ISSN 1648-3898

CHILDREN'S CONCEPTIONS OF ANIMAL BREATHING: A CROSS – AGE AND CROSS – CULTURAL COMPARISON

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Abstract. *Research on children's ideas about biological phenomena showed that their interpretations of natural phenomena often differ from those of scientists. The purpose of this study was to investigate children's ideas about animal breathing systems. This study was descriptive in nature and consisted of a cross age and cross cultural design involving the collection of qualitative data from a total of 549 children from two distinct countries, Slovakia (n = 248) and Turkey (n = 301). The results revealed that understandings of invertebrates breathing systems were generally poorer than understandings of vertebrates breathing systems. Turkish children acquired better scores than Slovakian children. Although some children were able to identify breathing organs of animals, they had difficulties with describing how breathing works.*

Key words: *alternative conceptions, animals, breathing, primary children.*

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Introduction

Children's acquisition of biological knowledge has attracted interest of many psychologists and educational researchers. Acquisition of biological knowledge in early childhood is characterised by animism which means children are unable to differentiate between living and non-living things (Inagaki & Hatano, 1996). Later in preschool age, young children's understanding of biological phenomenas is influenced by their personal experiences with themselves and living organisms (Teixeira, 2000). The findings of experimental works rather suggest that children's keeping animals as pets or their personal experiences with consuming foods might provide to acquire their information about basic aspects of life and understand functions of organ systems (Inagaki, 1990; Teixeira, 2000; Prokop, Prokop, & Tunnicliffe,, 2008). However, researchers emphasize that children during the school age have not still developed their biological conceptions according to scientific accepted theories and their conceptions about natural phenomena often differ from those of scientists (Carey, 1985). These differing conceptions have been described as misconceptions in the literature (Fisher, 1985), the term that we use throughout this text to refer to children's conceptions that are different from scientifically accepted conceptions. It is widely accepted that these differing conceptions are resistant to change, they interact with knowledge presented by teachers and result in unintended learning outcomes; they are similar across age, abilities, gender, and culture and they are found frequently among teachers as well as students (Fisher, 1985; Wandersee, Mintzes, & Novak, 1994; Yen, Yao, & Chiu, 2004; Yip, 1998). For this reason, it is much more important for science educators to identify children's conceptions about a phenomenon, particularly, before introducing the conceptions related to it.

Prevalence and types of children's misconceptions

Over the past three decades, many of studies in science education have mostly focused on children's biological ideas in science. Although a number of these research studies have investigated students' conceptions about the photosynthesis (e.g., Özay & Öztas 2003), diffusion and osmosis (Tekkaya, 2003), cell (Lewis, Leach, & Wood-Robinson, 2000), ecology (Munson, 1994), forest (Strommen, 1995), seeds (Jewell, 2002), human body (Mintzes, 1984), digestive system (Teixeira, 2000; Ozgur & Pelitoglu, 2008), circulatory system (Sungur, Tekkaya, & Geban, 2001), endocrine and urinary system (Prokop, Fančovičová, & Tunnicliffe, 2009a), animal classification (Braund, 1998; Kattmann, 2001; Trowbridge & Mintzes, 1988), animals (Tunnicliffe, Gatt, Agius, & Pizzuto, 2008), and insects (Shepardson, 1997, 2002), lack of research on the area of students' conceptions about animal breathing reveals the need for the present research. To our best knowledge, only two researchers indirectly investigated students' conceptions about animal breathing (Trowbridge & Mintzes, 1985, 1988). Trowbridge and Mintzes (1988) examined students' alternative conceptions in animal classification at the elementary, secondary, and college levels. They found that only 5% of college biology majors thought that crawfish was a vertebrate. Thus, it is essential for research in science education to continue to expand our understanding of children's conceptions about biological phenomena (Prokop *et al.*, 2008).

Cultural component of children's misconceptions

Researchers such as Mintzes and Wandersee (1998) and Inagaki and Hatano (2006) emphasized that the culture is one of the important variables which affects children's conceptions. These conceptions that children have should also be distributed to people irrespective of culture. However, there has been very limited research that compared children's ideas about biological conceptions across cultures (Reiss *et al*., 2002). The majority of the existing studies have been carried out mostly with samples from a single country. Depending on specific cultural factors (abilities, social classes, teachers and textbooks, etc.), studies are needed to be done in different countries.

Methods for identifying misconceptions among children

To understand a breathe system as a complex concept, it is essential to recognize the differences between vertebrate and invertebrate respiratory system (Prokop *et al*., 2008). More currently, Prokop *et al*. (2008) pointed out that "a typical feature of misunderstanding of internal organs in invertebrates was drawing of a gaseous exchange system" (Prokop *et al.*, 2008, p. 437). Their findings showed n that children's virtually all drawings of the stag beetle and crawfish a typical higher vertebrate lung 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) (Prokop *et al*., 2008). Although there is a general expectation that the prevalence of alternative conceptions is higher in younger children compared with older ones (Carey, 1985), Prokop *et al.* (2008) failed to find evidence that older children are able to recognize the difference between vertebrate and invertebrate respiratory system. Thus, these results could be simply interpreted as misunderstanding of children about animal respiration. However, considering the fact that more than half of children did not include respiratory system in the drawings of invertebrates, and "general" instruction to children (by asking "draw what do you think what was inside the animal when it was alive") have been used, it is questionable what ideas about animal breathing children really have.

Another fact is that how children conceptions vary with gender because females have somewhat higher interest in biology than males (e.g., Prokop, Prokop, & Tunnicliffe, 2007a). For example, Prokop *et al.* (2008) reported that children's alternative conceptions about animals are more frequently found in females. Furthermore, the findings of Mintzes and Wandersee (1998) indicated that "naive ideas" or alternative conceptions may stem from gender.

Purpose

The review of the literature demonstrates there are a few research studies dealing with children's conceptions of animal breathing systems. The present study, therefore, is focused on children's conceptions about animal breathing systems in various age groups, moreover, in samples of two different countries, Slovakia and Turkey. Kao (2007) noted that students from different living environment have different conceptual comprehension. The culture of the learners and the culture of school science will influence science learning, as well as the negotiation and validity and interpretation of data through the social processes (Packer & Goicoecha, 2000). With this aspect of the study, we believe that the study would provide the benefit on how conceptions regarding animal breathing are characterised in two different cultures.

We were motivated by the fact that there is lack of cross-cultural research in this field thus any generalizations from current findings are heavily limited. Accordingly, the paper specifically explores the following questions: 1) What are Turkish and Slovakian children's conceptions about animal breathing systems? 2) How much do children's conceptions about breathing of vertebrates and invertebrates change from the forth to eight grade? 3) Is there any difference between Turkish and Slovakian children's conceptions of animal breathing?

Methodology of Research

The study is descriptive and reflects a cross age survey, including the collection of qualitative data (student drawings and responses to open-ended questions). Data were analyzed in a descriptive manner to identify the conceptions and patterns in students' responses. Later statistical analyses were followed to determine the significance in the frequency of the identified student conceptions. With cross- age study, we were able to collect data from students with varying graders of educational experiences that provided us access to an extent of student conceptions.

Instrument

One of the research methods commonly used for identifying children's conceptions or understandings of natural phenomena is drawings (e.g. Reiss & Tunnicliffe, 2001; Prokop, Prokop, Tunnicliffe, & Diran, 2007b), sometimes supplemented by interviews (Teixeira, 2000; Žoldošová & Prokop, 2007), open-ended questions (Prokop & Fančovičová, 2006) or multiple choice questions (Trowbridge & Mintzes, 1988; Kubiatko & Prokop, 2007). Khwaja and Saxton (2001) suggested that specific type of instruction (e.g., "draw bones that are inside your body") can lead in different, but more accurate results comparing with very general instruction like "draw what you think is in your body". In this study, drawings were used as part of a breathe task to represent and communicate their meaning (Kress, Jewitt, Ogborn, & Tsatsarelis, 2001). The drawings represent what children view as crucial and salient. Children generate the drawings based on their prior experiences and existing conceptions. Thus they reflect unique social, educational, and cultural experiences of the students (Shepardson *et al*., 2007).

In the present study, the questionnaire developed by researchers was used to gather the data. Silhouettes of both vertebrates (frog, snake, fish and bird) and invertebrates (snail, earthworm, bee and crawfish) were presented in the questionnaire.

We followed a simple instruction for each silhouette: "Please draw what you think how XX [e.g. snail] breathes (you may use "→" for clear description where the air comes inside and outside an animal). And we asked to describe what the name of breathing organ is" whereby "XX" represents one of eight animals" (see also Appendix A). We recognized separately the organ systems in each drawing and analyzed according to 1) The type of organ system, 2) Inspiration, and 3) Expiration. We focused mainly on children's understanding of the functions of animal breathing and assessed both drawings (especially direction of air coming inside and outside an animal) and written responses (e.g., this animal breathes by lungs). Prior to definite administration of the questionnaire, third author of this

paper interviewed 15 Turkish children 9 – 15 years old to examine whether children are fully able to understand the formulation of our planned tasks. It was found that all children were able to answer our questions and just in few instances they did not have any idea about breathing of some animals. In interviews, children were asked to explain breathing in four vertebrates (frog, snake, fish and bird) and five invertebrates (snail, earthworm, wasp, beetle and crawfish). Because bees and wasp showed similar responses (most probably because both of them are insects), we omitted these two animals from the final version of the questionnaire and used a bee as a well known example of an insect in Turkey and Slovakia. All examples of selected animals are typical examples of vertebrates and invertebrates that represent different types of breathing systems and are known from biology textbooks by Slovakian and Turkish children. In order to provide scientific validity of the questions and tasks in the questionnaire, our research instrument was independently submitted to two biology professors from two different universities, two primary science teachers and secondary biology teachers in each country for their comments. More specifically, they were asked to evaluate: (1) Whether are questions acceptable in terms of scientifically accepted ideas for particular level of children; (2) Whether wording of the questions is appropriate for ages of children in sample; and (3) Whether the questions serve for the aim of this study. In the sequence of this procedure, all questions were criticised and thus the validity of the questions were provided.

Administration and analysis of the questionnaire

A total of 549 children (9–15 years old, grade 4 - 8) from four randomly selected Slovakian and (N= 248) and four Turkish elementary schools (N= 301) participated in the study. The number of boys and girls was 234 and 315 respectively. The mean age of children was 11.77 year (SE = 0.07) with no difference with respect to country (Mann-Whitney U test, $U = 37263.5$, $p = 0.97$). These schools were typical state schools with about 400 – 1200 enrolment.

The selection of the children was done randomly by class teacher, with instruction from the researcher that children selected be of about willing to participate in the research. The questionnaire with tasks (see below) was administered on a single occasion. Initially, each child was given a sheet of paper with the questionnaire that asked for several details that could potentially affect their knowledge about animal breathing. The children were asked (1) for their age/grade and (2) for their gender. The authors claimed to students that the questionnaire is not an exam, it said that it was a tool what they thought about animal breathe. The children needed approximately 25 - 30 min for completion of the questionnaire in both countries. The drawings on each animal were scored with 1 point per each correct explanation resulting in a maximum score of 3 per each animal. Drawings were coded by two co-authors from each country. After this independent scoring, all authors met personally in August 2008 in Slovakia and thus compared children's drawings and scores. Firstly, written responses on open-ended questions were discussed and coded. In the few cases where our scorings differed we discussed the responses until we agreed on the category to be awarded. At the end of all these analyses, it was calculated that the inter-rater reliability coefficient was 0.97. These results also confirmed that our scoring system was reliable.

Results of Research

General patterns of children's ideas about animal breathing

Results of the analysis of students' drawings are summarized in Figure 1. These findings show that the trend for Turkish and Slovakian children was consistent for drawings of four animal species, frog, snake, fish and bird. As can be seen, the trend in children's drawings was in favour of vertebrate animals. It is worth noting that Turkish children showed a high level of understanding in the drawing of earthworm as well as other vertebrate animals. This pattern may correspond with the difference of science curriculum between two countries. The findings also show that Turkish children had better scores from five of eight animal species compared with Slovakian children. Only scores from

breathing of snail, crawfish and fish did not differ significantly between countries. When comparing the ideas about breathing between vertebrate and invertebrate animals, it is clear that vertebrates were much better understood (see Figure 1). With regard to invertebrates, snail, bee and crawfish scored worst, only earthworm (especially in Turkey) was understood similarly like vertebrates. It may stem from children's informal experiences. With regard to vertebrates, bird scored best, then frog and snake and finally a fish.

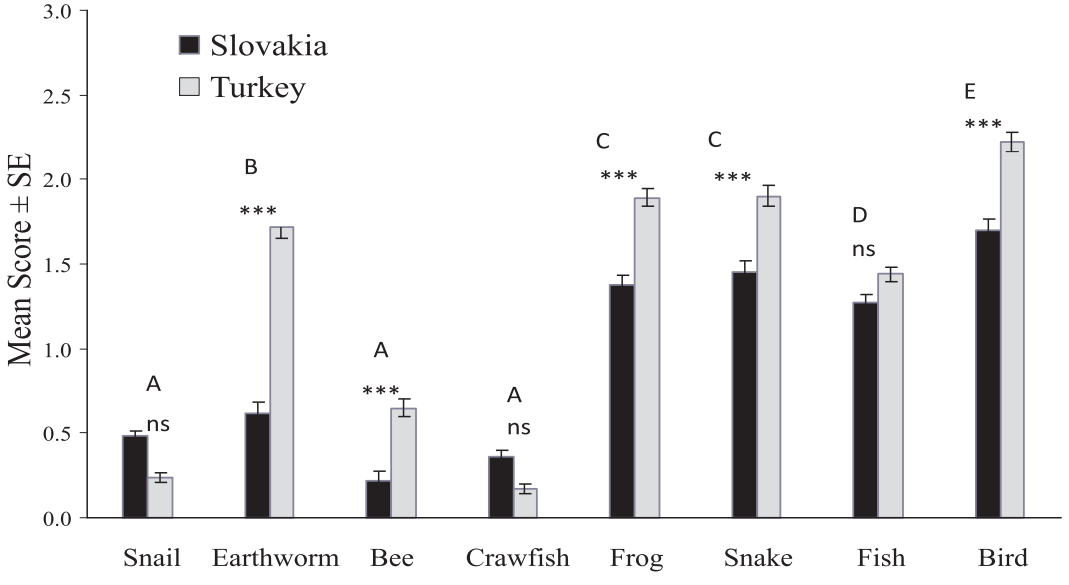

Figure 1. Children's mean scores with breathe of eight different animals. Different letters denote significant differences between animals based on Tukey post-hoc tests (A vs. B-E, $p < 0.001$, B vs. C, E, $p < 0.001$, B vs. D, $p < 0.05$, C vs. D, E, $p < 0.001$, D vs. E, $p < 0.001$). Asterisks denote significant differences between countries based on Tukey post-hoc tests (*ns* = not statistically significant, *** $p < 0.001$).

Breathing organ

The percentages values of Slovakian and Turkish children who gave the correct answer on the general question *"describe what the name of breathing organ is" are* presented in Table 1. The responses given for this question show that less than half of children were able to give the correct explanation for the questions related to the breathing organ. The majority of children in both countries were able to give the correct explanation for only two animal species. These were fish and bird. It was found that 76 % of Slovakian children and 60 % of Turkish children successfully answered the question about main breathing organ of fish. Slovakian and Turkish children's answers for main breathing organ of bird were 57 % and 71%, respectively. This means that children were relatively more sure when identifying fish and bird, but less sure when they were faced with animals with which they do not often encounter in their daily live. This may stem from children's experiences with fish and bird in their daily lives. As could be seen in Table 1, breathing organs of other animal species are identified less than fish and bird. Looking at Table 1, it is seen that only 6 % and 8 % of Slovakian and Turkish children successfully answered the main organ of a frog. About 30 % of children in both countries thought that a bee breathes with lugs. Similarly, about 20 % of Slovakian and Turkish children thought that the main breathing organ of crawfish was lungs. Also, it is interesting to note that some children (17-13%) thought that earthworms breathe with lungs. In addition, the large number of the "do not know" answers shows the problems with animal breathing.

Effect of age

Figure 2 shows the effect of age in interaction with country differences. For easier description of this result, we used overall score from all 8 animals (with maximal possible score 24) for comparison. As can be seen in Figure 2, Turkish children scored better than Slovakian children in 4th, 5th, 6th grade did, but overall score in grade 7 and 8 were not statistically different. A comparison of the means within each country by the Tukey post-hoc test showed that Slovakian children had very similar overall score with respect to grade. Only 8th grade children scored little better than other children (Tukey's $p < 0.05$). Significant results were found in Turkey. Fifth grade children scored better than 4th graders (Tukey's $p = 0.001$), 5th and 6th grade had similar score (Tukey's $p = 0.50$) and 6th graders scored best (all p's except for 5th grade < 0.001). Eight graders had similar score like 4th graders (Tukey's $p = 1.0$). Interestingly, overall score of 7th graders consistently dropped down in both two countries. Although it is difficult to explain this phenomenon, similar trends were reported by Prokop, Prokop and Tunnicliffe (2008) so it seems to be a rule rather than accident. Inspection of Gender × Grade interaction showed that girls scored better than boys in grade 6 and opaque pattern was found in grade 8. It is difficult to explain why this interaction occurred but the cause of this phenomenon remains unclear.

Table 1. Frequency (%) of main breathing organ systems reported by Slovakian and Turkish children.

		Breathing system						
Animal	**Country**	**Skin**	**Trachea**	**Epipodites on thoracal limbs**	**Gills**	**Lungs**	**Do not know**	**Others**
Snail	Slovakia	5	0.4	0	0.4	41 *	40	13
	Turkey	9	0	0	14	24 *	13	41
Earthworm	Slovakia	37 *	0	0	0	17	39	8
	Turkey	42 *	0	0	3	13	20	6
Bee	Slovakia	2	21 *	0	0	27	47	4
	Turkey	0	20 *	0*	3	31	11	35
Crawfish	Slovakia	0	0.4	0*	34 *	18	39	8
	Turkey	2	5	3	6 *	16	41	27
Frog	Slovakia	6 *	0	0	19	35 *	35	4
	Turkey	8 *	0	0	18	32 *	9	33
Snake	Slovakia	8	0	0	1	43 *	44	4
	Turkey	17	0	0	5	47 *	12	19
Fish	Slovakia	0	0	0	76 *	6	17	2
	Turkey	0	0	0	60 *	5	12	23
Bird	Slovakia	0	0	0	0	57 *	39	4
	Turkey	2	0	0	3	71 *	9	15

* Responses coded as correct

General patterns of children's ideas about breathing organ systems

In general even if a child had correct idea by which organ an animal breathe, it was difficult for children to show where the air come inside or outside in invertebrate animals. This means that even some children have formal knowledge about the name of animal breathing system, he/she has not clear idea how it works. Therefore, we analysed expiration and inspiration organs of all animals from children' drawings and written answers. The results showed that there were different patterns of children misunderstanding about animal breathing in vertebrates and invertebrates. Many of children thought that inspiration and expiration breathing organs of animals were different. Table 2 reports the percentages of main organs for inspiration by children. Although less than half of children reported that snails breathe by lungs, only one Turkish children knew that snails have special opening for breathing. Instead more than half of all children thought that snails breathe through their mouths. Similarly, about 20 % of children thought that earthworm inspire air by their mouths. One exception was an earthworm in which breathing through skin seems to be easier to understand comparing with other invertebrates. It can be concluded that breathing process of snails was however almost unknown. Very interesting situation was found in breathing of a bee among Slovakian children. More children incorrectly thought that bee breathes by lungs (see Table 1) and even about 20 % were correct with tracheas, only one child was able to show pores on bee's body as places where inspiration takes place. In Turkey, about 20 % of all children consistently knew the name of bee's breathing system and were able to show tracheal openings. Breathing by mouths was however relatively frequently shown by children in both countries (see Table 2 and 3). However, none of the Slovakian children and just 3 % of Turkish children correctly knew that crawfish breathe through epipodites on thoracal limbs. Therefore, we also counted gills as correct answers because gills are in fact more close to reality that for example lungs or skin. Inspiration of crawfish was frequently misunderstood with mouth (Table 2).

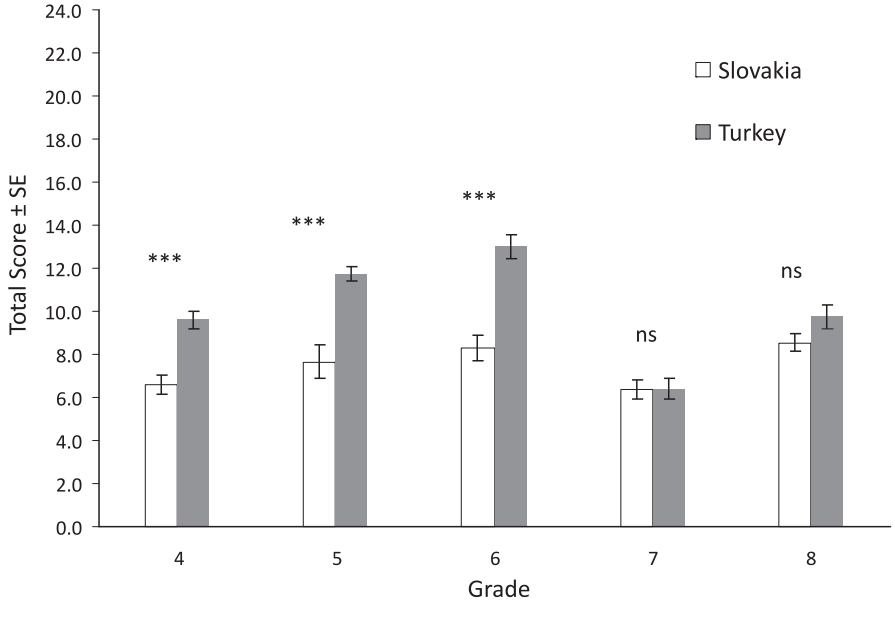

Figure 2. Children overall score from animal breathing with respect to country and grade (ns = not statistically significant, *** $p < 0.001$).

Table 2. Frequency (%) of main organs used for inspiration reported by children.

		Organ for inspiration						
Animal	**Country**	**Skin**	**Mouth**	**Nose**	**Pores**	**Thoracal limbs**	**Do not know**	**Others**
Snail	Slovakia	2	53	4	0	0	30	10
	Turkey	9	64	1	0	0	14	12
Earthworm	Slovakia	13 *	22	1	0	0	43	21
	Turkey	57 *	19	4	0	0	14	5
Bee	Slovakia	0.4	52	4	0.4 *	0	36	8
	Turkey	2	39	3	20 *	0	18	19
Crawfish	Slovakia	0	27	4	0	0*	56	13
	Turkey	5	35	0	1	3 *	52	3
Frog	Slovakia	4 *	50 *	9 *	0	0	3	3
	Turkey	11 *	52 *	12 *	0	0	14	10
Snake	Slovakia	1	46 *	25 *	0	0	27	1
	Turkey	22	60 *	10 *	0	0	8	0
Fish	Slovakia	0	25 *	1	0	0	38	37
	Turkey	0	28 *	2	0	0	13	58
Bird	Slovakia	0	61 *	12 *	0	0	26	1
	Turkey	2	49 *	25 *	0	0	17	7

** Responses coded as correct*

Table 3 presents the percentages of main organs for expiration reported by children. Less (26%) than half of Slovakian children and most (64 %) than half of Turkish children thought that snail expiration air by mouth. Similarly about 30 % of children thought that bee expiration air by mouth. In the case of crawfish, 19 % of Slovakian children and 32 % of Turkish children incorrectly thought that crawfish expiration air by mouth. Similar to the findings in Table 2, no one Slovakian children and just 3 % of Turkish children correctly knew that crawfish breathes through epipodites on thoracal limbs. This result supports the idea that expiration of crawfish is frequently misunderstood with mouth. It is interesting that 17 % Turkish children incorrectly thought that snake breathes by skin only. The same findings related to breathing of bee were also found in Table 2. Although most of children incorrectly thought that bee breathes by lungs (see Table 1) and even about 20 % were correct with tracheas, only one child was able to show pores on bee's body as places where expiration takes place. Consequently, when comparing the results in Table 2 and 3, it can be concluded that children of both countries *thought that animals inspire air by mouth.*

Table 3. Frequency (%) of main organs used for expiration reported by children.

		Organ for expiration						
Animal	**Country**	**Skin**	**Mouth**	**Nose**	**Pores**	**Thoracal limbs**	**Do not know**	**Others**
Snail	Slovakia	1	26	1	0	0	56	17
	Turkey	9	64	11	0	0	14	3
Earthworm	Slovakia	10 *	9	1	0	0	53	27
	Turkey	62 *	15	3	0	0	14	7
Bee	Slovakia	0	27	2	0.4*	0.4	60	10
	Turkey	2	36	11	20*	0	18	14
Crawfish	Slovakia	0	19	1	0	0*	67	13
	Turkey	5	32	0	1	3 *	54	4
Frog	Slovakia	0.4 *	26*	7 *	0	0	59	7
	Turkey	9 *	46 *	23*	0	0	14	8
Snake	Slovakia	1	25 *	13*	0	0	54	8
	Turkey	17	58 *	17*	0	0	8	0
Fish	Slovakia	0	15	0	0	0	54	31
	Turkey	0	17	4	0	0	13	67
Bird	Slovakia	0	36 *	4*	0	0	54	5
	Turkey	2	48 *	29*	0	0	17	4

* Responses coded as correct

In detail, children's mean scores from breathing of inverterates are shown in Figure 3. Interestingly, 2 – 5 % of all children incorrectly showed that animals expire air through anus. These patterns were found in all eight animals examined. A similar number of children thought that snail, bee and crawfish inspire air through their antennae or that a bee inspire air by wings. Sixteen percent of Turkish children thought that fish inspire air through fins.

All examples of vertebrate animals in this study can inspire air to lungs through mouth which is frequently thought to be an organ for air inspiration (Figure 4). This is probably why inspiration was generally better understood by children compared with expiration or type of organ for breathing. Organ system for brething of a frog and snake was correctly identified by half of children (see Table 2). However, snake was somewhat more frequently thought to be breathed by the skin compared with other vertebrates (Tables 1–3). Breathing by gills in fish was very well known (Table 2), but mechanism of expiration was poorly understood (Table 3). Only 26 % of Slovakian and 42 % of Turkish children correctly identified gills as the place of expiration. Breathing of birds was relatively well understood comparing with other animals.

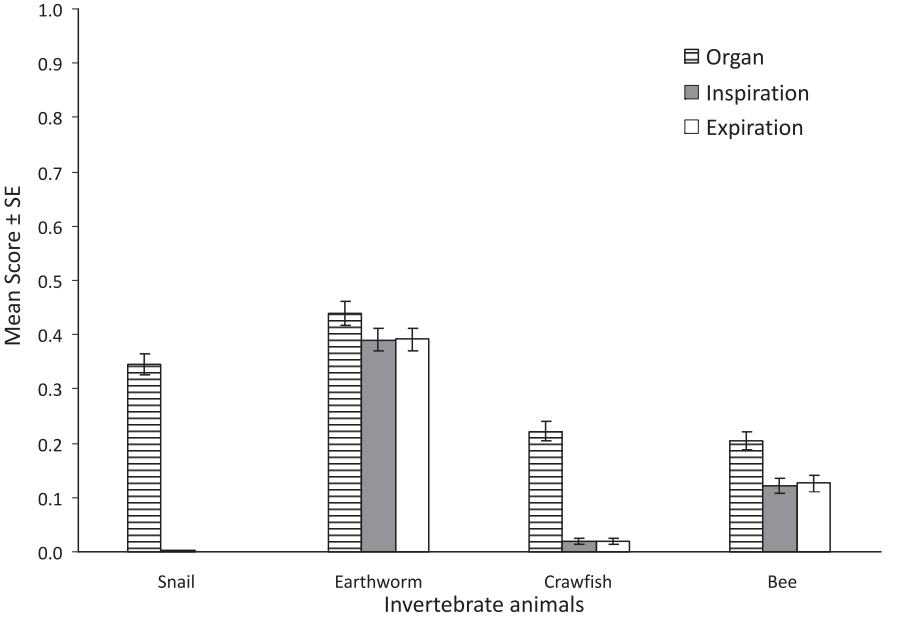

Figure 3. Children's mean scores from breathing of invertebrates.

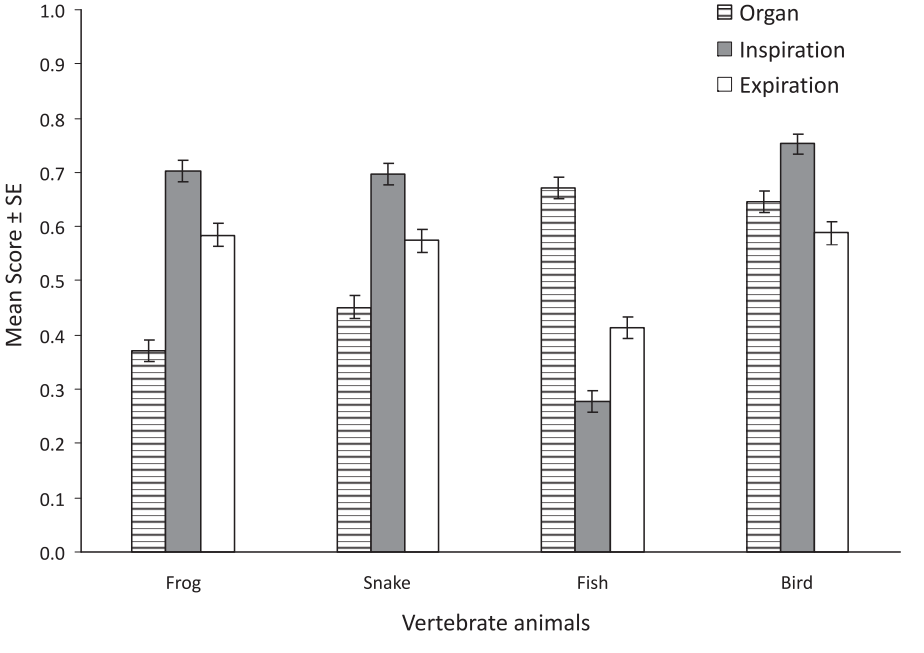

Figure 4. Children's mean scores from breathing of vertebrates.

Figure 5 shows that a drawing of the breathing system of a bee of a Slovakian 14 year old girl. As can be see from Figure 5, children thought that a bee breathes by abdomen.

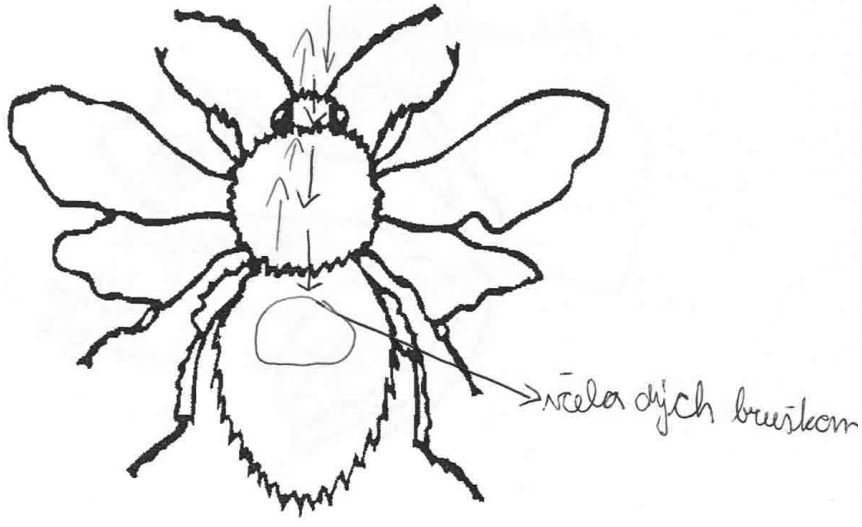

Figure 5. A drawing of the breathing system of a bee by a Slovakian 14 year old girl (Grade 8). Girls's description of the drawing means "A bee breathes by tummy".

Factors influencing children's ideas

The results of the repeated analysis of variance (ANOVA) of the breathing scores from eight animal species are shown in Table 4. Almost all effects except for gender were strong enough to indicate differences with respect of all of these variables. These results show that especially cultural differences affects children's conceptions. The results also show that children's grade is one of the important factor affects children's conceptions.

Table 4. Analysis of variance of children's ideas of animal breathing, by country, gender, grade and animal species.

Test of between-subject effects					
	Sum of Squares	DF	Mean Square	F	p
Country	109.32	1	109.32	85.77	<0.001
Gender	0.01	1	0.01	0.01	0.93
Grade	152.23	4	38.06	29.86	<0.001
Country × Gender	0.04	1	0.04	0.03	0.86
Country × Grade	39.43	4	9.86	7.73	<0.001
Gender × Grade	47.91	4	12.00	9.40	<0.001
Country × Gender × Grade	63.21	4	15.80	12.40	<0.001
Error	674.29	529	1.28		

Test of within-subject effects

	SS	DF	MS	F	p
Species	1195.72	7	170.82	338.15	<0.001
Species× Country	196.14	7	28.02	55.47	<0.001
Species × Gender	14.50	7	2.07	4.10	<0.001
Species × Grade	157.81	28	5.64	11.16	<0.001
Species × Country × Gender	17.05	7	2.44	4.82	<0.001
Species × Country × Grade	146.27	28	5.22	10.34	<0.001
Species × Gender × Grade	121.29	28	4.33	8.58	<0.001
Species × Gender × Grade × Country	100.53	28	3.59	7.11	<0.001
Error	1870.58	3703	0.51		

Discussion

This study provides first detailed evidence about children's ideas of breathing system of vertebrate and invertebrate animals in two distinct countries. It was found that significant proportion of children in all age groups in both countries misunderstood the functions of animal breathing, especially those of invertebrates. Boys showed similar ideas about animal breathing like girls. Overall Turkish children scored significantly better than Slovakian children. Especially a sample of Slovakian children showed low variability of understanding of animal breathing when compared with various age groups, which means alternative conceptions are resistant to change even after formal effect of school system. As age of children increased, the mean score from breathing decreased and showed very similar trends between Turkish and Slovakian sample. The methodology used in this study supports earlier criticism of "general instructions" of children by researchers which states that more specific instruction leads to more accurate results (Khwaja & Saxton, 2001; Prokop, Fančovičová, & Tunnicliffe, 2009a).

Significance of gender

The present study failed to show any differences among children's ideas about animal breathing system with respect to gender. Initially, this result is not surprising when we consider the alternative conceptions that are expected to be distributed randomly irrespective of the effect of gender (Wandersee & Mintzes, 1998). Our findings are consistent with the findings of Prokop *et al.* (2007a), who did to find any gender difference among children's conceptions of birds. Investigating children's ideas of internal animal organs, however, resulted in better score of girls compared with boys (Prokop *et al.*, 2007c, 2008) although girls showed more alternative conceptions regarding internal skeleton of invertebrates (Prokop *et al.*, 2008). Why then girls in the present study showed the same level of understanding of animal breathing like boys? We suggest that design of our research instrument did not allow children to express only factual knowledge like it could be when children were asked "What do you think was inside an animal when it was alive" (Tunnicliffe & Reiss, 1999; Prokop *et al.*, 2007c, 2008). This argument can be supported either by the fact that students do not necessarily understand the function of organs what they most frequently draw (Prokop & Fančovičová, 2006) and by better score of *organs* compared with '*nspiration* or e*xpiration* in invertebrates (Figure 3) that were worse understood for children relatively to breathing of vertebrates. In addition, our tasks were most probably addressed to knowledge that could be acquired by children in formal biology

settings rather than by their personal experiences that are responsible for some gender differences in understanding of animal anatomy (Prokop *et al.*, 2008).

The effect of age and country

Slovakian sample of children showed no apparent difference in children's understanding of animal breathing. Both 4th and 5th graders that inexperienced with zoology course showed similar mean score from animal breathing tasks like older children. In contrast, Turkish children scored better especially children from grades 4 – 6. There is general assumption that alternative conceptions should be comparably distributed across cultures (Mintzes & Wandersee, 1998). If so, why these differences between countries occurred? We suggest that educational reform in Turkey in 2005 (Koc, Isiksal, & Bulut, 2007) can be responsible for these differences. This reform is based on constructivist approach which states that children knowledge cannot be directly transmitted but must be actively constructed by learners (Ausubel, 1968; Mintzes & Wandersee, 1998). Turkish curriculum developers adapt a reformist philosophy that supports children's active construction of their knowledge through problem solving, exploration, reflection and communication, and other thought-provoking processes that require high level cognitive demand (Koc *et al.,* 2007). In contrast, Slovakian system is based on 'traditional' educational approach which ignores experiential learning and teaches students how to succeed standardised tests and nothing more. Because constructivist approach has various benefits such as better learning outcomes in biology (Christianson & Fisher, 1999; Wu & Tsai, 2005), it can be assumed that Turkey benefits from educational reform in terms of better understanding.

Differences caused by animal species in tasks

Previous research has revealed that children's ideas of what is inside animals are influenced by animal species which means that some animals are understood better than others (Tunnicliffe & Reiss, 1999; Prokop *et al.*, 2007c, 2008). The present study totally supports these finding because we found significant differences in children's understanding of various animals. In general, drawings of vertebrates scored better than drawings of invertebrates. This difference most probably originated by "making analogies" between unfamiliar animals or even humans and animals (Inagaki, 1990; Prokop *et al.*, 2008) which could result in incorrect drawings of respiratory system of invertebrates. Especially drawing vertebrate breathing organs, which is more familiar to children (Reiss & Tunnicliffe, 2001), inside invertebrates, may responsible for low mean scores. Breathing of earthworm was better understood compared with other invertebrates probably because breathing through skin is easier and understandable than breathing through tracheas or other organ systems. Importantly, organ systems were better understood than mechanisms of inspiration and expiration in all invertebrates which means that acquiring formal knowledge about the name of particular breathing system does not necessarily result in an understanding of *how* breathing works. This is perfectly illustrated in example of a snail, in which a considerable number of children were aware about the name of breathing system of snail, but almost none of children were able to describe how it breathes. Similarly, breathing organs of fish seems to be relatively well known, but simple describing the way how breathing works was problematic for children. The reason why breathing of birds was best understood can be supported by "making analogies" hypothesis that was described earlier (Inagaki, 1990; Prokop *et al.*, 2008). Birds and snakes, but no other vertebrates in tasks, have similar breathing system like humans, thus making analogies between humans and birds could result in drawings with high scores. On the other hand, snakes are often misclassified with invertebrates by children (Braund, 1998), so tasks with snakes were probably perceived confusing by children.

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 breathing systems. 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 students' certain ideas through drawings. Interviewing would have allowed us to resolve at least some such uncertainties. On the other hand, interviews generally resulted in limited sample sizes, which are partly compensated for by the large number of participants used in our research. Also, we did not ask children whether they lived on 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 (Paul & Serpell, 1993) and future career choice (Serpell, 2005). However, considering the fact that animals are less frequently owned by Turkish students (Prokop, Özel, & Uşak, 2009b), confounding effects of keeping animals (which could favour Turkish children) is less likely.

Conclusion and Educational Implications

Breathing of animals was found to be poorly understood by children of various age groups, especially in Slovakia. The methodological approach with specific instruction used here provided more accurate results in comparison with earlier research (e.g. Reiss & Tunnicliffe, 2001; Prokop *et al.*, 2007c, 2008). We therefore recommend to use this approach in further research. As expected in previous research, children "make analogies" and frequently use typical vertebrate breathing organs to explain breathing in unfamiliar organisms like invertebrates or simply do not know. Although many children are able to name organ systems of particular animals, they are less able to explain how breathing works. These patterns were more pronounced among Slovakian children than Turkish children. Considering that new, constructivist approach application in Turkey can be responsible for these differences, we propose that further experimental research in this field is necessary. Moreover, little is known about how construtivist approach is effective in the elimination of children's alternative conceptions of animals. At present, we cannot be sure whether constructivist approach *per se*, or other cultural differences can be responsible for better mean scores in Turkish children. With regard to educational practise, teachers should be aware of children's conceptions of animal breathing system. Using problem based learning and practical works with demostrations (e.g. with the use of computer softwares) of how animals breathe would be very benefitial for children in terms of developing correct conceptions of animal biology.

Acknowledgement

We would like to thank to Professor Joel J. Mintzes for his discussions about research instrument used in this tudy.

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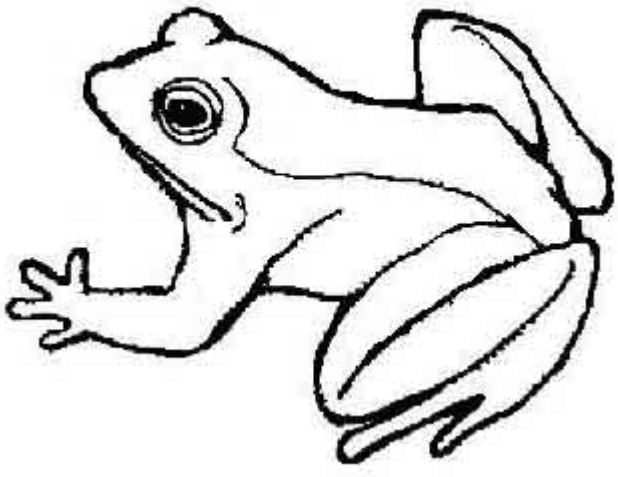

Appendix A. Example of one task from the questionnaire used in this study. The same instruction was used for examining children's ideas about breathing of all eight animals. For more details about instruction see methods.

Received 27 August 2009;
accepted 10 December 2009

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