst the children. This is because adults and children tend to avoid invertebrates, because they are small and behaviourally and morphologically unfamiliar to humans (Davey, 1994; Kellert, 1993; Wilson, 1987).

Limitations of the study

Two aspects of our research limit results of the present study. First of all, we used only a single method of children's drawing to examine children's knowledge about animal' anatomy. We acknowledge that a more intensive methodology, for example one that combined drawings with subsequent interviews (see White & Gunstone, 1994), would allow children more fully to demonstrate their understanding. For example, in some cases it was difficult for us to identify certain of the internal organs drawn. Interviewing would have allowed us to resolve at least some such uncertainties. On the other hand, interviews generally result in a

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limited sample sizes, which is partly compensated by large number of participants used in our research. Also, we did not ask children if they live in farms or not. Recent studies suggest that experiences with interactions with animals, especially in early childhood, are associated with long-term animal related preferences and attitudes (Ascione, 1993; Paul & Serpell, 1993) and future career choice (Serpell, 2005). Although we are not aware whether owning a pet would result in different attitude/experiences with animals in comparison with keeping farm animals only, we agree that this categorization would also result in more accurate results. On the other hand, keeping farm animals such as hens were reported by a very small sample of children which make these comparisons problematic.

Secondly, our instruction of children to draw *what is inside animals* was not directly subjected on the presence of bones. More specifically, children were not aware that we are also interested in their ideas about bones inside animals an they could therefore include animal skeleton less frequently in comparison with other organ systems (Khwaja & Saxton, 2001). We, however, controlled for this possibility by excluding vertebrates from analysis of the presence or absence of internal skeleton and only invertebrates were used. This was because the absence of bones inside a *vertebrate* could not mean definitely that children have not developed a mental model of animal skeleton (Khwaja & Saxton, 2001). However, the presence of bones inside an *invertebrate* clearly refers about misunderstanding of internal skeleton and our analysis therefore does not contain misinterpretation of this fact. In other words, our results report the *least* number of children that misclassified invertebrates like vertebrates, but this number cannot be considered definite.

Conclusion

Keeping pets significantly contributes to children's factual knowledge about the anatomy of animals especially of vertebrates. Ignorance of invertebrates because the few children who

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keep such species probably influences the results about misunderstandings of invertebrates' internal skeleton. Another alternative, that is not mutually exclusive, is the lack of teaching about invertebrates. We suggest that biology/science teachers should encourage children to rear a diverse range of animals, particularly invertebrates that can be obtained and reared easily. Primary teachers should plan studies with easily seen and kept invertebrates such as meal worms (*Tenebrio* sp.) or brine shrimps, *Artemia salina* (e.g. Tomkins & Tunnicliffe, 2001) Special attention should be focused on children from families from lower socioeconomic status, because these children showed fewer experiences with rearing animals than other children. More research on children's interest in invertebrates and its influence through educational programmes (Lindemann-Matthies, 2005) is needed.

In summary, asking children to draw the internal anatomy of familiar species show that Slovakian children have incomplete understandings of what is inside animals. This is documented by the few children whose drawings reached level 6 or 7.

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Figure 1. Year 12 girl drawing of a rat scored on the level 6 (i.e. two major systems, the respiratory and digestive, are indicated).

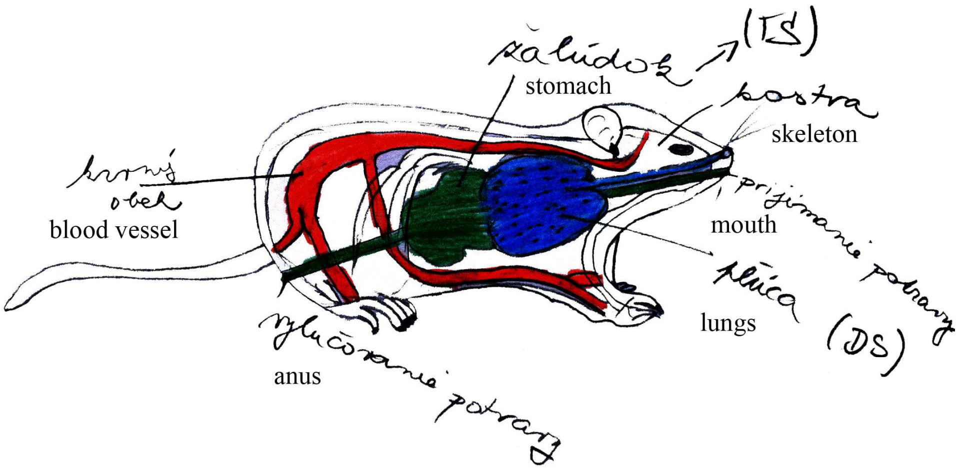

Fig. 2. Year 2 boy drawing of a crawfish with internal skeletons scored on the level 2 (i.e. only brain is placed at appropriate position).

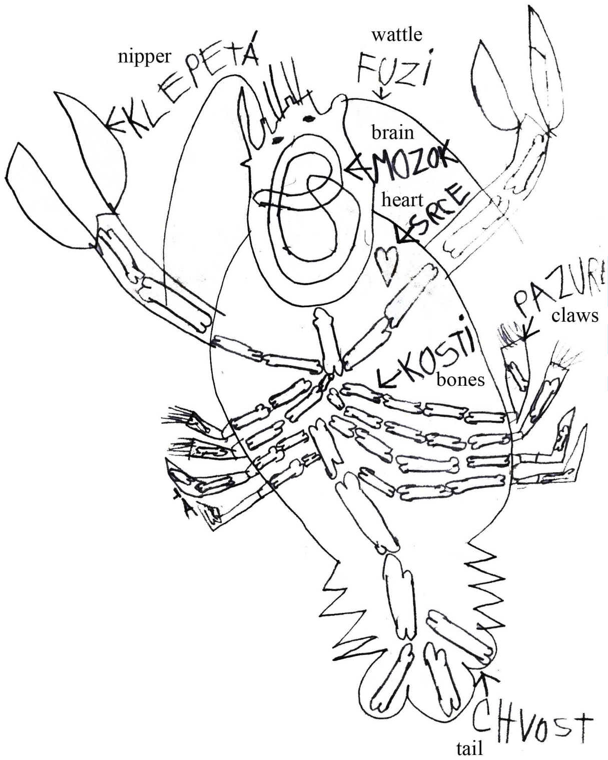

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Figure 3. Differences in the mean score of drawings of animals drawn by children (n = 1541).

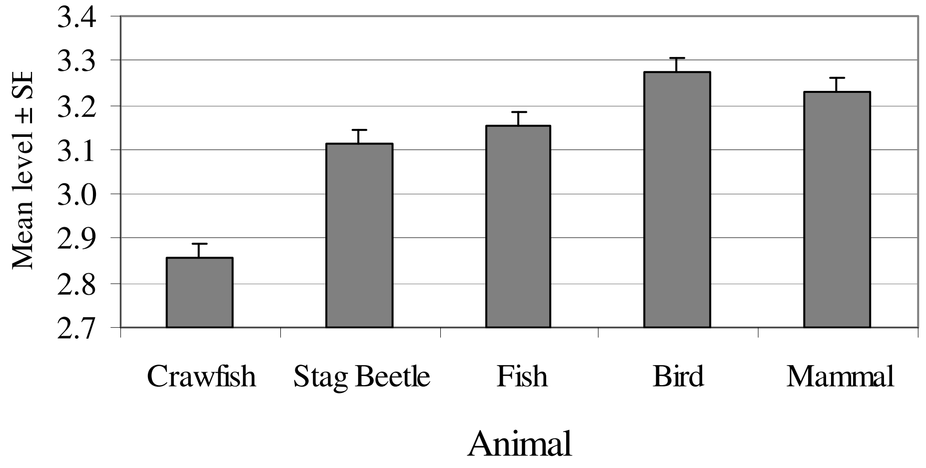

Figure 4. Age - related differences in mean scores obtained from children's drawings (n = 7705) of animal internal organs.

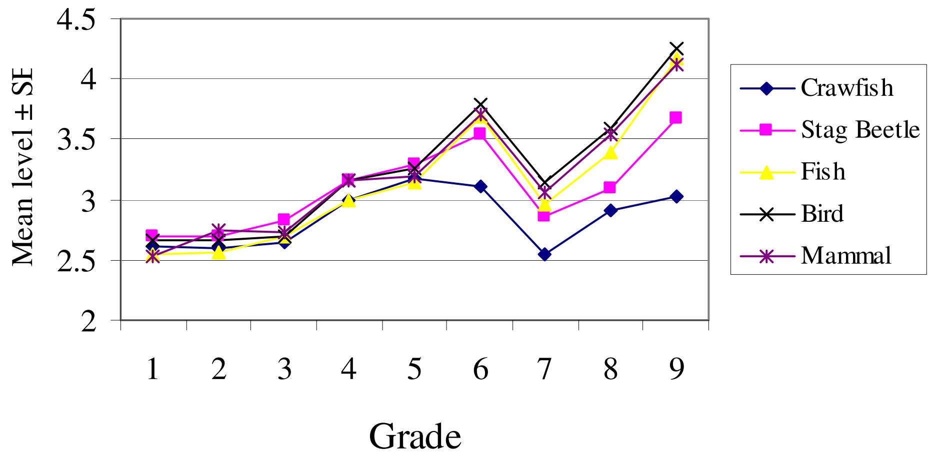

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Figure 5. The effect of keeping animals on children's knowledge about what is inside animals. Black bars denote children that did not report keeping any animal, grey bars denote children that reported keeping a single animal and open bars are children that reported to keep two or more animal species.

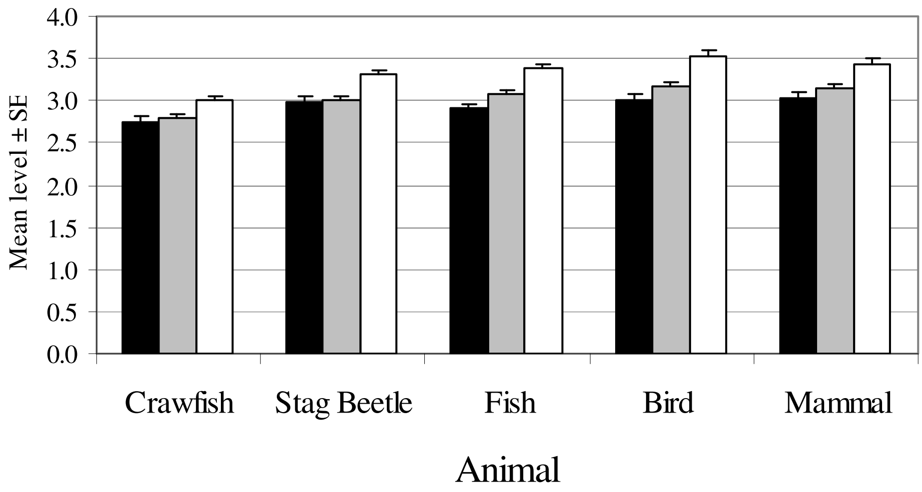

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Figure 6. The occurrence of misclassification of invertebrates among Slovakian elementary school children (n = 1541). Crawfish black bars denote crawfish, grey bars denote stag beetle.

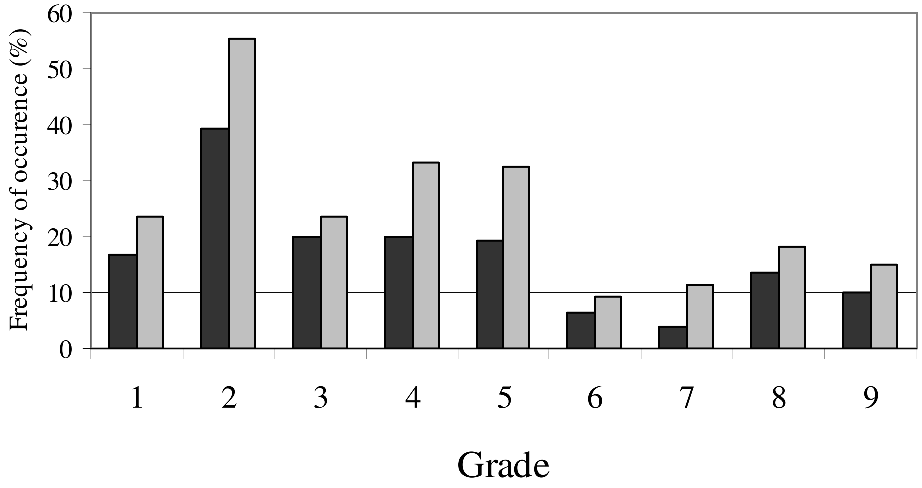

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Figure 7. Gender differences in the misclassification of invertebrates. Black bars are boys, grey bars girls. $**P < 0.01$

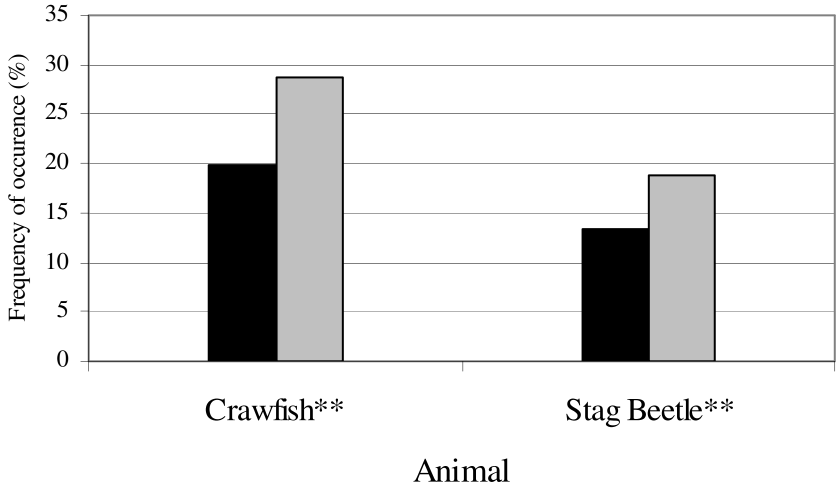

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Table 1. Seven point scale used for scoring organ systems (Tunniciffe & Reiss, 2001)

Level 1	No representation of internal structure
Level 2	One or more organs (e.g. bones and blood) placed at random
Level 3	One internal organ (e.g. brain or heart) in appropriate position
Level 4	Two or more internal organs (e.g. stomach and intestine) in appropriate positions but no relationships indicated between them
Level 5	One system indicated (e.g. gut connecting head to anus or connections between heart and blood vessels)
Level 6	Two or three major systems indicated out of skeletal, circulatory, digestive, gaseous exchange, reproductive, excretory and nervous
Level 7	Comprehensive representation with four or more systems indicated out of skeletal, circulatory, digestive, gaseous exchange, reproductive, excretory and nervous

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Table 2. Means and standard errors (SE) for drawings of five animal species with respect to age (N = 1541 participants).

Grade	Crawfish		Stag Beetle		Fish		Bird		Mammal		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	N
1	2.61	0.11	2.69	0.10	2.54	0.11	2.66	0.12	2.54	0.12	114
2	2.59	0.09	2.69	0.09	2.56	0.09	2.66	0.10	2.75	0.10	170
3	2.65	0.09	2.83	0.09	2.69	0.09	2.70	0.10	2.73	0.10	161
4	3.00	0.09	3.15	0.08	3.00	0.09	3.15	0.09	3.16	0.09	192
5	3.17	0.09	3.28	0.09	3.14	0.09	3.26	0.10	3.19	0.10	166
6	3.11	0.08	3.54	0.08	3.68	0.08	3.78	0.09	3.70	0.09	205
7	2.55	0.08	2.86	0.08	2.96	0.08	3.15	0.09	3.06	0.09	205
8	2.92	0.09	3.10	0.09	3.39	0.09	3.58	0.10	3.54	0.10	160
9	3.02	0.09	3.67	0.09	4.17	0.09	4.26	0.10	4.13	0.10	168

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Table 3. The most reported animals reared by Slovakian children with respect to age (N = 1541 participants).

	% of animals reported as pets											
Grade	Dog	Cat	Hamster	Fish	Parrot	Tortoise	Rabbit	Guinea Pig	Mouse	Hens	Other	N of reported animals
1	40.8	13.6	4.8	9.6	8.8	5.6	9.6	4.8	0.0	0.0	2.4	125
2	37.2	15.3	8.7	13.1	7.1	7.7	5.5	2.7	1.1	0.5	1.1	183
3	41.8	7.4	5.8	15.9	6.3	10.1	3.7	5.3	0.0	0.5	3.2	189
4	32.3	11.5	8.6	10.5	10.9	10.5	4.5	4.8	1.3	1.6	3.5	313
5	34.9	16.4	11.5	7.1	8.9	7.8	4.1	3.3	1.5	1.9	2.6	269
6	32.3	11.7	12.8	10.7	10.1	8.3	5.1	3.2	1.6	0.8	3.5	375
7	38.2	13.1	10.5	6.3	12.5	7.7	4.6	2.8	1.1	1.1	2.0	351
8	31.2	15.5	13.2	9.5	7.3	8.2	6.3	1.6	1.9	0.9	4.4	317
9	33.5	11.4	11.7	10.4	9.2	9.8	1.9	4.7	2.2	0.9	4.1	316
% of all animals	35.0	12.9	10.5	10.0	9.4	8.6	4.7	3.6	1.4	1.0	3.1	-

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Table 4. The effect of selected variables (factors) on Slovakian children's alternative conceptions of invertebrates.

	Crawfish			Stag Beetle		
Factor	df	Wald's χ^2	p	df	Wald's χ^2	p
Age	1	61.36	0.0001	1	79.09	0.0001
Parent educational level	1	0.46	0.49	1	1.67	0.2
Gender	1	10.87	0.0009	1	11.47	0.0007
Raising animals	1	0.0008	0.98	1	0.009	0.92
Gender x raising animals	1	1.83	0.18	1	0.059	0.81

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