SCIENCE LITERACY: THE POINT OF VIEW OF STUDENT INTO UNDERSTANDING THE INTERNAL ANATOMY OF SELECTED VERTEBRATES

Amauri Betini Bartoszeck[1]
Leandro Kruszielski[2]
Flavio Kulevicz Bartoszeck[3]

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ABSTRACT: How do people develop understandings of what is inside certain vertebrates including themselves? This study based on a quantitative investigation looks at students' understandings of internal structures of a rat, a fish, a bird and themselves. A cross-sectional approach was used involving a total of 696 students in southern Brazil from seven different age groups (ranging from four years old to first year Biology undergraduates). Students were asked to draw what they thought were inside the specimens above. Data analysis was carried out following a scoring protocol and entered into SPSS. Gender differences were not statistically significant, whoever, it shows the extent to which student understanding increases with age and the degree to which students know more about some organs and organ systems than others. Educational implications and aspects of science literacy are discussed.
KEYWORDS: Anatomy. Biology education. Drawings. Science literacy. Vertebrates.

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[1]Corresponding author: Associate Professor, Fellow in Basic Medical Education, Physiology [ECFMG, Philadelphia, PA; University of Washington, Seattle, WA], Department of Physiology, Laboratory of Neuroscience & Education, The Federal University of Paraná, Curitiba, PR, Brazil; e-mail: abbartoszeck@gmail.com, bartozek@ufpr.br
[2]Assistant Professor, Don Bosco College, Department of Psychology, Curitiba, PR, Brazil; e-mail: leandro.psi@gmail.com
[3]Assistant Professor, Philosophy and Psychology, specialist in Neuropsychology, Instituto de Neurociência & Educação do Paraná, INEPR, Centro Estadual de Educação Básica para Jovens e Adultos Paulo Freire, Curitiba, Paraná, Brazil; e-mail: flaviookb@gmail.com

ALFABETIZAÇÃO CIENTÍFICA: O PONTO DE VISTA DO ESTUDANTE SOBRE O ENTENDIMENTO DA ANATOMIA INTERNA DE VERTEBRADOS SELECIONADOS

RESUMO: Como as pessoas desenvolvem a compreensão do que está dentro de certos vertebrados incluindo elas mesmas? Este estudo baseado em investigação quantitativa, averigua a compreensão que os estudantes têm acerca das estruturas internas de um rato, um peixe, um pássaro e deles mesmos. Foi usada uma abordagem transversal, envolvendo um total de 696 alunos no sul do Brasil de sete diferentes faixas etárias (variando de 4 a 25 anos), incluindo normalistas e alunos de graduação em Biologia. Foi-lhes solicitado que desenhassem o que achavam que haveria no interior dos animais supracitados quando vivos. Os desenhos coletados foram analisados seguindo-se uma escala de pontuação para órgãos e sistema de órgãos. Os dados obtidos foram analisados estatisticamente com o programa SPSS. A diferença de gênero não foi estatisticamente significativa, e a análise mostrou a extensão na qual a compreensão aumenta com a idade e o grau no qual o estudante conhece mais sobre certos órgãos e sistemas de órgãos do que outros. São discutidas implicações para a alfabetização científica e educação biológica.
PALAVRAS-CHAVE: Anatomia. Educação biológica. Desenhos. Alfabetização científica. Vertebrados.

ALFABETIZACIÓN CIENTÍFICA: El PUNTO DE VISTA DEL ESTUDIANTE SOBRE LA COMPRENSIÓN DE LA ANATOMIA INTERNA DE VERTEBRADOS SELECCIONADOS

RESUMEN: ¿Cómo las personas desarrollan la comprensión del que está dentro de ciertos vertebrados, incluyendo a ellas mismas? Este estudio es fundamentado en una investigación cuantitativa, que averigua la comprensión que los estudiantes tienen acerca de las estructuras internas de un ratón, un pájaro, un pez y de ellos mismos. Se usó un abordaje transversal, involucrando un total de 696 estudiantes, en el sur de Brasil, de siete diferentes grupos de edad (variando de 4 a 25 años), incluyendo normalistas y alumnos de graduación en Biología. Les solicitó que dibujasen lo que creían que habría en el interior de los animales mencionados

cuando vivos. Los dibujos colectados fueron analizados siguiéndose una escala de puntuación para órganos y sistema de órganos. Los datos obtenidos fueron analizados estadísticamente con el programa SPSS. La diferencia de género no fue estadísticamente significativa, y el análisis señaló la extensión en el cual la comprensión aumenta con la edad y el grado en el cual el estudiante conoce más sobre órganos y sistemas de órganos que otros. Son discutidas implicaciones para la alfabetización científica y educación biológica.
PALABRAS CLAVE: Anatomía. Educación biológica. Dibujos. Alfabetización científica. Vertebrados.

INTRODUCTION

The process of scientific literacy still represents a heavy burden to kindergarten, primary and secondary school teachers and also to faculty in their deciding what and in which way to better teach their students. Moreover, acquiring such literacy is also a complex task for pupils if they are to achieve some understanding of biological form and function (PENICK, 1998, ROWETT, 1999, BRANDI; GURGEL, 2002). Little is known what differences there are between what kindergarten children, primary, secondary and undergraduate students know about human organs and organ system, compared to those of other vertebrate animals. Understanding is taken here as the meaning a community of students and scholars share concerning biological concepts, for instance the localization of the nervous system and how it performs its actions (GREENFIELD, 1996, HOWARD, 2000, Mc CRONE, 2002) in the intact animal, including human beings.

Previous studies as carried out by Schilder & Wechesler, (1935) interviewed children aged 4 to 13 asking what is inside the human body and got as a response that it contained blood, bones and eaten food. Tait & Archer, (1955) collected drawings from both hospital patients and healthy adults and students aged 11 to 13 showed, when analyzed, a larger representation of bones and muscles on the outlines done by school age students, instead than those by adults. Gellert, (1962), interviewed hospital patient children and adolescents aged 4 to 17, examining a developmental progression of knowledge about body organs, found that there was an increase in knowledge of body organs in general. Porter, (1974) analyzed outlines of the entire human body filled by children aged from 6 to 11 years old and found that children mentioned a greater number of body organs than previous studies. On the other hand, Blum, (1977) requested educated adults (aged 21 to 51 years old) to outline the human body and draw and label the internal organs. The most frequent organ drawn was the heart. An early overview of children´s concepts of the human body was carried out by (MINTZES, 1984).

Osborne et al., (1992) asked infants (aged 5 to 7), lower juniors (aged 8 to 9) and upper juniors (aged 10 to 11) what they have inside their bodies and expected this information

to be shown in their drawings and interviews. The most mentioned organs were heart, bones, stomach and brain. Further studies carried out with children (4 year olds) although with small samples, allowed the development of a preliminary "scale of complexity" for different organs (FLEER, 1994). Rabello, (1994) studied in eastern Brazil with a few children (3 pupils of 7, 8, 9 years old) the conceptions of their human body by means of drawings of their internal structures and interviews. Children, in a semi-structured interview, as hospital patients, drew body organs on a prepared outline, placed muscles & brain in a correct position into 93% of the drawings (McEWING, 1996). A holistic view of internal body maps was investigated whether children (7 to 11 year-olds) connect tubes between organs and organ system models, particularly the respiratory, cardiovascular and digestive systems, and most of the drawings depicted suspended organs floating inside the body (CUTHBERT, 2000).

More recently, Tunnicliffe & Reiss, (1999a, b) investigated how pupils (4 year-olds to 20 year-olds) identify and understand the structure of internal organs and organ systems of vertebrate animals including human beings and developed a seven-point scoring scale to allow international comparative studies. It was followed by a series other studies emphasizing the internal anatomy of human beings in different countries, cultures and perspectives (REISS; TUNNICLIFFE, 2001, SCHMIDT, 2001, REISS; TUNNICLIFFE; BARTOSZECK et al., 2002, MANOKORE; REISS, 2003, ÓSKARSDÓTTIR, 2006, GATT; SALIBA, 2006, ÖZSEVGEÇ, 2007; BARTOSZECK; MACHADO; AMANN-GAINOTTI., 2008; PATRICK; TUNNICLIFFE, 2010). Organ and organ systems of selected vertebrates including human beings were investigated with primary, secondary and college students in England and found that few drawings achieved the highest score that was expected (REISS & TUNNICLIFFE, 2001). Other studies carried out in Slovakia which also included invertebrates internal structures (e. g. a stag beetle & a crawfish) besides vertebrates contributed to students´ knowledge of internal organs (PROKOP; PROKOP; TUNNICLIFFE; DIRAN, 2007, PROKOP; PROKOP, TUNNICLIFFE, 2008).

Valuable data were obtained on how children (4 to 10 year-olds) in northeastern Brazil understand the functioning of human digestion (TEIXEIRA, 2000, OLIVEIRA, 2000) A similar approach was carried out in India, Brazil, England and Turkey respectively (RAMADAS; NAIR, 1996, SELLES; AYRES, 1999, ROWLANDS, 2004, ÇAKICI, 2005). It was also investigated how the topic of digestion is represented in primary school textbooks in Portugal, the nervous system in French and Tunisian textbooks and the circulatory system in Brazilian textbooks (CARVALHO; CLÉMENT, 2007, CLÉMENT; MOUELHI; ABROUGUI, 2006, SELLES; AYRES; RESNIK, 2001).

An understanding of excretory and digestive systems on the perspective of the conception of "continuous tubing" were investigated with children aged 7 to 10 years in England (TUNNICLIFFE, 2004). Circulation models were also explored with Brazilian students (SELLES; AYRES; RESNIK, 2001). Interviews were used to clarify misconceptions on human circulatory system in Turkey and representations in Spain (SUNGUR; TEKKAYA; GEBAN, 2001, LÓPEZ-MANJÓN; ANGÓN, 2009). Mans & Treagust, (1998) investigated Australian student´s conceptions of respiration by means of simple instrument (paper and pencil).

On the other hand, the authors of the present study also wanted to clarify which organs & organ systems are possibly more difficult to understand and be represented in a sample from a developing country, as prospective Biology teachers in another setting rated kidney, brain, and spinal cord as the most difficult (KOKSAL; CIMEN, 2008).

OBJECTIVE

This study aims to investigate in a cross-age study how previous knowledge, pre-school children, primary and secondary pupils, pupils at a "College of Education" for teacher training (a former secondary 4 years course) and Biology undergraduates hold in their minds, concerning the inner parts of organisms, specially organs and organs systems, are constructed as they get older in their interaction with school and the world at large (LAWSON, 1988).

METHODS

Sample and procedure

This study looks at the understandings of pupils aged 4 to 25 of the structure of animal (including human) internal organs and organ systems found in them. A cross-sectional approach was used in which pupils of different ages were shown a sample of the selected vertebrates, each on a separate occasion, a rat, a bird a fish (taxidermically prepared or fresh) and in the last session themselves as a model as had Tunnicliffe; Reiss, (2001). The pupils at each age were asked to draw what they thought was inside the animals when they were alive. Although pupils represent their own internal anatomy and that of the other animals of the present study in two dimensions, such representation can be taken as the expressed models, i. e. as representations of phenomena available for the general public, and this particular case for the pupils (BUCKLEY; BOULTER; GILBERT, 1997, GILBERT; BOULTER; ELMER, 2000). However, this expressed model is related but is not equal with the mental model, i. e. the private and personal cognitive representations the students have over this matter (JONSON-LAIRD, 1988). The use of drawings as a research tool in education is discussed among others by (COX, 1989; 1997, HAYES; SYMINGTON; MARTIN, 1994, MAcPHAIL; KINCHIN, 2004). Backett-Milburn e McKie, (1999) examined the relevance of drawings as a technique that enables children to communicate their thoughts.

The Ethical Research Committee of the Higher Education Institution approved the main goals of the proposal of the present study. All data were collected subjected to full consent of parents, teachers, head masters, principles of all educational institutions involved in this project.

Fieldwork was carried out in the southern part of Brazil, in the Paraná State capital Curitiba, in two Schools of Infancy Education, two

Secondary Schools, a "College of Education" for teacher training ("Escola Normal") and a four years research University undergraduate course. The School of Infancy Education no. I (reception children for 4 to 6 year--olds) is a private school, the School of Infancy Education no. II is a state funded school. The Secondary School no. III enrolls students aged 7 to 18 and the Secondary School no. 4 (for 11 to 18 year-olds) both state funded, i. e. non-fee paying which is a mix of academics and military training institution. Data were also collected at a four years "College of Education" for teacher training ("Escola Normal") which is being discontinued, where students are training to be primary school teachers, and from 1st year Biology undergraduates from a research University, who intend to be mainly secondary school teachers and a few university faculty (Table 1)

Table 1: Year of attendance at Brazilian schools organized under criteria based on pupils´ performance, age groups, corresponding grades and N =number of students in each age category.

Year	Age	Grade	N
0 (reception)	4 to 6	K-II, K-III	86
1	7 or 8	1st, 2nd	32
2	9 or 10	3rd, 4th	34
3	11 or 12	5th, 6th	151
4	13 or 14	7th, 8th	203
5/6	15 to 17	9th, 10th, 11th	165
7/8	18 to 25	"College of Education", 12th/Biology undergraduates 1st year	21
Total			696

On separate occasions, the students were presented with a piece of plain paper and a single dead specimen of a white Wistar laboratory rat (*Rattus norvegicus*) [taxidermically prepared] a woodpecker (*Chrysoptilus melanochloros*) [taxidermically prepared], a salt water fish corbina (*Sciaena aquila*) [fresh]. On each occasion, the pupils were asked to draw what they thought was inside the creature shown when it was alive. Pupils were not examined under formal examination conditions but were told to draw on their own, without copying from the drawing of anyone nearby.

In the final session, students were asked to draw what they thought was inside themselves taking them as models.

Pupils were told to write their first names, age on the top of a A4 sheet of paper. After that, they were given 10 to 15 minutes to complete each drawing. They were told to look at the specimen presented on the set-up and asked to draw what they think is inside it. They were assured that it was not being referred to the inner dead parts of the exposed animal. Many of the pupils spontaneously labeled the internal structures represented in their drawings. Those who asked if they were expected to label their drawings indicating the inside structures were told that it was up to them to decide if they wanted to do so. The teacher wrote labels on the drawings for the 4, 5 and 6 year-olds pupils when requested, but only the exact words in places pointed by the children. The fieldwork was conducted in whole class settings. Due to the fact that specimens were presented on different occasions on average every 35 days after the previous presentation, sample sizes vary within each age across the four species drawn because of pupils absences. In the end, data were obtained from 24 reception children (aged 4 to 6) (year 0), 8 year 1 children (aged 7 or 8), 10 year 2 children (aged 9 or 10), 38 year 3 children (aged 11 or 12), 52 year 4 children (aged 13 or 14), 45 year 5/6 pupils (aged 15 to 17), 8 year 7/8 at the "College of Education" (aged 18 to 25), and Biology undergraduates (aged 18 to 25) for the rat (Fig. 1)

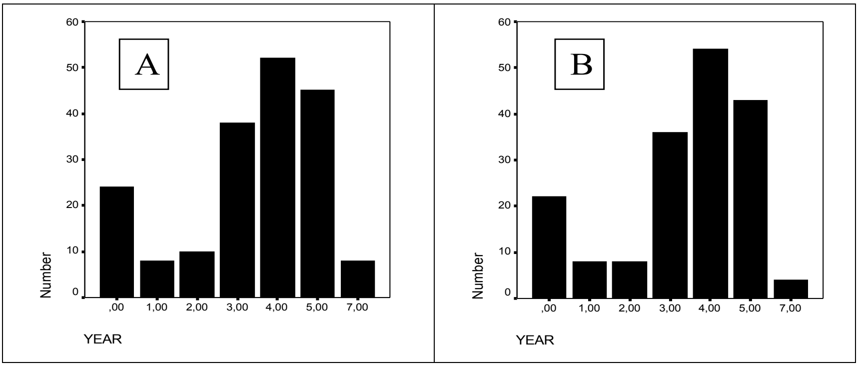

Figure 1: A - Number of pupils within each age category present during the presentation of the rat. B - Number of pupils within each age category present during the presentation of the bird. The data obtained for the bird were: 22 reception children, 8 year 1, 8 year 2, 36 year 3, 54 year 4, 43 years 5/6, and 4 years 7/8 (Fig. 1B).

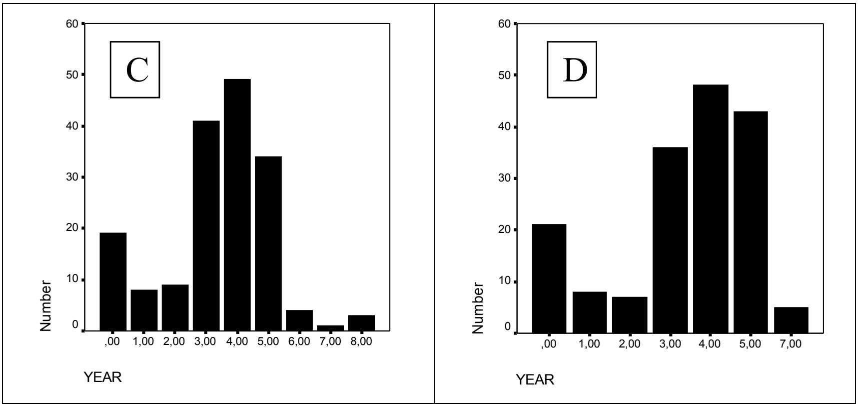

Figure 1: C - Number of pupils within each age category present during the presentation of the fish. The data obtained for the fish were: 19 reception children, 8 year 1, 9 year 2, 41 year 3, 49 year 4, 38 years 5/6, and 4 years 7/8 (Fig. 1C). D - Number of pupils within each age category present during the presentation of the human. The data obtained for the human were: 21 reception children, 8 year 1, 7 year 2, 36 year 3, 48 year 4, 43 years 5/6, 5 years 7/8 (Fig. 1D).

The authors were not known by any of the participants of the present research. An outline of Brazilian southern school science curricula emphasizing biological aspects is depicted on Table 2.

Table 2: Brazilian school science curricula (biological).

Year	**Age (years old)**	**Contents**
0 (reception)	4-6	Types of animals: invertebrates, vertebrates.
1	7-8	Growth of human beings.
2	9-10	Invertebrates & vertebrates in relationship to environment and human beings; basic concepts of bones & muscle, nervous system, sense organs.

3	11-12	Comparative basic animal morphology & physiology including digestion, respiration, circulation, excretion, movement, sense organs & nervous system.
4	13-14	Human anatomy & physiology of digestion, respiration, circulation, excretion, locomotion, endocrine organs, neural coordination, sexual education, drugs, diseases.
5-6	15-18	Organisms & environment, basic genetics, embryology, comparative human & animal physiology.
7	18-25	Educational biology
8	18-25	Morphology, internal anatomy of invertebrates & vertebrates including human anatomy, practical laboratory classes.

Data analysis

A total of 696 drawings were collected. A definition of organ systems is presented on Table 3.

Table 3: Definition of organ systems (after Reiss and Tunnicliffe, 2001).

Skeletal system	**Skull, spine, ribs and limbs**
Gaseous exchange system	Two lungs, two bronchi, windpipe which joins to mouth and/or nose.
Nervous system	Brain, spinal cord, some peripheral nerve (sciatic nerve)
Digestive system	Through tube from mouth to anus and indication of convolutions and/or compartmentalization.
Endocrine system	Two endocrine organs (e. g. thyroid, adrenals, hypophysis) other than pancreas [scored within urogenital system]

Urogenital system	Two kidneys, two ureters, bladder and urethra or two ovaries, two fallopian tubes and uterus or two testes, two epididymis and penis.
Muscular system	Two muscle groups (e.g. lower arm and thigh) with attached points of origin.
Circulatory system	Heart, arteries and veins into and/or leaving heart and, at least to some extent, all round the body.

Scoring of the drawing to evaluate the different levels of biological understanding attained by these pupils was carried out by the first two researchers and two graduate students following criteria developed in the scoring scale formulated by Tunnicliffe and Reiss, 1999a, Tunnicliffe and Reiss, 2001 (Table 4). The few disagreements over scoring were discussed by the authors concerning organ and organ system levels achieved until a conclusion was reached.

Table 4: Organ & organ system scoring scale (after Reiss and Tunnicliffe, 2001).

Level 1	No representation of internal structure.
Level 2	One or more internal organs (e. g. bones and blood placed at random.
Level 3	One internal organ (e. g. brain or heart) in appropriate position.
Level 4	Two or more internal organs (stomach and a bone “unit” such as the ribs) in appropriate positions but no extensive relationships indicated between them.
Level 5	One organ system indicated (e. g. gut connecting head an to anus).
Level 6	Two or three major organ systems indicated out of skeletal, gaseous exchange, nervous, digestive, endocrine, urogenital, muscular and circulatory.

Level 7	Comprehensive representation with four or more organ systems indicated out of skeletal, gaseous exchange, nervous, digestive, endocrine, urogenital, muscular and circulatory.

All the drawings were scored by five independent raters, the researchers and two graduate students given training, according to the level attained following to the ranking protocol of Table 4. Next it was decided whether the drawing met the criterion for organ system, for instance "N " (capital letter) for nervous system, "E " for endocrine system. Otherwise, each drawing was checked whether at least one organ was depicted and if it did a lower case letter was used, e. g. "u " for urogenital or "g " for gaseous exchange (respiratory system) as on Table 5.

Table 5: Organ systems definition and its components. Capital letters meant the drawing had a complete organ system. Lower case letters meant the drawing had at least one organ representing that organ system (after PATRICK; TUNNICLIFFE, 2010).

Organ system	Definition
Skeletal system	
[S or s]	skull, spine, ribs and limbs
Gaseous exchange [G or g]	two lungs, two bronchi, windpipe which joins to mouth and/or nose
Nervous system	
[N or n]	brain, spinal cord, some peripheral nerve (e.g. sciatic nerve)
Digestive system [D or d]	through tube from mouth to anus and indication of convolutions and/or compartmentalization
Endocrine system [E or e]	two endocrine organs (e. g. thyroid, adrenals, pituitary) except pancreas and gonads

Urogenital system [U or u]	two kidneys, two ureters, bladder and urethra or two ovaries, two fallopian tubes and uterus or two testes, two epididymes and penis
Muscular system [M or m]	two muscle groups (e. g. lower arm and thigh) with attached points of origin.

Figure 2 represents the drawing of a year 7 girl (aged 20 years) of what she thought was inside herself, the drawing is scored as level 6GDnu of understanding. It shows two satisfactory organ systems -namely gaseous exchange (respiratory system) and digestive of the eight possible organ systems but also an organ of the nervous system (brain) and a part of the endocrine system (ovaries), but here included in the urogenital system. Notice that "fallopian tubes" are in fact structures belonging to female genital system. However, the authors adhered to the original definitions when analyzing the drawings of this sample for the sake of convenience (Reiss and Tunnicliffe, 2001). Data were entered into SPSS program for analysis. All statistical tests are 2-tailed.

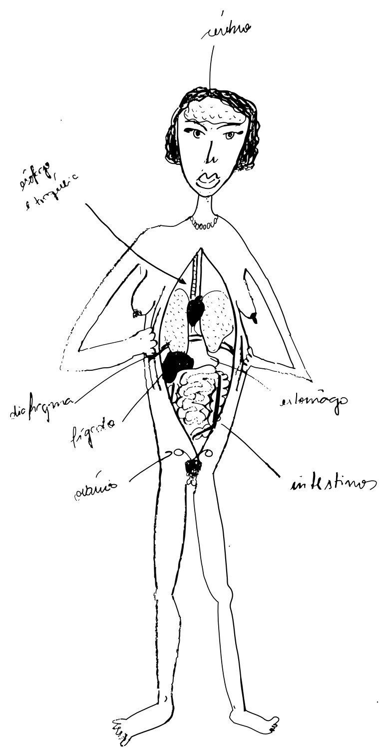

Figure 2: A drawing done by a Year 7 girl (aged 20 years) of what she thought was inside herself. The drawing is scored 6 GDnu according to the method described in the text. (Captions read: cérebro=brain, esôfago/traquéia=esophagus/trachea, diafragma=diaphragm, fígado=liver, ovário=ovary, estômago=stomach, intestino=bowels).

RESULTS

Levels of understanding attained for rat and other species studied.

The highest levels attained were 4 (40.0%) and 5 (25.9%) by inspection of the drawings representing the rat (Fig. 3). A significant correlation was found between levels attained (mean = 4.25; SD= 1.20) and age category (mean= 3.41; SD= 1.78) as depicted in Figure 3 and Figure 1 as well relationships evaluated by Pearson correlation coefficients ($r = 0.57$, $p<0.001$) for this and the other species studied

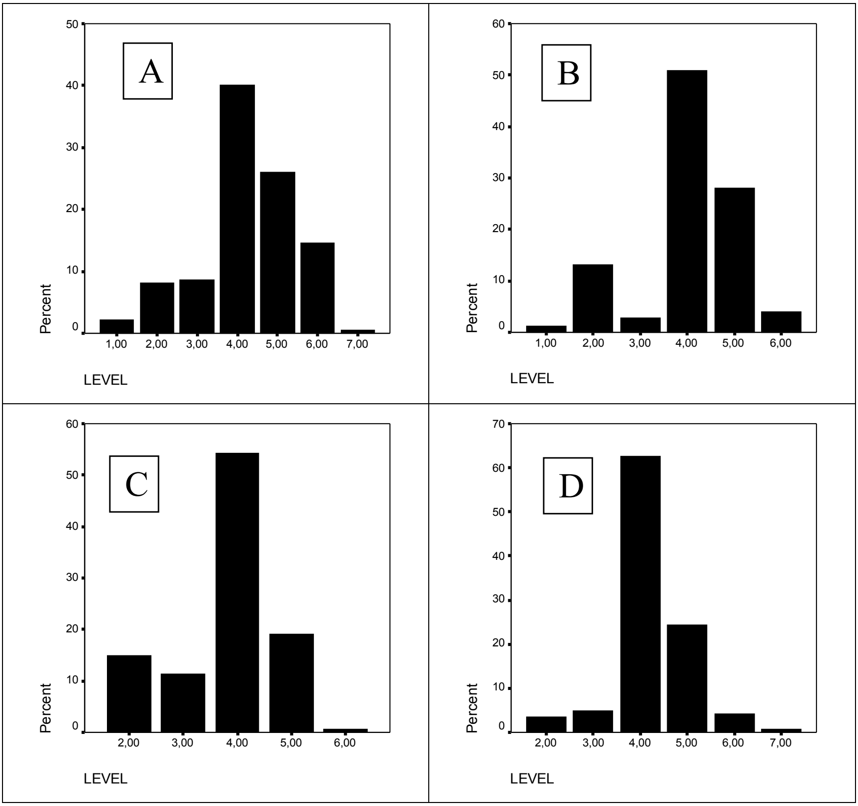

Figure 3: A - The percentage of pupils whose drawings attained different levels of understanding defined by the scoring scale for the rat. B - The percentage of pupils whose drawings attained different levels of understanding defined by the scoring scale for the bird. C - The percentage of pupils whose drawings attained different levels of understanding defined by the scoring scale for the fish. D - The percentage of pupils whose drawings attained different levels of understanding defined by the scoring scale for the human.

As for the bird the highest levels attained were 4 (59.9%) and 5 (28.0%). A significant correlation was found between levels attained (mean = 4.03; SD=1.04) and age category (mean =3.37; SD= 1.7) as depicted in Figure 3 and Figure 1 (r =0.60, <0.001).

As for the fish the highest levels attained were 4 (54.2%) and 5 (19.0%). A significant correlation was also found between levels attained (mean = 3.79; SD=0.94) and age category (mean= 3.29; SD=1.72) as depicted in Figure 3 and Figure 1 (r =0.44, <0.001).

Finally, the highest levels attained for human were 4 (62.5%) and 5 (24.4%). A significant correlation was found here as well between level (mean =4.22; SD=0.77) and age (mean =3.40; SD=1.73 as depicted in Figure 3 and Figure. 1 (r =0.31, p<0.001). No statistical significance was found in the levels attained by gender when scoring for the four vertebrates.

Participants' understandings of organ systems.

Putting together all the data, and thus ignoring differences between drawings resulting from student age, gender, degree of biology knowledge of the participants Figure 4 shows for each organ system the percentage of pupils whose drawing displayed an organ system as defined above in the analysis section for the rat and the other vertebrates.

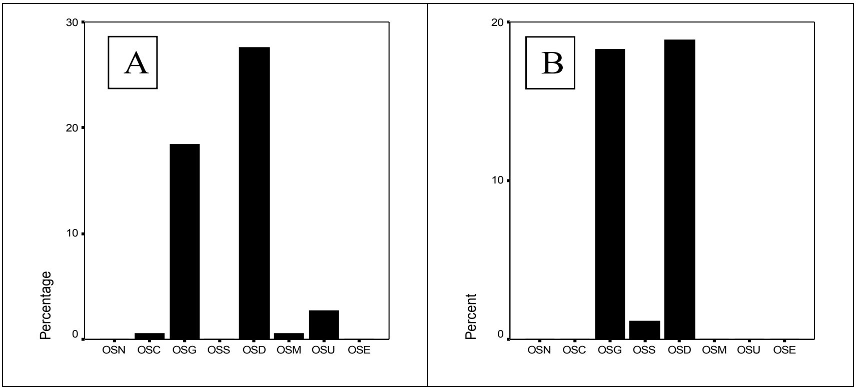

Figure 4: A -The percentage of students whose drawings displayed an organ system as described in the text. (OSN/nervous, C/circulatory, G/gaseous, S/skeletal, D/digestive, M/muscular, U/urogenital, E/endocrine for the rat). B - The percentage of pupils whose drawings displayed an organ system as described in the text. (OSN/nervous, C/circulatory, G/gaseous, S/skeletal, D/digestive, M/muscular, U/urogenital, E/endocrine for the bird).

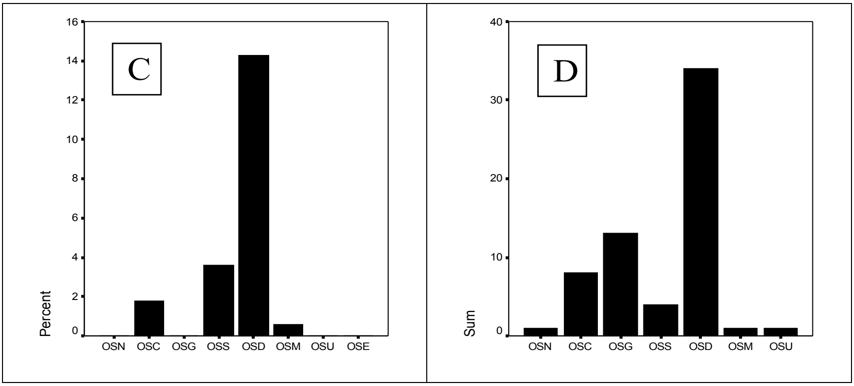

Figure 4: C - The percentage of pupils whose drawings displayed an organ system as described in the text. (OSN/nervous, C/circulatory, G/gaseous, S/skeletal, D/digestive, M/muscular, U/urogenital, E/endocrine for the fish). D - The percentage of pupils whose drawings displayed an organ system as described in the text. (OSN/nervous, C/circulatory, G/gaseous, S/skeletal, D/digestive, M/muscular, U/urogenital for the human).

The findings in this section revealed that for each of the eight organs systems, pupils had difficulties to draw the organ system sufficiently completely to be classified by the raters as an organ system. The digestive system and gaseous system (in the case of the rat, the bird) and the digestive system (in the case of the fish and human) were of the eight organ systems as the best classified of the organ systems.

Participants' understandings of organs

Again merging together all the data, and thus ignoring differences between the drawings resulting from pupils age, gender, degree of biology knowledge of the participants Figure 6 shows for each organ system the percentage of the students whose drawing represented an organ (rather than the entire organ system) for the rat as defined above in the Analysis section.

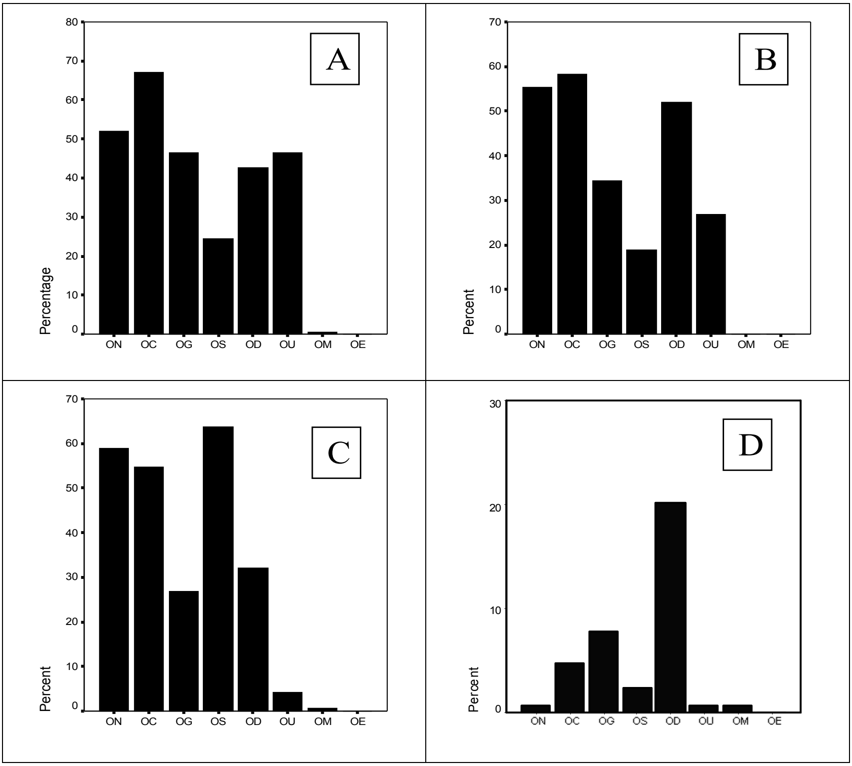

Figure 5: A -The percentage of pupils whose drawings represented an organ (rather than the entire organ system) for each organ system (ON/nervous, C/circulatory, G/gaseous, S/skeletal, D/digestive, U/urogenital, M/muscular, E/endocrine for the rat).B - The percentage of pupils whose drawings represented an organ (rather than the entire organ system) for each organ system (ON/nervous, C/circulatory, G/gaseous, S/skeletal, D/digestive, U/urogenital, M/muscular, E/endocrine for the bird).C - The percentage of pupils whose drawings represented an organ (rather than the entire organ system) for each organ system (ON/nervous, C/circulatory, G/gaseous, S/skeletal, D/digestive, U/urogenital, M/muscular, E/endocrine for the fish). D- The percentage of pupils whose drawings represented an organ (rather than the entire organ system) for each organ system. (ON/nervous, C/circulatory, G/gaseous, S/skeletal, D/digestive, M/muscular, U/urogenital, E/endocrine for the human).

However, students performed much better drawing an organ than in drawing whole organ systems. For example, more than 60.0% of the drawings showed an organ (nearly always the heart) in the circulatory system, and more than 50.0% of the drawings represented the nervous system except human, (nearly always the brain) and also the digestive system (stomach) in more than 30.0% of the drawings. On the other extreme, only 1.7% in all animal´s drawings showed a part of the muscular system and the endocrine was almost non-existent. There are also certain clear differences between the rankings in figures 5 and 4, particularly with respect to the circulatory (heart) and nervous system (brain) which are poorly represented as a whole system (Fig. 5, yet components of both are very frequently drawn (Fig. 4).

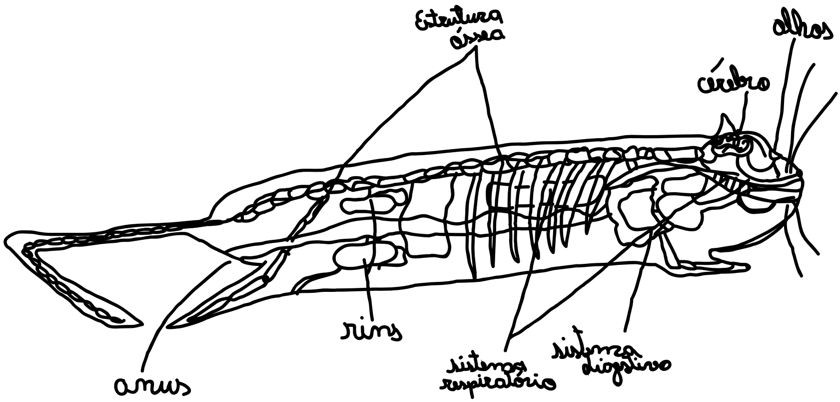

Figure 6: A drawing done by a year 2 boy (aged 10 years) of what he thought was inside the rat. The drawing is scored as 6 SD nu according to the method described in the text. (Captions read: olhos=eyes, cérebro=brain, sistema digestive=digestive system, sistema respiratório=respiratory system, estrutura óssea=bone structure, rins=kidneys, ânus=anus).

The levels at which the drawings are drawn and species specific differences

Firstly, the effective level for each of the four species drawn is level 4 and level 5. Secondly, any differences between species are probably small, however the highest level 6 achieved was when pupils draw the rat (14%) instead when drawing themselves (4%). But, if one considers level 4 pupils did much better (62, 9%) with human, fish (55.0%) and bird (52.0%) probably reflecting the familiarity with the sequence of animal presentation, i.e. rat, bird, fish and human (Table 6).

Table 6: The percentage (%) of drawings at each level, for each of the species being drawn.

Level	Human (n=168)	Rat (n=185)	Bird (n=175)	Fish (n=168)
1	0.0	2.2	1.1	0.0
2	3.6	8.1	13.1	14.9
3	4.8	8.6	2.9	11.3
4	62.5	40.0	50.9	54.2
5	24.4	25.9	28.0	19.0
6	4.2	14.6	4.0	0.6
7	0.6	0.5	0.0	0.0

Closer examination of the drawings reveals much of the interest with respect to what students drew about the non-human animals. For example, if one just examines the drawings done by yr. 5 pupils, i. e. 10 and 11 year-olds in about middle track of their "fundamental" schooling (total 8 years), Figure 6 shows a boy's drawing of the rat. The boy has successfully drawn bones in the rat's skull and spine and members, in addition to showing a range of organs found roughly the same place in both humans and rats. If one searches in the other end, for instance year 8 students (Biology undergraduate) he presents the rat skeleton, digestive system and partially the nervous system as represented in Figure 7.

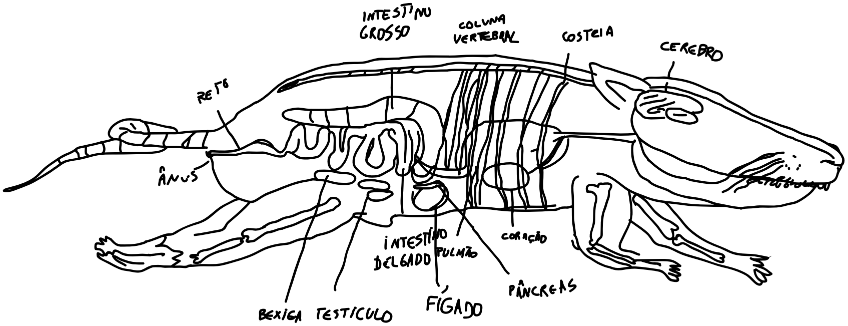

Figure 7: A drawing done by year 8 boy (aged 19 years) of what he thought was inside the rat. The drawing is scored as 6 SD ncue according to the method described in the text. (Captions read:cérebro=brain, costela=rib, coluna vertebral=vertebral column, intestino grosso=large intestine, reto=rectum, ânus=anal canal, bexiga=bladder, testículo=testis, fígado=liver, intestino delgado=small intestine, pulmão=lung, pâncreas=spleen, coração=heart).

DISCUSSION

Few previous cross-sectional studies, to our knowledge discussed how children´s drawings of organ systems and organs of vertebrates developed establishing basic transitory categories (TUNNICLIFFE; REISS, 2001, PROKOP; PROKOP; TUNNICLIFFE; DIRAN, 2007, PROKOP; PROKOP; TUNNICLIFFE, 2008). As the characterizations depicted present similarities as well as differences, that prompted the authors to carry out research replicating the previous study using a common methodology in a different culture to a developing country, in this case southern Brazil.

One out of 8 year 7/8 pupils reached level 7 but twenty-seven out of 45 year 5/6 students reached level 6 of understanding with respect to the rat drawing; four out of 5 year 7/8 pupils reached level 6 but fourty--three year 5/6 pupils reached level 5 with respect to the bird drawing; one out of 4 year 7/8 pupils reached level 6 but thirty-two out of 38 year 5/6 students reached level five for the fish; one out of 5 year 7/8 students reached level 7 but 7 out of fourty-three 5/6 students reached level 6 for human.

Although older students attained higher levels than the younger when comparing the percentage of levels achieved taken as representative level 4 for all specimens shown, very few students attained either level

6 or 7 of understanding as detailed in the text.. Further analysis revealed that the mean levels attained are almost the same for the rat (4.25), bird (4.03), human (4.22) and a little less for the fish (3.79). A similar trend was also noticed for the drawings of internal structures in other studies carried out in England and Slovakia respectively (TUNNICLIFFE; REISS, 2001, REISS; REISS, 2001, PROKOP; PROKOP; TUNNICLIFFE, 2008).

Most accurately and frequently organ system displayed was the digestive and the one drawn less often was the muscular for all 4 species. This last same trend was observed in our data with relation to the endocrine and urinary systems as similar findings in Slovakia (PROKOP; PROKOP; TUNNICLIFFE , 2009).The organs depicted most often in the drawings were the heart and the brain for all 3 species except human.

The authors recognize that collecting drawings plus holding an interview with the pupils would clarify to what organ and organ systems they were referring to and thus express their understanding much better, as was expressed in a similar study carried in a different culture (REISS; TUNNICLIFFE, 2001). Such interview would be an opportunity to avoid ambiguities in the interpretation of the drawings. However, drawings were done and collected in different occasions, and any interview, to be fully valuable in eliciting the understanding of the interviewee should have to be carried out soon after the pupil handed in their drawing, as s/he would still have it fresh in their mind what s/he intended to depict on the sheet. On the other hand, such an approach would interfere with the programmed schedule of the duration of classes along the fact that not all the pupils were present in every occasion.

It is worthwhile that studies are carried out to identify further the sources of pupils' knowledge and understanding of animals. Most of the Brazilian textbooks for primary, secondary and Biology science, as for example Amabis and Martho, 2001, Frota–Pessoa et al., 2008 cover the basics of external and internal anatomy & physiology as well as classification of animals, ranging from sponges up to human beings in a phylogenetic scale. English students, according to Tunnicliffe and Reiss, (1999 b), indicate other sources of biological knowledge such as television, zoos and natural history museums, instead of the school. It is noteworthy how few of the students' drawings of pupils in the Brazilian sample reached level 6 as described in the text. All it was expected on the drawings is to depict at least two organ systems according to the definitions in the text. It seems that, although pupils achieve good marks in other science and biology examinations, they seem to have a scant knowledge of internal anatomy of the specimens presented.

Capturing the expressed models, i. e. representations of phenomena placed in the public domain on how organ system and organs of vertebrates develop and expand throughout other educational settings in representative selected regions in Brazil should be a collaborative goal in itself, and the subject for future investigations (BUCKLEY, 1997, BORGES, 1999). Therefore, in spite to the fact that this kind of research was carried out in other countries with longer scientific traditions, it is still fundamental to know what pupils think about organs and organs systems (|JORDAN; GRAY; DEMETER; LIU; HMELO-SILVER, 2008). It is fundamental that the practice of "observing with meaning" is taught from pre-school onwards i.e. the brain as a functional unit related to learning and memory; the kidney as a unit that filters and excretes toxic products (Johnston; 2005, TUNNICLIFFE; UECKERT; 2007). The latter concepts are highly relevant when discussing structures and functions of vertebrates.

Probing students´ thinking in this particular issue is the starting point for more effective teaching in the classroom. As a consequence science teachers would be able to elicit ways to add new knowledge to the existing biological knowledge structure of the pupils.

The drawings analyzed in this paper refers to a representative sample from southern Brazil, thus generalizations would be premature to make concerning the whole Brazilian educational system. Additional research on the same topic should be carried out in other regions of the country to compose a clearer picture.

The authors hypothesize that building regional science curricula organized under general concepts, considering different levels of development in the country, and integrating cultural local knowledge and popular experiences, would bring meaningful improvement for Biology learning and teaching at all levels.

Educational implications.

Our study has educational implications for pre-school, primary and

secondary science and specialist biology teachers.

- teachers should stimulate pupils to understand how isolated organs work as a first step to include them within organ systems. For instance, for more advanced pupils could look at the endocrine "virtual rat", or a model of the kidney and associated excretory system organs (ODENWELLER; HSU; SIPE; et al., 1997, WILKINSON, 1990, TUNNICLIFFE, 2004);
- simple model to demonstrate "hands-on" reflex arcs and motor highways made from knife switch & lamp or pieces of yarn and paper clip can be used, to emphasize form and function of the nervous system (CHAN; PISEGNA; ROSIAN; DiCARLO, 1996, MORENO; MILLER; THARP; et al, 1997);
- visual hard copy for virtual and Internet atlas are available covering the internal & external anatomy of common invertebrates and vertebrates as well as the human body (GUIZZO, 1999, GUIZZO, 2002);
- another educational approach more relevant for advanced students and undergraduates, the use of "coloring books' with a similar to drawing organ and organs system (KAPIT; MACEY; MEISAMI, 2000);
- there are children´s books about human organs & organ systems for primary school (VANCLEAVE, 1995; ARNOLD, 1997; 2002) and secondary school (FERREIRA da SILVA, 2000) which can provide information at an appropriate conceptual level.
- Finally an approach for out of classroom learning is to make focused use through visits in Natural Science and Integrative Museums, of specimens available in the museum, so that learners could observe vertebrate organs in jars and trays which offer rich informal learning experiences free of charge in

Brazil (SILVA Jr., 1995, TUNNICLIFFE, 2000).

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REFERENCES

AMABIS, J. M.; MARTHO, G. R. **Conceitos de biologia**: classificação, estrutura e funções dos seres vivos. São Paulo: Moderna, 2001. 511 p. (Biological concepts: classification, structure and function in living organisms).

ARNOLD, N. **Sangue**, **ossos e pedacinhos**. São Paulo: Melhoramentos, 2002. 158 p. (Blood, Bones and Body Bits/Scholastic LTD, UK).

ARNOLD, N. **Digestão nojenta**. São Paulo: Melhoramentos, 2002. 156 p. (Disgusting Digestion/Scholastic , UK).

BARTOSZECK, A. B.; MACHADO, D. Z.; AMANN-GAINOTTI, M. Representations of internal body image: a study of pre-adolescents and adolescent students in Araucária, Paraná, Brazil. **Ciências & Cognição**, v.13, n. 2, p. 139-159, 2008.

BLUM. L. H. Health information via mass media: study of the individual´s concepts of the body and its parts. **Psychological Reports**, n. 40, p. 991-999, [20--].

BORGES, A. T. Como evoluem os modelos mentais. **Ensaio-pesquisa**,

educação em ciências, v.1, p. 85-125, 1999. (How the mental models evolved).

BRANDI, A. T.; GURGEL, C. M. A alfabetização científica e o processo de ler e escrever em séries iniciais: emergências de um estudo de investigação-ação. **Ciência & Educação**, v. 8, n.1, p. 113-125, 2002. (Science literacy and the process of reading and writing in primary school: conclusions in a study of action-investigation).

BUCKLEY, B.; BOLUTER, C.; GILBERT, J. Towards a typology of models for science education. In: GILBERT, J. **Exploring models and modeling in Science and Technology Education**. Reading, UK: University of Reading, 1997. p. 90-105.

CARVALHO, S. G.; SILVA, R.; CLÉMENT, P. (2007). Historical analysis of portuguese primary school textbooks (1920-2005) on the topic of digestion. **International journal of science education,** v. 29, n. 2 p. 173-193, 2007.

CHAN, V.; PISEGNA, J. M.; ROSIAN, R. L.; DiCARLO, S. E. Construction of a model demonstrating neural pathways and reflex arcs. **Advances in physiology education**, v. 16 n.1, p. S14-S42, 1996.

CLÉMENT, P.; MOUELHI, L.; AROUGUI, M. (2006). Héréditarisme, béhaviorisme, constructivisme: le système nerveux dans les manuels scolaires français et tunisiens. **Aster,** v. 42, p. 69-204, 2006.

COX, M. Children's drawings. In: HARGREAVES, D. J. **Children and the arts.** Buckingham: Open University Press, 2004. p. 43-58.

COX, M. **Drawings of people by the under-5s**. London: Falmer Press, 1997. 112 p.

CUTHBERT, A. J. (2000). Do children have a holistic view of their internal body maps? **School Science Review**, v. 82, n. 299, p. 25-32, 2000.

EDUCAR, v. 14, p. 91-113, 1998. (Teaching science literacy).

FERREIRA da SILVA, L. A. **O corpo humano**: a máquina maravilhosa. Rio de Janeiro: Ediouro, 2000. 361 p.

FROTA-PESSOA, O. **Biologia.** São Paulo: Scipione, 2008. 334 p.

GILBERT, J. K.; BOULTER, C. J.; ELMER, R. Positioning models in science education and in design and technology. In: GILBERT, J. K.; BOULTER, C. J. **Developing models in science education.** Dordrecht: Kluwer, 2000. p. 3-17.

GREENFIELD, S. A. **The human mind explained**: an owner's guide to the mysteries of the mind. New York: Henry Holt, 1996, 192 p.

GUIZZO, J. **O corpo humano.** São Paulo: Ática, 1999. 64 p. (The human body/ Dorling Kindersley, London).

______. **Animais.** São Paulo: Ática, 2002, 64 p. (The animals/Dorling Kindersley, London).

HAYS, D.; SYMINGTON, D.; MARTIN, M. Drawing during science activity in the primary school. **International Journal of Science Education**, v.16, n. 3, p. 265-277, 1994.

Health information via mass media: study of the individual's concepts of the body and its parts. **Psychological Reports,** v. 40, p. 991-999, 1977.

HOWARD, P. J. **The owner´s manual for the brain**: everyday applications from mind-brain research. Marietta: Bard Press, 2000. 831 p.

Johnson-Laird, P. N. **The computer and the mind**: an introduction to cognitive science. Cambridge: Harvard University Press, 1998. 444 p.

Johnston, J. **Early explorations in science**. Buckingham: Open

University Press, 2005. 220 p.

JORDAN, R.; GRAY, S.; DEMETER, M., LIU, L.; HMELO-SILVER, C. (2008). Adding behavior to thinking about structure & functions. **The american biology teache**r, v.70, n. 60, p. 329-330, 2008.

KAPIT, W.; MACEY, R. I.; MEISAMI, E. **The physiology coloring book.** California: Benjamin Cummings, 2000. 161 p.

KOKSAL, M. S.; CIMEN, O. Perceptions of prospective Biology teachers on importance and difficulty of organs as a school subject. **World Applied Sciences Journal,** v. 5, n. 4, p. 397-405, 2008.

LAWSON, A. E. The acquisition of biological knowledge during childhood: cognitive conflict or tabula rasa? **Journal of research in science teaching,** n. 25, p. 185-199, 1988.

LÓPEZ-MANJÓN, A.; ANGÓN, Y. P. Representations of the human circulatory system. **Journal of biological education**, v. 43, n. 4, p. 152-158, 2009.

MAcPHAIL, A.; KINCHIN, G. The use of drawings as an evaluative tool: students´ experiences of sport education. **Physical education and sport pedagogy,** v. 9 n.1 p. 87-108, 2004.

McCRONE, J. **How the brain works**. London: Dorling Kindersley, 2002. 72 p.

MORENO, N. et al. **Brain Link activities**: motor highways. Houston: Wow Publications, 1997. 40 p.

ODENWELLER, C. M. et al. Laboratory exercise using “virtual rats” to teach endocrine physiology. **Advances in physiology education***,* v. 18 n. 1, p. S24-S40, 1997.

OLIVEIRA, G. F. da. Conceituando digestão na educação infantil.

In: ENCONTRO PERSPECTIVAS DO ENSINO DE BIOLOGIA, 7., 2000. São Paulo. **Anais…** São Paulo: 2000. p.755-757. (The concept of digestion in pre-school education).

OSBORNE, J.; WADSWORTH, P.; BLACK, P. **Processes of life**: primary space research report. Liverpool: Liverpool University Press, 1992. 89 p.

PATRICK, P. G.; TUNNICLIFFE, S. D. Science teachers´drawings of what is inside the human body. **Journal of Biological Education,** v. 44, n. 2, p. 81-87, 2010.

PORTER, C. S. Grade school children's perceptions of their internal body parts. **Nursing research***,* v. 23, n. 5, p. 384-391, 1974.

PROKOP, P.; FANCOVICOVÁ, J. Students´ ideas about the human body: do they really draw what they know? **Journal of Baltic Science Education**, n. 2, n.10, p. 86-95, 2006.

PROKOP, P.; FANCOVICOVÁ, J.; TUNNICLIFFE, S. D. The effect of type of instruction on expression of children´s knowledge: how do children see the endocrine and urinary system? **International Journal of Environmental & Science Education**, v. 4, n.1, p. 75-93, 2009.

PROKOP, P.; PROKOP, M.; TUNNICLIFFE, S. D.; DIRAN, C. (2007). Children´s ideas of animals´ structures. **Journal of Biological Education***,* v. 41, n. 2, p. 62-67, 2007.

PROKOP, P.; PROKOP, M.; TUNNICLIFFE, S. D. Effects of keeping animals as pets on children´s concepts of vertebrates and invertebrates. **International journal of science education**, v. 30, n. 4, p. 431-449, 2008.

RABELLO, S. H. de S. A criança, seu corpo, suas idéias. **Ensino em Re-Vista,** v. 3, n.1, p. 15-29, 1994. (The child, her body, and her ideas).

RAMADAS, J.; NAIR, U. The system idea as a tool in understanding conceptions about the digestive system. **International Journal of Sience Education**, v. 18, n. 3, p. 355-368, 1996.

REISS, M. J.; TUNNICLIFFE, S. D. Students' understandings of human organs and organs systems. **Research in science education**, v. 31, n. 3, p. 383-399, 2001.

REISS, M. J.; TUNNICLIFFE, S. D.; BARTOSZECK, A. et al. An international study of young people's drawings of what is inside themselves. **Journal of Biological education**, v. 36, n. 2, p. 58-64, 2002.

ROWETT, H. G. Q. **Basic anatomy & physiology**. London: John Murray Publishers, 1999. 142 p.

ROWLANDS, M. A. What do children think happens to the food they eat? **Journal of biological education**, v. 38, n. 4, p.167-171, 2004.

SELLES, S. E.; Ayres, A. C.; Resnik, T. Models of the human circulatory system in science textbooks: building a framework for representation analysis. In: **Proceedings of the third conference of european researchers in didactic of biology**, 2001, p. 217-228, Santiago de Compostela, Spain.

SELLES, S. E.; AYRES, A. C. Children's representations of digestive system from a model-based teaching learning perspective. In: **Proceedings ESERA**, p.11-13, 1999, Kiel, Germany.

SUNGUR, S.; TEKKAYA, C.; GEBAN, Ö. The contribution of conceptual change texts accompanied by concept mapping to students´understanding of human circulatory system. **School Science and Mathematics**, v. 101, n. 2, p. 91-101, 2001.

TEIXEIRA, F. M. What happens to the food we eat? Children's conceptions of the structure and function of the digestive system.

International Journal of Science Education, v. 21, n. 2, p. 507-520, 2000.

TUNNICLIFFE, S. D. The changing nature of science education. **Science Education International**, v.11, p. 31-32, 2000.

TUNNICLIFFE, S. D. Where does the drink go? **Primary Science Review**, v. 85, p. 8-10, 2004.

TUNNICLIFFE, S. D.; REISS, M. J. Student's understandings about animal skeletons. **International journal of science education**, v. 21, n. 1, p. 1187-1200, 1999.

TUNNICLIFFE, S. D.; REISS, M. What´s inside bodies: Learning about skeletons and other organ systems of vertebrate animals. In: **IOSTE, science and technology education**: **preparing for future citizens**. 2001, 2, p. 84-94, Paralimni, Cyprus.

TUNNICLIFFE, S. D.; UECKERT, C. Teaching biology- the great dilemma. **Journal of Biological Education**, v. 4, p. 51-52, 2007.

VANCLEAVE, J. **The human body for every kid**. New York: John Wiley, 1995. 223 p.

WHITE, R.; GUNSTONE, R. **Probing understanding**. London: The Falmer Press, 1992. 75 p.

WILKINSON, H. L. A simple model for teaching functions of the kidney nephron. **Midwest bioscene**, v. 16, n. 1, 3-11, 1990.

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