Children's ideas of animals' internal structures

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Children's understanding about animal internal structure can be affected by several factors which are poorly understood by teachers. We conducted a large sample study (n=702) of children aged 6-16 years (Grades 1-9) examining children's responses to animals of various size, species and dimensions (2D and 3D objects), and exploring factors which might affect the development of their knowledge. Each child made a drawing of what they thought was inside a specimen animal. We found that using 2D representations of an animal negatively affected the content of children drawings. The effect of animal size was shown only in children's understanding of skeletons, but not organ systems. The effect of animal species showed clear significant effect of children's ideas on both organ systems and skeleton. Investigation showed that parents' education level, children's experiences with animal-rearing and age significantly affected their scores from organ system. Surprisingly, school books were most frequently cited as sources of children's knowledge rather than their own experience, or information from the internet, encyclopaedias, television or parents.

Key words: Animals; Children' ideas; 2D and 3D objects; Anatomy; Drawings

Introduction

Building a knowledge base is a complex process for a child and a great deal of information is acquired from formal learning in school. The educational curricula mainly determine when, how, and what kind of information will be transferred via teacher-student interaction. Children's mental models and their knowledge about phenomena are therefore particularly dependent on the educational process. However, recent studies have shown that home and direct observations play an important role in children's understanding of biological phenomenon (Hatano and Inagaki, 1997; Tunnicliffe and Reiss, 1999b).

Ideas about the biological world are developed in early childhood prior to children reaching school age (Teixeira, 2000; Jaakkola and Slaughter, 2002). Then, after school age is reached, children's early explanations of the world are confronted with scientifically acceptable facts presented by the teacher. Some naïve concepts are successfully replaced with scientific ideas while others are resistant to conventional teaching approaches and remain unchanged (Munson, 1994).

Constructivist theory frames learning as an active, continuous process whereby students construct meaning based on prior ideas and experiences (Driver and Bell, 1986) through physically and mentally focussing on objects (Piaget, 1970). Unfortunately, personal observations of conventional teaching approaches show that they usually include second-hand presentations of biological phenomena, owing to time or financial limitations or other causes. For example, instead of observing real flowers, a child looks at photographs or 3D models of a flower and their ideas about the flower's structure is acquired accordingly.

Anatomy of human and other animals is traditionally considered one of the most important parts of biology in elementary schools in Slovakia. Biology is taught separately from other science subjects. Children aged 8-9 years old (grade 3) are taught basic facts of human anatomy, such as the position and function of major organs in the body. Older children learn more precise anatomy of vertebrates and invertebrates at 11-12 (grade 6) and human anatomy when they are 12-13 (grade 7).

Dissections of some invertebrates (mainly earthworms) and vertebrates (fish, birds or rats) were common in practical work in elementary school biology in Slovakia in former times (P Prokop, unpublished data). Recently however, there has been increasing concern over the ethical considerations of using animals in teaching (Predavec, 2001) and, consequently, use of living organisms in schools has decreased (Reiss and Beaney, 1992). Teachers must, therefore, use real on non-real reprentations such as 2D projections (photographs or drawings) (Reid, 1990), computers (Maloney, 2002), or 3D images such as clay sculptures of internal organs (Waters *et al*, 2005) in traditional biology lessons. Thus, the understanding of children's concepts about the internal structure of live animals (largely constructed indirectly without direct observations) is an important area of research into children's ideas. There are several ways of gathering children's knowledge (White and Guntone, 1994). Current works of Tunnicliffe and Reiss (Tunnicliffe and Reiss, 1999a; Reiss and Tunnicliffe, 2001; Reiss *et al*, 2002) are based on a method of analysing children's drawings. This work examines children's knowledge about skeletons and other internal organs of humans and animals. The researchers asked children: "*Draw what you think is inside your body*", then each of the drawing was hierarchically categorised in order to distinguish between drawings of different levels.

Regardless of other factors that could limit the results obtained from such drawings (e.g. Khwaja and Saxton, 2001), Tunnicliffe and Reiss (1999b, p1444) who were investigating children's views of animals pointed out that "the use of stuffed animals is more realistic than the use of drawings or photographs". However, no study has specifically examined the effect of different types of presentation on children told to draw their ideas of a particular animal. In addition, Trowbridge and Mintzes (1985) maintained that children classifying animals make decisions based on relative size or perceived importance of body parts. A big bird would therefore be perceived somewhat differently than smaller specimens notwithstanding that their internal structure is principally the same. To date, no experimental support for this idea exists.

Perhaps surprisingly, research into children's ideas about anatomy showed that age and gender (Tunnicliffe and Reiss, 1999a, 2001) influenced understanding. However, other factors – such as parents' educational level, that could affect children's attitudes and thus achievement in science (George and Kaplan 1998), or children's experiences with raising animals (Inagaki 1990) – have been largely overlooked. Moreover, most of these studies have been carried out in the UK (works of Tunnicliffe and Reiss, except Reiss *et al* 2002) and their relevance to other countries such as Slovakia remains unclear. In the present study, we experimentally examined:

1. How the use of 2D (e.g. pictures) and 3D (e.g. taxidermy) specimens or the size of a specimen influenced children's responses.
2. How various factors, such as experiences with animal rearing, parents' education, age and gender influence children's ideas about the internal structure of various animals and what sources of information they use.

Methods

Some 702 children (6-16 years old) from four Slovak elementary schools participated in the study (children remain at elementary school until they go to the high school). Initially, each child was given a questionnaire to obtain details that would potentially affect their knowledge about animal anatomy. The children were asked: 1) their age; 2) sex; 3) if they bred animals; 4) if they had a personal computer at home; and 4) the final exam score for their last biology examination (to control for differences between subgroups).

We also examined the parents' educational background as follows: completion of elementary school only was classified as Level 1, high school as Level 2 and university as Level 3. Because mothers' and fathers' educational level significantly correlated, we used the mean level of both parents in the analyses. More details about parents' education levels are shown in Table 1.

To examine the effect of 2D and 3D objects on children's responses, children were randomly assigned to two groups. Children in Group 1 (N = 324) were shown taxidermically prepared animals (i.e. 3D). Children in Group 2 (N = 378) were only shown drawings of the same animals printed on separate sheets provided to each child (i.e. 2D). These drawings were of a similar size to the drawings used in school textbooks. No difference was found between the groups in terms of: children's exam scores from biology, (Group 1 vs. Group 2: mean exam score 1.85 vs. 1.95, t-test showed no significant difference); the number of boys and girls (52% boys and 48% girls in Group 1 and 53% boys and 47% girls in Group 2); age (10.9 yrs vs 10.7 yrs, t-test, not significant); or number of children that reared animals (80% in Group 1 and 78% in Group 2, chi-square test did not show significant difference).

Table 1. The education participants' parents.

	Mothers		Fathers	
Education completed	*N*	*%*	*N*	*%*
Elementary school	143	20.4	126	17.9
High school	499	71.1	515	73.4
University	54	7.7	44	6.3
No information	6	0.9	17	2.4
Total	702	100.0	702	100.0

Both 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 in a single occasion (see Figures 1 and 2 for examples). These animals were used because of their potential familiarity with Slovakian children as all are relatively common in Slovakia.

In order to examine the effect of size of specimen, 56 randomly selected children (28 boys and 28 girls aged 10-14 years) were also shown a taxidermic hummingbird (*Chlorostilbon sp.*) immediately after they had finished drawing other taxidermically prepared animals. The hummingbird is conspicuously small (just about 7cm) relative to the starling (about 22cm). Scores of hummingbird vs. starling were compared using paired statistics: this is generally more sensitive than tests for independent samples and sample sizes (relative to tests for independent variables) do not need to be so large. A power test showed our sample size highly accurate for such comparison. This means that our sample size was representative and the same effect could be expected even with larger samples.

Children were asked to draw what they thought was inside each animal specimen when these animals were alive. After the children has finished these drawings, they were asked on a separate questionnaire if they had gained their information about internal animal structure from: a) their own observation; b) encyclopaedias; c) parents; d) TV/internet/CD/DVD; e) school books; or f) other sources. These categories were modified after Tunnicliffe and Reiss (1999b).

Organ systems and skeletons in the drawings were identified and scored to a seven point scale according to Tunnicliffe and Reiss (1999a, 2001) (Table 2 and 3 and Figures 1 and 2). Two of us separately and independently scored the drawings. In the few cases where the scores differed, we discussed the drawing until we agreed on the level to be awarded. The accuracy of the scoring system was confirmed by high values of reliability coefficients that exceeded critical value 0.7 (Nunnaly 1978) and were calculated both for organ system (Cronbach's α = 0.93) and skeleton (α = 0.73). Sample sizes are not identical in all analyses, because participants who did not complete a question were automatically excluded from the analysis.

Results

Children's responses

Two- and three-dimensional specimens

Using two-dimensional or three-dimensional specimens showed a significant influence on children's scores of organ systems of

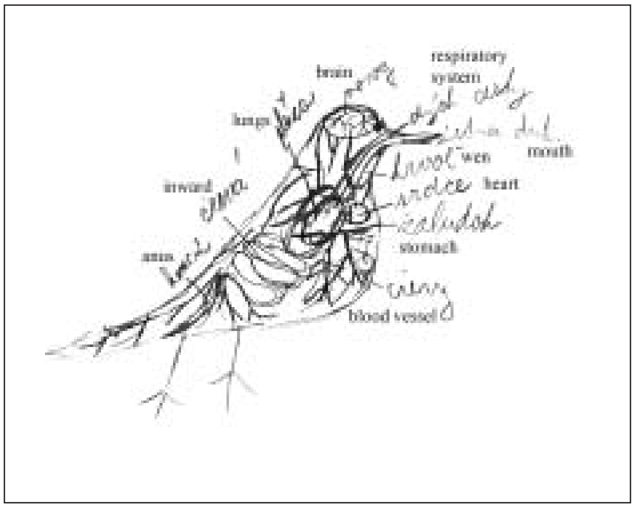


Figure 1. Year 7 girl drawing of European starling based on taxidermically prepared animal. Scores: skeletons = 1; organ systems = 6.

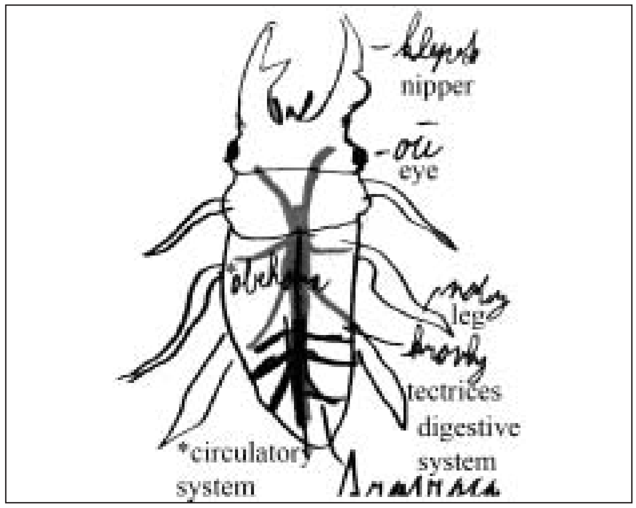


Figure 2. Year 7 boy drawing of the Stag beetle based on two-dimensional object. Score: organ systems = 5

all animal species (multivariate ANOVA: $F_{5,696} = 2.73$, $P < 0.05$, Figure 3). Detailed inspection of these results shows that mean score of each animal species drawn by looking on the 3D object was higher than with 2D objects at $P < 0.01$ level of significance. This shows that children were more willing/able to draw the internal structures of animals to a 'higher' level when taxidermically prepared animals were available. There was no significant effect between 2D and 3D animals on the drawing of skeletons for the three vertebrate species. This finding indicates that perhaps the 2D representation is familiar to the children and the skeleton is two-dimensional in character when looked at.

The size of specimens

Taxidermically prepared starlings and hummingbirds were gradually offered to a sample of randomly chosen participants (N = 56). Figure 4 shows that organ system of both starling and hummingbird was drawn at similar level. However, children drew the skeleton of hummingbird at significantly higher level than the skeleton of starling. This means that when children were allowed to draw their idea about bird skeleton, they were more able/willing to draw the skeleton at higher level when a taxidermically prepared hummingbird was present. In contrast, the same children were less willing/able to draw the bird skeleton when taxidermically prepared starling was present. This may be due to the size of the specimens or greater familiarity with the starling than the hummingbird.

Knowledge of what is inside an animal

Four factors which could potentially affect children's knowledge of what is inside animals were examined – children's age, parents' education, children's experiences with animal rearing and gender differences. The results of multivariate analysis of covariance (MANCOVA) with these effects as factors and scores from either organ system or skeleton obtained from children's drawings defined as dependent variables are shown in Table 4. This analysis allows for simultaneous comparison of means of several independent categorical predictors and continuous variables. The results indicate that the influence of several independent factors on scores from organ system and skeleton differ somewhat. Whilst the effect of age and parents' education on children's scores of the organ system were clearly significant, only age influences children's understanding of vertebrate skeletons.

Interestingly, children's experiences with animal rearing and gender showed marginally significant effects on scores of the organ system. Children experienced with animal rearing (N = 554) tended to have better scores of organ systems than inexperienced ones (N = 145 and three failed to provide information). The effect of gender was equivocal, because mean scores of organ systems of particular animals were sometimes better for boys and in other cases better for girls.

As might be expected, the effect of age on children's understanding of either organ systems or skeletons showed clearly a linear relationship. The level of knowledge increased with age. Importantly, Pearson correlation coefficients (r) calculated for the age and the score from organ systems were narrower (r = 0.35-0.56) than correlations calculated for

Table 2. Seven point scale used for scoring skeleton drawings.

1	No bones
2	Bones indicated by simple lines or circles
3	Bones indicated by 'dog bone' shape and at random or throughout body
4	One type of bone in its appropriate position
5	At least two types of bone (e.g. backbone and ribs) indicated in their appropriate positions
6	Definite vertebrate skeletal organisation shown (i.e. backbone, skull and limbs and/or ribs)
7	Comprehensive skeleton (i.e. connections between backbone, skull, limbs and ribs)

Table 3. Seven point scale used for scoring organ system drawings

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

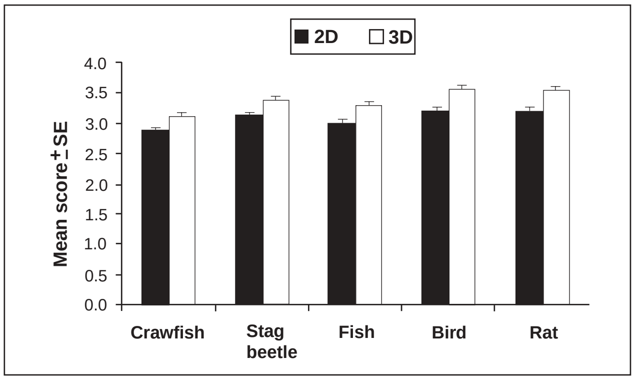


Figure 3. The effect of 2D (black bars) and 3D (open bars) presentation of animals on children's scores of organ systems.

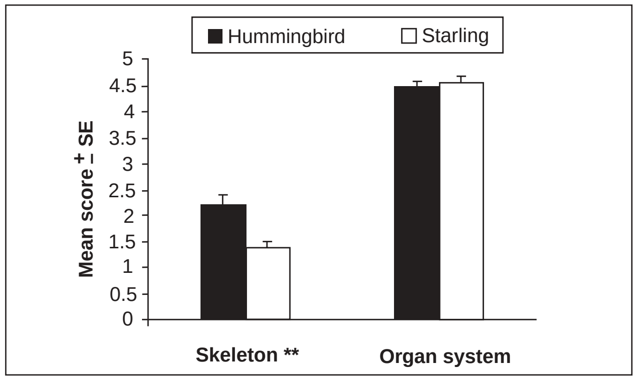


Figure 4. The effect of hummingbird (black bars) and starling (open bars) presentation on children's scores of skeletons and organ systems. Asterisks (**) denote significant difference (P < 0.01) as a result of paired t-test.

knowledge of the skeleton (r = 0.0-0.08). Means of pooled data of all animals, regardless of gender and other potential differences, are shown in Figure 5.

Parents' education ranged from 1 to 3 with the mean of 1.87 (SE = 0.02). All correlation coefficients between the scores for organ systems and parents' education were positive and ranged from 0.17 to 0.21. This would suggest that the higher the parents' level of education, the greater the score for organ system knowledge. However, the parents' education correlated much more with the children's biology exam scores. The higher the parents' education level, the better the exam score (r = -0.33, P < 0.001). This suggests that parents' education does not affect children's knowledge about animal anatomy *per se*, but indirectly, perhaps through their children's intelligence.

The particular animal being drawn

Differences in mean scores for skeleton or organ system could be also caused by children's knowledge about particular animal species (Tables 5 and 6). Figure 6 shows that scores for the organ system were generally better than scores for the skeleton. One-way analysis of variance (ANOVA) showed that the mean score for both organ systems ($F_{4,3505}$ = 10.9, P < 0.001) and skeletons ($F_{2,2103}$ = 23.1, P < 0.001) significantly differ with respect to the animal species being drawn. In particular, the organ systems of the bird and rat were relatively better drawn than those of fish and crawfish. In contrast, the skeleton of the fish was better drawn than the skeleton of the bird or rat. Better knowledge of fish skeletons is not surprising, because fish is both a traditional food (especially on Christmas Eve) and is shown in cartoons (Tunnicliffe and Reiss, 1999a). We therefore suggest that almost all children would have personal experience of fish bones. Furthermore, it is easier to draw typical fish skeletons than a bird or rat, because a fish skeleton does not include limbs and a tail.

Sources of knowledge

School books were most cited sources of knowledge, with encyclopaedias second (Figure 7). Parents and TV/Internet/CD/DVD were sources of information for a minority of children. This is probably because only about one half of all participants (382 of 702, 54%) reported owning home computers. Own observation of animal anatomy was cited by up to 20% of all children. Gender differences were not apparent.

Table 4. Factors affecting knowledge of organ systems and skeletons.

	Organ systems		*Skeletons*	
Factor	*F (5,689)*	*P*	*F (3,691)*	*P*
Age	70.99	0.00	3.55	0.01
Parents' education level	5.30	0.00	0.21	0.89
Animal rearing	2.13	0.06	0.43	0.73
Gender	2.15	0.06	1.24	0.30
Animal rearing x gender	1.03	0.40	0.53	0.66

Discussion

The contribution of our study rests on two main points. First, it explores some factors which might affect children's responses. Second, it provides evidence about some of the factors which could affect Slovak children's ideas about what is inside animals, as measured from the process of drawing.

Scores for organ systems obtained in the presence of preserved animals (3D) significantly differ from those obtained from two dimensional drawings. Furthermore, the mean level of achievement for skeleton drawing was greater when children drew a hummingbird than a starling. We propose that these differences may be attributed to children's motivation or willingness to be alerted by more interesting objects such as three-dimensional preserved animals or the beautifully coloured and unfamiliar hummingbird. These findings should be of interest of researchers because they show how children's responses can be influenced by these factors.

The mean level of achievement for organ system drawings of primary children (grades 1-4) ranged mainly between 2 and 3, while the mean levels for secondary children (grades 5-9) ranged between 3 and 4. Primary children's ideas about what is inside animals included random placement or just one organ placed at an appropriate position. This is not surprising

Figure 5. Differences in mean scores and standard errors of organ systems (pooled data from all animals shown in black bars) and skeletons (pooled data from all vertebrates shown in open bars) with respect to children's age differences.

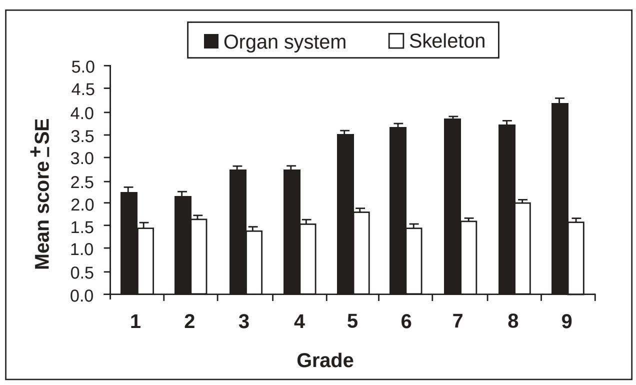


Table 5. The levels attained by children of different ages when drawing organ systems of animals.

	Crawfish		*Stag beetle*		*Fish*		*Bird*		*Rat*		
Grade	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*	N
1	2.24	0.16	2.31	0.14	2.22	0.15	2.24	0.15	2.18	0.15	51
2	2.13	0.12	2.24	0.11	2.06	0.11	2.15	0.11	2.21	0.11	84
3	2.74	0.12	2.89	0.11	2.57	0.12	2.73	0.12	2.68	0.12	81
4	2.69	0.12	2.89	0.11	2.51	0.11	2.82	0.11	2.76	0.11	87
5	3.40	0.13	3.59	0.11	3.31	0.12	3.65	0.12	3.56	0.12	78
6	3.31	0.12	3.65	0.11	3.64	0.12	3.75	0.12	3.85	0.12	80
7	3.30	0.11	3.75	0.10	3.83	0.10	4.09	0.11	4.13	0.11	99
8	3.26	0.13	3.58	0.12	3.58	0.12	4.08	0.12	4.01	0.12	74
9	3.68	0.13	4.01	0.12	4.28	0.13	4.44	0.13	4.50	0.13	68

because the primary biology curriculum in Slovakia does not require deeper understanding about animal anatomy. However, 3rd graders should have relative good knowledge about human anatomy and thus better knowledge about animals could be expected. We suggest that primary children are either unable to generalise their knowledge about human anatomy to animals or primary teachers that are not specialists in biology partly neglect this topic.

Drawings of organ systems by older children in grades 8-9 should score highest because they have completed zoology and human anatomy studies. Mean levels ranged around 4-4.5 which indicate that these children have a good understanding of the placement of particular organs, but their understanding of organ systems is still imperfect. This is especially true for the fish and invertebrates, probably because they are less familiar with these than with humans (Tunnicliffe and Reiss, 1999a, 2001). Another problem arose from the prevalent use of earthworms as a representative invertebrate in Slovak biology curricula. Practical work on invertebrates in 6th grade is restricted to observing only the morphology and behaviour of earthworms. Dissections are not carried out or viewed and the anatomy of the earthworm is taught through drawings in biology textbooks. Thus, the absence of other invertebrates such as arthropods in biology practical work could result in a lower level of children's knowledge about the internal organs of invertebrates, such as the crayfish and Stag beetle used in this study.

The scores for the skeleton drawings showed little variability. In agreement with Tunnicliffe and Reiss (1999a), the fish skeleton was relatively better drawn than skeleton of other vertebrates. However, Slovakian children achieved generally lower scores in their skeleton drawings than did English children. This could be because the method used did not pay special attention to drawing skeletons (see Khwaja and Saxton 2001). However, the instructions used were the same as those used by Tunnicliffe and Reiss (1999a), so our data could reflect lower knowledge of skeletons than English children. Further study is needed to establish a better understanding of these differences.

We found that children's experiences with raising animals had a marginal effect on their mean score about internal organs. This is in accordance with Inagaki (1990), who found a significant effect of raising goldfish on children's factual and conceptual knowledge about them. Unlike Inagaki's (1990) study, which was based on a small sample of participants (18 experienced and 18 inexperienced children) restricted to raising only a single species of an animal (i.e. goldfish), we show in this study a general increase of knowledge related to animal anatomy in children who have personal experience in raising a variety of animal species.

We also found a relationship between children's exam scores and level of education of their parents which, although indirect, agrees with the current explanation of genetically and environmentally fixed intelligence (Ivanovic *et al*, 2004 and references therein). Educational levels of both parents, therefore, significantly affect children's school success.

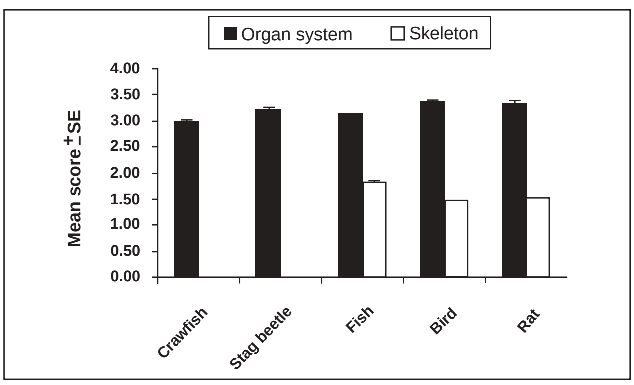
Slovakian children reported school textbooks as the main sources of knowledge about anatomy. This contrasts with Tunnicliffe and Reiss (1999b), who found that schools were significantly less likely to be cited by English pupils as sources of biological knowledge about identity and the taxonomic position of several species of animals. However, their study was not strictly related to internal animal organs, but focused on animal morphology, behaviour or habitat which can be probably be influenced by other sources of knowledge (e.g. their own observations or from films about nature). We therefore cannot compare these differences directly.

Although drawings are commonly used in current research focused on children's knowledge about anatomy (e.g.

Table 6. The levels attained by children of different ages when drawing skeletons of vertebrate animals.

	Fish		*Bird*		*Rat*		
Grade	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*	*N*
1	1.43	0.16	1.59	0.12	1.31	0.13	51
2	1.68	0.13	1.61	0.09	1.57	0.10	84
3	1.74	0.13	1.20	0.09	1.25	0.10	81
4	1.77	0.12	1.44	0.09	1.44	0.10	87
5	2.12	0.13	1.51	0.10	1.73	0.10	78
6	1.63	0.13	1.31	0.10	1.36	0.10	80
7	1.82	0.12	1.49	0.09	1.45	0.09	99
8	2.27	0.14	1.81	0.10	1.91	0.11	74
9	1.72	0.14	1.37	0.10	1.59	0.11	68

Figure 6. A comparison of knowledge of organ systems (black bars) and skeletons (open bars) across several animal species.



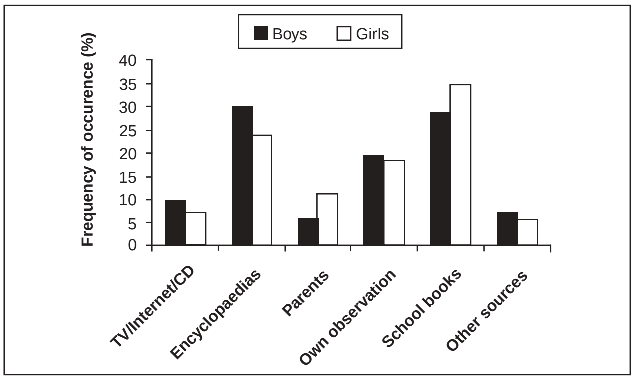


Figure 7. Sources of information about what is inside animals cited by Slovakian children.

Tunnicliffe and Reiss, 1999a, 2001; Reiss and Tunnicliffe, 2001; Reiss *et al*, 2002), interviews can reveal more about children's concepts (e.g. Strommen, 1995). Despite this, our approach allowed us to do comparisons with other studies at international level. We therefore believe that our data would be useful for both future research and practical teaching.

Educational implications

Our work has several educational implications related to formal science or biology education:

- practical work focused on invertebrate zoology should not be restricted to the use of a single representative species such as the earthworm
- science teachers should pay more attention on teaching animal skeleton systems. Our study indicates that Slovakian children's knowledge of animal skeletal systems is poor
- using real (live or preserved) and novel (or unfamiliar) animals in biology or science lessons is probably more attractive for children in terms of gaining their attention and interest rather than using two-dimensional presentations
- children's knowledge about animals can be influenced through rearing pets or various animal species in schools
- in general, special attention should be addressed to children from families with parents who only attained a lower education level.

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