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YOUNG CHILDREN'S IDEAS ABOUT SNAIL INTERNAL ANATOMY

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Abstract. *Drawings can serve as a useful tool for analyzing children's understanding of scientific phenomena. This study examined children's understandings about internal structure of the snail. Children from kindergarten at age 5 and from primary school of age 7 and 10, were asked to draw their concept about the internal structure of the snail. The results demonstrate the alternative conceptions held by the children. Analysis showed some significant differences in interpretation between both age groups and gender. Age related differences were in understanding of nervous, circulatory, muscle and digestive system, and such features as food, bones and mucus. Gender differences were not so significant at present studies. There were only few statistically significant observations concerning gender, that boys more often than girls consider mucus and other organisms (such as bacteria) as a part of snail internal structure. The girls drew more in the category food (7 years old) and bones (10 years old). The results also revealed ideas which made sense to the learner, but are not biologically accurate, such as organs located in the foot.*
Key words: *alternative conceptions, drawings, invertebrates, mental models, snails.*

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Introduction

Analysis of student's drawings is becoming increasingly popular among researchers seeking to elicit information about pupils' understanding of natural phenomena (Barraza, 1999; Reiss & Tunniciffe, 2000; Reiss & Tunnicliffe, 2001; Ehrlén, 2009). Although it might be sometimes difficult to analyze drawings for a variety of reasons such as: drawings might be difficult to recognise what's on them, some children find it more enjoyable to draw while others may not like to draw (Osborne & Gilbert, 1980; Novak & Musonda, 1991; Salmon & Pipe, 2000), some pictures may represent only a small part of what actually a child knows about the subject, because they can not draw all that they know. On the other hand, drawings are a popular way of children presenting their world among young at kindergarten or in early year classes at school. Gardner (1980) points out that drawings or paintings are important in preschool years and "they become less central and less common as the school years pass". Classical biology teaching involves using drawings as representations of biological objects, although it seems to be a neglected area in teaching nowadays. Dempsey and Betz (2001) also point out that drawing is an important skill in the learning and teaching of biology, but also that biology teachers do not spend time on developing that skill. These authors report that drawings are closely connected with observation and interpretation of nature, and both are key components of the scientific process.

In the last few years some researchers have used a combined method to explore data, where drawing analysis have been used together with interviewing some children from the whole group (Osborne & Gilbert, 1980; Ehrlén, 2009; Bartoszeck & Tunnicliffe, 2013). Ehrlén (2009) describes that analysis of children's drawings may be a tool for collecting information about children's conception, but this is only when we know the meaning children give to their own drawings.

In working with cross age studies we acknowledge that children's ideas develop and thus change as they grow older. Children at the age of 5 or 6 often have "an intuitive sense of what an organized picture should be like", while an older oriented child is intent on getting every detail in the correct relationship, taking into account the sense of the whole (Gardner 1980). Children formulate ideas about natural objects at an early age, and these ideas are often resistant to change (Trowbridge & Mintzes, 1985; Trowbridge & Mintzes, 1988; Shneider & Stern, 2013; Hołówka, 1986). However, some alternative conceptions (Driver *et al*., 1994) seem to yield more readily to non-school experiences or formal instructions (Trowbridge & Mintzes, 1988). The research done by Prokop, Kubiatko and Fančovičová (2007), showed that some misconceptions about birds were more frequently found in Slovakian younger children, while others were common across all age classes. On the other hand Bell (1981), who studied pupils in New Zealand, indicated that pupils of all age groups shared an alternative conception about animals and animal groups. Her findings were supported by the results published by Trowbridge and Mintzes (1988).

Pooley and O'Connor (2000) suggested that what people feel, believe and know about the environment influences their attitude toward it. This may also apply to living creatures, such as spiders and bats (Prokop & Tunnicliffe, 2008). As Iozzi (1989) has shown in his research, these beliefs and attitudes may serve as a stronger predictor of pro-environmental behaviour than pure environmental knowledge. In addition, Roth (1992) showed that environmental literacy of citizens may include some level of environmental knowledge and attitudes. Bearing that in mind, we consider that it is important to explore understanding and attitudes towards particular living objects. Furthermore, basic human emotions play an important role in social interaction and thus, especially negative emotion, such as disgust and fear may negatively influence human willingness to protect animals (Prokop & Fančovičová, 2013). Gender may be one of the factors which determine emotions also in human-animal interactions (Herzog, 2007). Prokop and Fančovičová (2013) showed that females expressed a higher distaste for cryptic and aposematic animals than males. Howe and Rua (1999) showed that females prefer biology more than males.

Children are interested in the world that surrounds them - that includes living creatures (Rinsland, 1946; Tunnicliffe, 1996; Zoldosova & Prokop, 2006; Tomkins & Tunnicliffe, 2007; Prokop, Prokop & Tunnicliffe, 2008) as well as artificial representations such as Pokémon (Balmford *et al.* 2002). Although they can name and recognise more animals than plants (Tunnicliffe & Reiss, 1999; Lindemann-Matthies, 2005; Partick & Tunnicliffe, 2011), the way children "see" animals differ. The most "lovable" seems to be mammals (Trowbridge & Mintzes, 1988; Lindemann-Matthies, 2005; Prokop, Prokop & Tunniclife, 2008; Partick & Tunnicliffe, 2011; Prokop & Fančovičová, 2013) or birds (Prokop & Fančovičová, 2013), which are the most "human like". In contrast, children tend to avoid invertebrates like insects, spiders and other "bugs" because they are small and have many legs, or are too hairy and behaviourally unlike humans (Kellert, 1993; Morris & Morris, 1965; Prokop & Tunnicliffe, 2008). What is more crucial is that from an early age children should be introduced to a wide range of animal species, especially those that are not vertebrates (Patrick *et al*., 2013). Snails seem to be somewhere in between, they are usually not perceived as very ugly and disgusting, but not very lovable as well. A different opinion was presented by Randler, Hummel and Prokop (2012) who showed that snails are considered disgusting by children. This idea was supported by Davey and co-workers (1998) who noticed that fears of some invertebrates such as snails do not appear to have any obvious or compelling adaptive benefit. On the other hand, snails are common in every ecosystem existing in Poland. These animals occur on many levels of trophic chains. Twenty three gastropod species are listed in the Polish Red Data Book of Animals (Głowacinski & Nowacki, 2004). Mostly, due to the role they play in ecosystems, gastropods are an important part of the Polish biology curriculum. It is interesting to know what children across ages think about snails and what understanding regarding those animals they have in order to improve their relationships with these animals. There is some work on children's understanding (conceptions) on human internal anatomy (Mintzes, 1984; Carey, 1985; Osborne, Wadsworth & Black, 1992; Hmelo-Silver, Marathe & Liu, 2007) and some of these have the drawings analyzed (Reiss & Tunnicliffe, 2001; Prokop & Fančovičová, 2006; Bartoszeck, Machado & Amann-Gainotti, 2011). Understanding of internal structures of animals is a relatively neglected area. However, a few researchers dealt with identifying such children's conceptions through drawings (eg. Reiss & Tunnicliffe, 2000; Prokop *et al*. 2007). To the best of authors' knowledge, there is no research done on identifying student's conceptions about internal structure of snails.

The present study was conducted to examine the extent to which pupils' alternative conceptions (understanding of internal structure of animal) change as a function of age or gender. The research question was: how age and gender may influence children's ideas about the internal structure of snail.

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Methodology of Research

General Background of Research

Research was carried on using two tools: analysis of drawings associated with children's comments from individual interviews with their drawing (similar to Ehrlén, 2009). A few younger children required us to have further conversations about their drawing activity in addition to the direct instruction given before they had an idea of something to draw.

The study was conducted in Poznan, which is a city in the north-west part of Poland. Poznan is known for its green areas, parks and even nature reserve located within it. The area has recently a water shortage and the problem of agriculture is frequently mentioned in the media.

Sample Selection

The children, having been investigated during this research attended two public schools located in Poznan. Schools were randomly chosen. Ethical considerations were discussed and approved by the principals of the schools.

The researcher worked in three age groups, one at age 5 (kindergarten, 57 children), four classes of pupils at age 7 (first class of primary school 105 children) and four classes of pupils age 10 (fourth class of primary school 83 children). Together 245 drawings were analysed.

Instrument and Procedures

Children were provided individually with an A4 sheet of paper, pencils and crayons. Interviewers made notes on what was going on during research and the pupils' answers during or immediately after the research. Children were motivated to draw by showing a live specimen of a Roman snail *Helix pomatia* which is the largest and most common snail in Poland. They were then asked to draw on an A4 sheet of paper what they thought was inside a snail. They were allowed to draw for 20 minutes. The fieldwork was conducted in their whole class setting. In each case a researcher interviewed a child whilst they were drawing. Special attention was given to labelling by the researcher of what children think they drew (especially for younger who were not able to label the picture). The children were also asked to mark their age and gender on the drawing (for the younger participants it was done by a researcher).

Data Analysis

After collecting drawings, each was numbered and coded according to the age and gender of the child. Afterwards each drawing was scored. Two people carried out this process. Firstly, they scored them separately. Then they met and discussed the drawings on which they disagree, until they agreed on the same score. The scale used was based on the scale proposed by Reiss and Tunnicliffe (2000 & 2001) and modified to be suitable for drawings of snails. The proposed scale was adjusted to measure children's understanding about snail internal structure. The "artistic" value of the drawings was not taken under consideration in this research. No notice was taken about age, during the scoring of the draw. After discussion, the authors agreed to rubric scale, attached below (Table 1):

Table 1. The rubric scale used to allocating a grade to the drawings.

Level	Source of knowledge/Snail drawing characteristics
0	Nothing inside, but we know it is snail/ child indicated there was something
1	No representation of internal structure/is something in it without name of an organ
2	One or more internal organs placed at random
3	One internal organ in appropriate position
4	Two or more organs in the appropriate position
5	One organ system indicated
6	Two or more major organs system indicated
7	Comprehensive representation with four or more organ systems indicated

In the rubric scale above, the researchers required to give a definition of particular organs belonging to a system. Organs were represented by a small letter of the name of the system. Any complete system drawn would be denoted by the capital letter. Authors agreed to definitions attached below:

Nervous system – cerebral ganglia, optic nerve, nerves,
Digestive system – mouth, salivary duct, stomach, intestine, anus (optional crop and liver)
Secretory system – mucus gland, mucus duct,
Circulatory system – heart, vessels, arteries, blood,
Muscular system – muscles in the leg, muscles attached to shell,
Urinal system – kidney, secretory hole,
Reproductive system – ovotestis, (or ovary and testis), oviduct, spermduct, penis, vagina, genital pore, dart sac.

Furthermore, the authors distinguished such categories as belonging to: Cultural, Human template and Physiological.

In the Cultural category, the authors included the drawings, which presented interior of the snail as a home, for instance with furniture, bathroom or TV.

In a Human Template category, the authors distinguished three subcategories, which contained the organs and elements characteristic to human, such as:

b – human bones, back bone; d – internal organs (spleen, appendix); f – human face, eyelashes, lips, hair, nose.

In the Physiological category, there were few subcategories distinguished in dependence of "physiological" products drawn by children such as:

m – mucus, o – offspring, f – food, t - other organisms (fly, bacteria), s – saliva, p - poop/pee.

The last featured category was an empty shell, when children drew and said in their interview that there was nothing in the shell, and all organs are in the 'leg'.

For example, below is attached the drawing of 10 year old which was scored 3ndkmHbPm (Figure 1).

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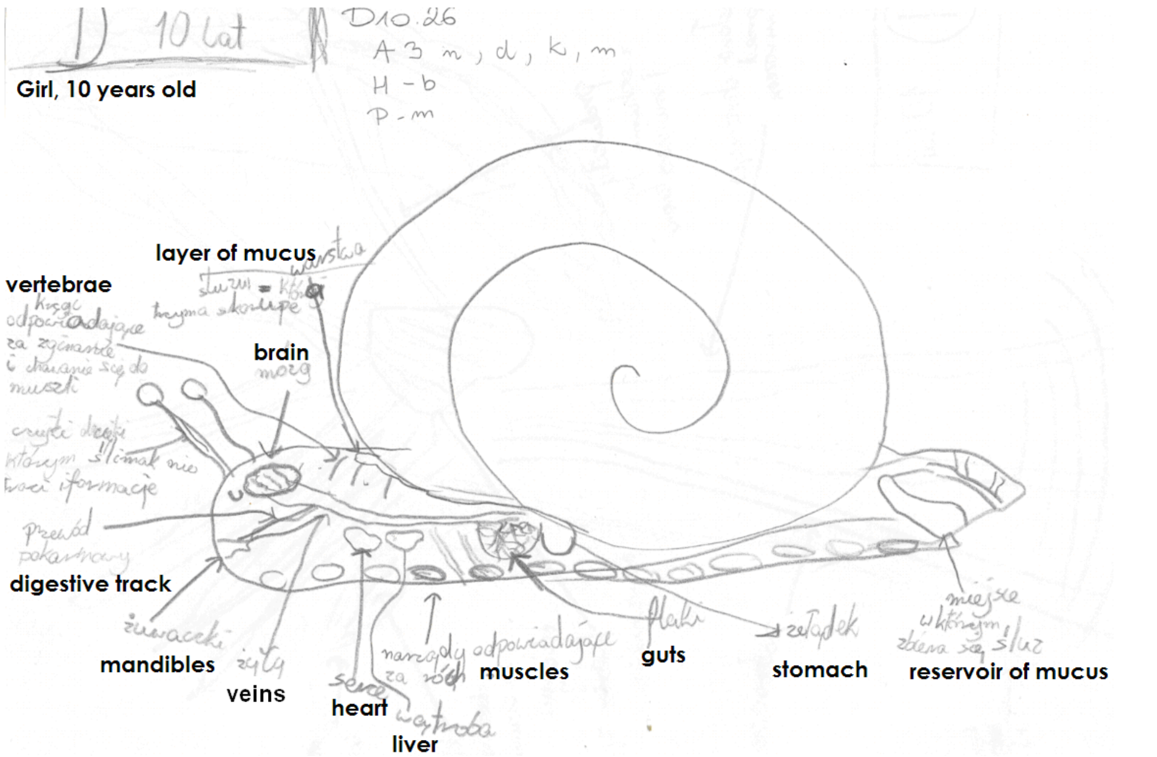

Figure 1: Drawing of 10 year old, which was scored 3ndkmHbPm.

(3 - level 3, one internal organ in appropriate position, n – some organs of nervous system, d – some organs of digestive system, k – some organs of circulatory system, m – muscular system, H – human templates which here are b – bones here vertebrae, P – physiological m – mucus).

Data were entered into Minitab and Excel for analysis. Randomized (n=9999) chi squared test was performed for detecting differences between levels and age groups, distinguished categories of structures and age groups and population structure. Also Fisher's exact test was performed for each trait to analyse differences between distinguished categories of structures and sex. All statistical analyses were performed in R 3.0.2 (R Core Team, 2013).

Results of Research

General Analysis of Children Drawings According to Rubric Scale

There were analysed 245 pictures using a rubric scale and the results are shown in table 1. There was statistically significant difference between age groups and levels of their drawings (Figure 2), (χ^2= 29.83, p<0.01).

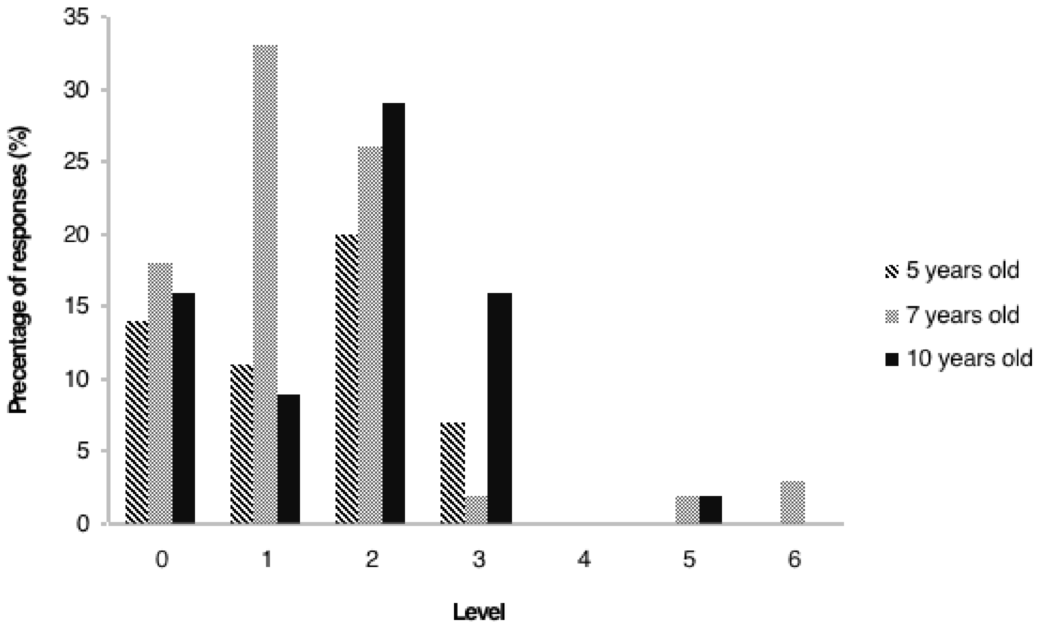

Figure 2: **Results of particular level in relation to age.**

The level 0 (no representation of snail) was most often found on the group of 7 year olds (Figure 1), the same as at level one. For level two (one or more internal organs placed at random) all analyzed age groups had similar results (between 20 and 30% of children in all groups). Children from group 3 (10 years olds), had the highest number of drawings on level three (one internal organ in appropriate position). There were no drawings found that were categorized to level four. Seven drawings were accurate for level 5 (4 children, 2 age 7 and 2 at age 10) and 6 (3 children all at age 7). No representations of level 7 were found.

Children's understanding about organ systems seems to be poor. The most frequent level achieved on drawings was level 2 - one or more internal organs placed at random (30% of all pictures). Digestive organ system was represented in drawings most frequently (level 3).

Students' Understandings of Internal Organs of a Snail

Pupils had understanding of an anatomical aspect of snails. The most frequent organ drawn was a heart (it appeared on 37% of all pictures). Next, were intestines (14%) and brain (11%). There were differences between genders, and the age groups of pupils.

Age-related differences in children understandings of internal organs of snails

Age-related differences in children's understanding of internal organs of snails were statistically significant in four cases, which include: nervous system (χ^2 =7.79, p= 0.02), circulatory system (χ^2 =5.92, p= 0.05), muscles (χ^2 =12.15, p<0.01) and digestive system (χ^2 =39.95, p=0.02), where older children had fuller drawings. Other internal structures that appeared on the pictures didn't show statistically significant differences in relation to age.

Although, the most frequent internal structure drawn was a heart, some interesting differences in age groups in organs of the digestive and nervous systems were observed. Organs of the digestive system were not present at all in pictures done by 5 years old, and appeared at 8% of pictures of 7 years old and in 33% pictures of the 10 year old group. An organ of the nervous system was present at 11% at 5 year old, 6% of 7 year old and 20% pictures done by 10 year old children.

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Gender-related differences in children understandings of internal organs of snails

The data were also tested by Fisher's Exact Test. Understanding of anatomical traits in relation to gender was not significant. The nervous system appeared at 11% of pictures done by girls and in 13% pictures done by boys. For the digestive system differences were also small (F=16%, M= 13%). A similar observation was drawn from data for circulatory system (F=37%, M=39%).

Additional Features Inserted on the Pictures

Among additional features the most frequently drawn was mucus – it appeared at 24% of pictures (26% at group of 5 year olds, 41% at 7 year olds and 1% at group of 10 year olds). Offspring were drawn only by 5 year old children (16%) and 10 year old children (6%). Understanding of internal anatomy of the snail differed in such features as food, bones and mucus between ages and gender. Girls drew more in the category food (7 year olds, $p=0.01$) and bones (10 year olds, $p>0.05$). The boys drew more instances, results of the mucus category (10 year olds, $p<0.01$).

Some pupils had drawn features that resemble a human face on their pictures. These include features like lips, eyelashes, nose in the category "Human template". This phenomenon was found in 18% of all pictures. Surprisingly, it was most common amongst 10 year olds (within this age, 45% use human facial features on the picture).

Drawings concerning cultural representation of the inside of snail were less frequent. Elements such as furniture appeared in 12% of all pictures. We had anticipated that this category would be more common among the youngest group, where the name "home" is used in stories describing the snail shell. These results show, that pupils of age 7 use cultural features most often (16% of all group age 7) and 13% of pupils aged 10 marked some cultural features, whereas only 5% of age 5 showed pictures of snails as having furniture such as TV, table and chairs inside the snail. In the 5 year old group a few drawings indicated a representation of the soul of the snail.

The data were also tested by Fisher's Exact Test for Count Data in R program. The data thus show that there are age-related and gender related differences.

Age-related differences in children's understandings of additional features

Age-related differences in children's understanding of additional features were only statistically significant in one case which was offspring as an internal structure of animal ($\chi^2 =12,87$, $p<0.01$).

Gender-related differences in children's understandings of additional features

Understanding of additional features as part of internal structure of a snail in relation to sex was statistically insignificant in analysed features.

The next data were tested by Chi-squared test of goodness-of-fit with simulated p-value (based on 9999 replicates). The students had understanding in the physiological aspects of snails, such as: mucus (girls $\chi^2 =7.65$, $p=0.023$; boys $\chi^2 =14$, $p<0.01$) and other organisms (boys $\chi^2 =10.70$, $p<0.01$).

Discussion

Children across ages are aware that a snail is a living creature and has to have some internal organs, because animals have "things inside". This observation is similar to the results of Reiss and Tunnicliffe (2001), who observed that pupils at every age are aware of internal structures, which were of humans in that case. Although children are not sure how to present internal structures (for example, about 9% of children drew internal organs only in the foot leaving the shell empty) or using the human as template (by drawing face features like eyelash, or appendix and spleen in the digestive system). One girl (D10.29), who drew all internal organs in the foot, explained that "shell has to stay empty, because it serves as home and snail is hiding itself in this home, so when it comes outside it leaves home empty".

There has been little research done on children's understanding of invertebrate internal structure. Invertebrates seem to be the least well-understood group of organisms among all age groups (Trowbridge & Mintzes, 1988). Prokop and co-workers (2007) reported that the organ systems of vertebrates were better drawn than those of invertebrates by Slovakian children. They also showed, that children at primary school ranged mainly between level 2 and 3, while at our investigations only the results from children at age 10 were between those levels. Younger children (aged 7) were mostly between 1 and 2 levels (Figure 2). None of the children who participated in this investigation had formally learnt about animal or human anatomy at school and it is not surprising that their knowledge is not therefore strictly scientific.

The most common organ drawn by children was a heart. This finding is in agreement with Reiss and Tunnicliffe (2001) and Prokop and Fančovičová (2006), who showed that the most common human internal organs drawn by the children were heart or bones. Those authors also noticed that there is a statistically significant likelihood of children drawing elements of the circulatory or skeleton system more than any other (Reiss & Tunnicliffe, 2001), and that some systems like urinary, reproductive or endocrine are hardly represented (Prokop & Fančovičová, 2006). In the presented research this lack of recognition of organs of a system was also true for respiratory system, which was not present at any of the pictures. What is also worth noting is the majority of organs which were drawn without further relationships neither to the same system (e.g. heart without veins) nor to the other system (e.g. heart was not connected with lungs). Similar observations were done by Prokop and Fančovičová (2006). Indicating bones inside an invertebrate was observed by Trowbridge and Mintzes (1988) and by Prokop and co-workers (2008). This was also noted in the drawings of the internal anatomy of crabs by Reiss and Tunnicliffe (2014). Trowbridge and Mintzes (1988) reported that between 21 and 30% of investigated students in their cross-age studies indicated snail as amphibian. Kattmann (2001) showed the predominance of non-taxonomic criteria (based mainly on the type of locomotion and habitat) that is apparent in the grades 4 and 5 in Germany. He also described that children classified snakes or ladybirds as snail. Such misclassifications and conceptions may lead to children's mental model which will be resistant for change through the formal learning process (Trowbridge & Mintzes, 1985; Trowbridge & Mintzes, 1988; Shneider & Stern, 2013; Hołówka, 1986; Kattmann, 2001; Prokop, Prokop & Tunniclife, 2008).

Gender differences were not so significant in the present study. There were only three statistically significant observations concerning gender. Namely, that boys more often than girls consider mucus and other organisms (such as bacteria) as a part of snail internal structure. Secondly, the girls drew more in the category food (7 years old) and bones (10 years old). Prokop, Prokop and Tunnicliffe (2008) showed that the girls had better knowledge about the anatomy of animals, but girls more frequently' misclassified' invertebrates by drawing bones inside the bodies of those animals. Girls also pictured bones inside a snail more frequently than boys, but this was not statistically significant in the whole investigated crowd, just in the third group (10 years old).

Using humans as a template for other animals is quite common among children and was reported by many researchers (e.g. Reiss & Tunnicliffe, 2000; Inagaki & Hatano, 2002, p. 358, Bartoszeck & Tunnicliffe, 2013), but it may lead to such misconception as snails having bones, spine, appendix or tonsils. There was also an interesting picture one presenting an extra head inside the shell (C10.49), student was explaining that "snail can regenerate so it has a spare (reserved) head to be able to think, when the first one is for some reason destroyed".

Student's own mental models are often constructed when a given task requires from students more general approach (Kattmann, 2001). The mental model of a snail that arises from present research is complex. Partially it depends upon age and gender. Younger children didn't draw digestive system at all, it appeared in the pictures made by older children. Prokop and Fančovičová (2006) noticed that organs of digestive system were not the one of the commonly drawn systems by Slovakian children, even between adults drawing human body internal structure. It is also worth noting, that some misconceptions about snails such as shell that stays empty and serves as home are resistant for change and occur in all age groups. Such conceptions arise from cultural aspects. Another example could be found in few pictures of 5 year old boys who draw a soul of the snails as a part of their internal structure. Accordingly, other authors observed children, who expressed that part of their internal structure is Jesus (Reiss & Tunnicliffe, 2001).

The most varied are conceptions of children's understanding on what exactly is inside the shell. Some of them draw some internal organs, but others just claimed that inside the shell is only mucus, or food, or it's empty. All those observations about children's' mental model of a snail are their pre-existing knowledge. As Bruner (1986) said, learning is an active process in which learners construct new ideas or concepts based upon their current/past knowledge.

Conclusions

Children have their knowledge that allows them to explain the world that surrounds them. Their knowledge is often incomplete and thus poor in biological terms, and they share some misunderstandings about animals with children from different cultures or with adults. Some of those ideas arise from analogies to vertebrate (to human in particular). Children usually have much less understanding of the anatomy of invertebrates and have their own explanations of what it is, hence these ideas are usually in agreement with scientific knowledge. Indeed, sometimes the child's knowledge may even indicate that snails are not either an animal nor any kind of living creature. What is also important to bear in mind is that mental models are quite resistant to change. Teachers should acknowledge that their pupils come to school with pre-existing models, knowledge, and they should recognize children's understanding before they plan and organize the lesson. Our research presented here supports recommendations that, because children benefit from encounters with animals in the school from an early age in school environment, such animals like invertebrates should be introduced. Children should be able to observe animals in their natural habitat, handle them, care for them etc. Such activities are crucial for making positive relationship between human and animals.

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References

Balmford, A., Clegg, L., Coulson, T., & Taylor, J. (2002). Why conservationists should heed Pokémon. *Science*, *295*, 2367-2367. Retrieved from http://www.bioteach.ubc.ca/TeachingResources/GeneralScience/PokemonWildlife.pdf

Barraza, L. (1999). Children's drawings about the environment. *Environmental Education Research*, *5* (1), 49-66. doi: 10.1080/1350462990050103.

Bartoszeck, A. B., Machado, D. Z., & Amann-Gainotti, M. (2011). Graphic representation of organs and organ systems: Psychological view and developmental patterns. *Eurasia Journal of Mathematics, Science & Technology Education, 7* (1), 41-51. doi: 10.12973/eurasia.204

Bartoszeck, A. B., & Tunnicliffe, S. D. (2013). What do early years children think is inside a tree. *The Journal of Emergent Science, 6*, 21-25.

Bell, B. F. (1981). When is an animal, not an animal? *Journal of Biological Education, 15* (3), 213-218. doi: 10.1080/00219266.1981.9654381

Bruner, J. (1986). *Actual minds, possible worlds.* Cambridge, MA: Harvard University Press.

Carey, S. (1985). *Conceptual change in childhood*. Cambridge: MIT.

Davey, G. C., McDonald, A. S., Hirisave, U., Prabhu, G. G., Iwawaki, S., Jim, C. I., ... & C Reimann, B. (1998). A cross-cultural study of animal fears. *Behaviour research and therapy*, *36* (7), 735-750. doi: 10.1016/S0005-7967(98)00059-X.

Dempsey, B. C., & Betz, B. J. (2001). Biological drawing a scientific tool for learning. *The American Biology Teacher*, *63* (4), 271-281. doi: 10.1662/0002-7685(2001)063[0271:BDASTF]2.0.CO;2

Driver, R., Asoko, H., Leach, J., Scott, P., & Mortimer, E. (1994). Constructing scientific knowledge in the classroom. *Educational researcher, 23* (7), 5-12. doi: 10.3102/0013189X023007005.

Ehrlén, K. (2009). Drawings as representations of children's conceptions. *International Journal of Science Education*, *31* (1), 41-57. doi: 10.1080/09500690701630455.

Gardner, H. (1980). *Artful Scribbles. The significance of children's drawings*. New York, NY: Basic Books.

Głowaciński, Z., & Nowacki, J. (Eds.). (2004). *Polska czerwona księga zwierząt: bezkręgowce*. [Polish red book of animals: invertebrates]. Cracow: IOP PAN.

Herzog, H. A. (2007). Gender differences in human–animal interactions: A review. *Anthrozoos: A Multidisciplinary Journal of the Interactions of People & Animals*, *20* (1), 7-21. doi: http://dx.doi.org/10.2752/089279307780216687.

Hmelo-Silver, C. E., Marathe, S., & Liu, L. (2007). Fish swim, rocks sit, and lungs breathe: Expert-novice understanding of complex systems. *Journal of the Learning Sciences*, *16* (3), 307-331. doi: 10.1080/10508400701413401.

Hołówka, T. (1986). *Myślenie potoczne: heterogeniczność zdrowego rozsądku.* [Common thinking: heterogeneity of common sense]. Warsaw: PIW.

Inagaki, K., & Hatano, G. (2002). *Young children's naive thinking about the biological Word.* New York: Psychology Press.

Iozzi, L. A. (1989). What research says to the educator: Part one: Environmental education and the affective domain. *Journal of Environmental Education*, *20* (3), 3-9. doi: 10.1080/00958964.1989.9942782.

Jones, M. G., Howe, A., & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education, 84* (2), 180-192. doi: 10.1002/(SICI)1098-237X(200003)84:2<180::AID-SCE3>3.0.CO;2-X.

Kattmann, U. (2001). Aquatics, flyers, creepers and terrestrials–students' conceptions of animal classification. *Journal of Biological Education, 35* (3), 141–147. doi: 10.1080/00219266.2001.9655763.

Kellert, S. R. (1993). Values and perceptions of invertebrates. *Conservation Biology, 7* (4), 845-855. doi: 10.1046/j.1523-1739 .1993.740845.x.

Lindemann-Matthies, P. (2005). 'Loveable' mammals and 'lifeless' plants: how children's interest in common local organisms can be enhanced through observation of nature. *International Journal of Science Education, 27*, 655–677. doi: 10.1080/09500690500038116.

Morris, R., & Morris, D. (1965). *Men and snakes*. London: Hutchinson & Co.

Mintzes, J. J. (1984). Naive theories in biology: Children's concepts of the human body. *School Science and Mathematics, 84*, 548–555. doi: 10.1111/j.1949-8594.1984.tb10179.x.

Novak, J. D., & Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. *American Educational Research Journal*, *28* (1), 117-153. doi: 10.3102/00028312028001117.

Osborne, R. J., & Gilbert, J. K. (1980). A technique for exploring students' views of the world. *Physics Education*, *15* (6), 376. doi:10.1088/0031-9120/15/6/312.

Osborne, J., Wadsworth, P., & Black, P. (1992). *Processes of life: Primary space project research report.* Liverpool: Liverpool University Press.

Patrick, P., Byrne, J., Tunnicliffe, S. D., Asunta, T., Carvalho, G. S., Havu-Nuutinen, S., Sigurjónsdóttir, H, Óskarsdóttir, G., & Tracana, R. B. (2013). Students (ages 6, 10, and 15 years) in six countries knowledge of animals. *Nordic Studies in Science Education*, *9* (1), 18-32.

Patrick, P., & Tunnicliffe, S. D. (2011). What plants and animals do early childhood and primary students' name? Where do they see them? *Journal of Science Education and Technology*, *20* (5), 630-642. doi: 10.1007/s10956-011-9290-7.

Pooley, J. A., & O'Connor, M. (2000). Environmental education and attitudes emotions and beliefs are what is needed. *Environment and Behavior, 32* (5), 711-723.

Prokop, P., & Fančovičová, J. (2006). Students' ideas about the human body: Do they really draw what they know. *Journal of Baltic Science Education, 2* (10), 86-95. Retrieved from http://www.zoo.sav.sk/prokop/articles/Prokop-FancovicovaJBSE06.pdf.

Prokop, P., & Fančovičová, J. (2013). Does colour matter? The influence of animal warning coloration on human emotions and willingness to protect them. *Animal Conservation, 16* (4), 458-466. doi: 10.1111/acv.12014.

Prokop, P., Kubiatko, M., & Fančovičová, J. (2007). Why do cocks crow? Children's concepts about birds. *Research in Science Education, 37* (4), 393-405. doi: 10.1007/s11165-006-9031-8.

Prokop, P. A., Prokop, M. A., Tunnicliffe, S. D., & Diran, C. (2007). Children's ideas of animals' internal structures. *Journal of Biological Education*, *41* (2), 62-67. doi: 10.1080/00219266.2007.9656064.

Prokop, P., Prokop, M., & Tunnicliffe, S. D. (2008). Effects of keeping animals as pets on children's concepts of vertebrates and invertebrates. *International Journal of Science Education*, *30* (4), 431-449. doi: 10.1080/09500690701206686.

Prokop, P., & Tunnicliffe, S. D. (2008). Disgusting" animals: Primary school children's attitudes and myths of bats and spiders. *Eurasia Journal of Mathematics, Science & Technology Education*, *4* (2), 87-97. Retrieved from http://www.ejmste.com/v4n2/Eurasia_v4n2_Prokop.pdf.

Randler, C., Hummel, E., & Prokop, P. (2012). Practical work at school reduces disgust and fear of unpopular animals. *Society and Animals, 20* (1), 61. doi: 10.1163/156853012X614369.

Reiss, M. J., & Tunnicliffe, S. D. (2000). Students' understandings about organs and organ systems in different animals. In Gayoso, I. G. R. (Ed.), *Proceedings of the III Conference of European Researchers in Didactic of Biology (ERIDOB): September 27th-October 1st, 2000, Santiago de Compostela (Spain)* (130). Santiago de Compostela: Univ Santiago de Compostela.

Reiss, M. J., & Tunnicliffe, S. D. (2001). Students' understandings of human organs and organ systems. *Research in Science Education*, *31* (3), 383-399. doi: 10.1023/A:1013116228261.

Rinsland, H. D. (1946). *A basic vocabulary of elementary school children*. New York: Macmillan.

Roth, C. E. (1992). *Environmental literacy: Its roots, evolution and directions in the 1990s*. Retrieved from http://files.eric.ed.gov/fulltext/ED348235.pdf.

Salmon, K., & Pipe, M.E. (2000). Recalling an event one year later: The impact of props, drawing and a prior interview. *Applied Cognitive Psychology*, *14* (2), 99-120. doi:10.1002/(SICI)1099-0720(200003/04)14:2<99::AID-ACP639>3.0.CO;2-5.

Schneider, M., Stern E., (2013). Uczenie się z perspektywy poznawczej: dziesięć najważniejszych odkryć. [Learning from the perspective of the most important cognitive discoveries]. In Dumont H., Istance D., Benavides F. (Eds.), *Istota uczenia się Wykorzystanie wyników badań w praktyce. [The essence of learning. The use of the research results in practice.]* (pp. 107-140). Warsaw: Wolters Kluwer.

Tekkaya, C. (2002). Misconceptions as barrier to understanding biology. *Hacettepe University Education Journal, 23*, 259–266.

Tomkins, S., & Tunnicliffe, S. D. (2007). Nature tables: Stimulating children's. *Journal of Biological Education*, *41* (4), 150-155. doi: 10.1080/00219266.2007.9656090.

Trowbridge, J. E., & Mintzes, J. J. (1985). Students' alternative conceptions of animals and animal classification. *School Science and Mathematics, 85* (4), 304-316. doi: 10.1111/j.1949-8594.1985.tb09626.x.

Trowbridge, J. E., & Mintzes, J. J. (1988). Alternative conceptions in animal classification: A cross- age study. *Journal of Research in Science Teaching*, *25* (7), 547-571. doi: 10.1002/tea.3660250704.

ISSN 1648–3898

Tunnicliffe, S. D. (1996). Conversations within primary school parties visiting animal specimens in a museum and zoo. *Journal of Biological Education*, *30* (2), 130-141. doi: 10.1080/00219266.1996.9655491.

Tunnicliffe, S. D., & Reiss, M. J. (1999). Building a model of the environment: how do children see animals? *Journal of Biological Education, 33*, 142-148. doi: 10.1080/00219266.1999.9655654

Zoldosova, K., & Prokop, P. (2006). Education in the field influences children's ideas and interest toward science. *Journal of Science Education and Technology*, *15* (3-4), 304-313. doi: 10.1007/s10956-006-9017-3.

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