SCIENCE LITERACY: THE DEVELOPMENT OF THE CONCEPT OF SKELETONS IN BRAZILIAN STUDENTS.

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ABSTRACT: This study is concerned with the development of the conceptions of vertebrate skeletons held by students. It is based on a quantitative investigation involving a total of 1890 students in Southern Brazil between ages of 4, or 6, to 25. This a cross-sectional study that investigates the structuring of understanding of bones and skeletons by means of the drawings of the students who were presented with taxidermy specimens of a rat, a woodpecker, a fish and asked to draw what they thought was inside these animals, including themselves. The resultant 8145 drawings were analyzed following a scoring protocol and then subjected to a multivariate linear statistical model to evaluate the significance of age, gender and animal being drawn. Gender differences were not significant. The majority of the students failed to understand the skeleton as a functional integrated unit. Implications for science literacy and biological education are discussed.
KEYWORDS: Biological Education. Science literacy. Drawings. Skeletons. Concepts.

ALFABETIZAÇÃO CIENTÍFICA: O DESENVOLVIMENTO DO CONCEITO DE ESQUELETO POR ESTUDANTES BRASILEIROS.

RESUMO: Este estudo diz respeito ao desenvolvimento do conceito de esqueleto dos vertebrados pelos estudantes. É fundamentado numa investigação

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quantitativa envolvendo 1890 alunos do sul do Brasil, de 4 à 25 anos. Este estudo transversal investiga a estruturação do entendimento de ossos e esqueletos por meio de desenhos. Foram apresentados aos alunos exemplares taxidermisados de um rato, um pica-pau, um peixe e lhes foi perguntado o que eles achavam que haveria dentro destes animais quando vivos, incluindo eles mesmos. Os 8145 desenhos foram analisados seguindo-se um protocolo de pontuação e posteriormente submetidos a uma modelagem estatística linear multivariada, para avaliar a significância da idade, gênero e tipo de animal que foi desenhado. A diferença de gênero não foi significante e a maioria dos estudantes não foi bem sucedida em apreciar o esqueleto como uma unidade funcional integrada. São discutidas implicações para a alfabetização científica e educação biológica.
PALAVRAS-CHAVE: Educação biológica. Alfabetização científica. Desenhos. Esqueleto. Conceitos.

ALFABETIZACIÓN CIENTÍFICA: DESARROLLO DEL CONCEPTO DE ESQUELETO POR ESTUDIANTES BRASILEÑOS

RESUMEN: Esta investigación busca el desarrollo del concepto de esqueleto de los vertebrados, por estudiantes. Es fundamentado en una investigación cuantitativa, involucrando 1890 alumnos del Sur de Brasil, de 4 a 25 años. Este estudio transversal investiga la estructuración del entendimiento de huesos y esqueletos, por medio de dibujos. Fueron presentados, a los alumnos, ejemplares disecados de un ratón, un pájaro carpintero y un pez, siéndoles preguntado lo que creían que habría dentro de esos animales cuando vivos, incluyendo ellos mismos. Los 8145 dibujos fueron analizados, siguiéndose un protocolo de puntuación y, posteriormente, sometidos a un modelado estadístico linear múltiples, para evaluar la edad, género y tipo de animal que fue dibujado. La diferencia de género no fue significante y la mayoría de los estudiantes no fueron bien sucedidos en apreciar el esqueleto como una unidad funcional integrada. Son discutidas implicaciones para la alfabetización científica y educación biológica.
PALABRAS CLAVE: Educación biológica. Alfabetización científica. Dibujos. Esqueleto. Conceptos.

INTRODUCTION

The process of scientific literacy still represents a huge problem to primary and secondary school teachers in their deciding what and how to teach. Moreover, acquiring such literacy is also complex for the students if they are to achieve some understanding of the biological phenomena (BRANDI; GURGEL, 2002).

This study is up to a point a replication to a previous study by Tunnicliffe; Reiss (1999b) carried out in England, but it has also the purpose of comparing the understanding of the same topic but in another culture as well as in a developing country. Relatively little is known on how the structuring process of biological concepts takes place, how they develop and change in different age groups (Reiss; Tunnicliffe, 1999). There has been no previous study on the development of the concept of bones or skeleton published by other researchers in Brazil.

There is a scarcity of studies that looked at people's understanding of what is inside animals, especially skeletons. Schilder; Wechesler (1935) interviewed children aged 4 to 13 asking what is inside the human body and got as a secondary response that bones result from the food the person eats. Drawings collected from both hospital patients and healthy male adults and students aged 11 to 13 showed, when analysed, a larger representation of bones and muscles on the outlines done by school age students instead of those by adults (TAIT JR.; ARCHER, 1955). Gellert (1962), interviewed hospital patient children and adolescents aged 4 to 17 where bones from limbs, trunk and skull were the most referred structures with some glimpses on bone function. Porter (1974) analyzed outlines of the entire human body filled by children aged from 6 to 11. Bones were also one of the parts most frequently named by them. Blum (1977) requested educated adults (aged 21 to 51 years old) to draw an outline of the human body and then label the internal organs. The most frequently drawn were the internal organs such as the heart, but some of the drawings did show some details of bone structure. Amann-Gainotti (1988) studied a characterization of the development patterns through which graphic representations of human bones were made by Italian children, 5 to 10 years old (61%), and adolescents, 11 to 14 years old (14,5%). On the other hand, Caravita; Tonucci (1987), Caravita; Halldén (1994) found differing results with respect to Italian children. Caravita (1996) requested Italian children, 7, 9 and 12 years old, to draw the human skeleton after they had observed the movements of their own bones, and built a human skeleton using plasticine and cardboard and also drawn the skeleton of animals (e.g. chicken) before and after the dissection of the bird. 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. Bones were one of the most frequent structures represented and mentioned in the interviews in all age groups analyzed. Children, in a semi-structured interview, as hospital patients, drew body organs on a prepared outline and placed bones in the correct position into 88% of the drawings (McEWING, 1996).

More recently, Tunnicliffe; Reiss (1999a) and Tunnicliffe; Reiss (1999 b) presented English school children from primary school (4-11 years old), secondary school (11-16 years olds) and Bachelor of Arts students (aged 18 to 22) common vertebrates, (which were taxidermy prepared or fresh, and asked them to draw what they thought was inside the specimens when they were alive and then subsequently what was inside themselves. These English researchers developed a ranking protocol (level 1 to 7) to facilitate the scoring of the drawings contemplating either skeletons or organ & organ systems Reiss et al., (2002), which, besides these purposes, would also serve as a "pattern" for international comparison studies.

OBJECTIVE

The aim of this study is to investigate, as a cross-age study, how the previous knowledge of pre-school children, primary and secondary students, teachers´ school students (a former secondary 4 years course) and Biology undergraduates hold in their minds, concerning the inner parts of organisms, specially bones, is build up as they grow older in their interaction with school and the world at large (LAWSON, 1988).

METHODS

Sample & procedure

This study looks at the students' understandings on the structure of animal (including human) skeletons and internal organs as well as the organ systems found in them. A cross-sectional approach was used in which students from different ages are shown different animals specimens and asked to draw on a blank A4-paper sheet by using their pencil what they think was inside these animals when they were alive. Cox, (1989, 1997) and Hayes et al. (1994) discuss some of the ways by which children can be asked in order to make drawings. The Ethics Research Committee of the Higher Education Institutions approved the main goal of "science literacy" proposal to which the present study is part of. All data were collected subjected to full consent of parents, teachers, head masters, and principals from all the educational institutions involved in this project.

The fieldwork was carried out in the Southern part of Brazil, in Curitiba-PR in a infant school nº. I (children aged 4) where children attending kindergarten II (K-II aged 4 pupils who would turn 5 during the school year period) and kindergarten III (K-III pupils who would turn 6 during the school year period) which is private, and an infant school nº. II, which is a state-supported school (year 0). The elementary school (year 1 to year 4) ages ranging from 7 to 14 and secondary school (year 5 to year 6) ages ranging from 15 to 18 selected was the State School nº. III.

The elementary (year 1 to year 4) and secondary (year 5 and 6) school, corresponding to senior high school [USA], State School nº. IV, which is a mix of academic and military training institution, was also selected. Both are state-supported schools, i.e. non-paying fee institutions. Data were also collected at a Teacher's School (year 7), who runs a Secondary 4 Year Teachers' Course ("Magistério/Escola Normal"), ages ranging from 18 to 25, whose students intend to be elementary school teachers, and from the 1st year Biology undergraduates from a four year course research University in Southern Brazil, (year 8) whose students intend to be mainly secondary school Biology teachers.

Equipment at premises

Infant schools nº. I and nº. II have very small libraries with a few children books and no pre-elementary science books. Neither one of them has a pre-elementary science laboratory nor a slide or overhead projector, a television, and a VCR. However, there were some small cages holding ducks, which sometimes were set free in the backyard and a few rabbits in school nº. I. The children's experience with the laboratory rat and woodpecker is usually limited to when children watch TV programs at home or visit zoos. They are rarely in direct contact with these specimens. Teachers in both schools compensate these limitations by gathering children together in an activity room where they listen to stories from a phonograph or under the shade of a tree where the teacher reads tales from a book. On the other hand, fish and crab are more commonly seen while visiting supermarkets and fishmongers or when the children go on fishing expeditions with their relatives.

Schools nº. III and nº. IV and the Teacher's school (which is a senior high school equivalent to grades 10, 11 and 12), had neither a slide/overhead projector, a television , nor a VCR, although a general library was available. Only school nº. III offers practical classes in an adapted Physics, Chemistry and Biology laboratory, but most of the biological material is kept in jars with conservation fluid. The student's contact with the sample animal object of this study was usually through fishmongers, TV programs, natural history museums or zoos. An outline of the Brazilian southern school science curricula emphasizing biological aspects is depicted on Table 1.

First-year Biology undergraduates were part of this study presented better audio-visual equipment to assist them. Slide/overhead projector, a TV and a VCR, and a room for computer physiological simulations are available. During practical classes, taxidermy and fresh specimens are used for studying internal anatomy-organ and organ systems – during Zoology Session for invertebrates in the 1st semester of theirs 3rd year and fish, bird, and rat bones in the 2nd semester. However, bones and organ and organ systems for human beings are studied during the activities of Anatomy Session in their 1st year.

Table 1. Brazilian school science curricula (biological).

Year	Age (years old)	Contents
0	4-6	Types of animals: invertebrates, vertebrates.
1	7-8	Growth of human beings.
2	9-10	Invertebrates & vertebrates in relation to the environment and human beings; basic concepts of bones & muscles, 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.

Procedure

A cross-sectional approach was used involving a total of 1890 students in Brazil from eight different age groups ranging from 4 to 25 (Table 1). A total of 8415 drawings were collected. On separate occasion, the students were presented with a single dead specimen of a

Wistar rat (*Rattus norvegicus*) (taxidermic), a woodpecker (*Chrysoptilus melanochloros*) (taxidermic), a salt water fish corbina (*Sciaena aquila*) (fresh), an edible crab (*Chasmagnathus granulata*) (fresh). This report covers only information provided by students about vertebrate skeletons – i.e. the two mammalian skeletons (rat, human), the bird skeleton (woodpecker) and fish skeleton (corbina). The data about what organ systems (e.g. digestive system, nervous system, reproductive system, etc) the students pin-pointed inside the animals as well as the exoskeleton of the crab will be dealt elsewhere.

On each occasion, the students were asked to draw what they thought was inside the creature shown when it was alive. Students were not examined under formal examination conditions but were told to draw by their own, without copying from their close classmate drawings. On the final session, the students were asked to draw what they thought was inside themselves taking them as models. Students were told to write their first names, age on the top of an A4 paper sheet. Then, they were given 10 to 15 minutes to complete each drawing and use the male/female genetic symbols to identify their sex condition to avoid ambiguous interpretation while scoring. All students were told to look at the specimen presented on the set-up brought by the first author and asked to draw what they think is inside the creature when alive, and were assured that it was not being referred to the inner dead parts of the exposed animal. Many students labelled the internal structures 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, 6 year old 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 an average of 35 days after the previous presentation, sample sizes vary within each age group and for the type of animal presented. Data were obtained from 242 kindergarten II, III (reception) children (aged 4 to 6) (year 0), 80 year-1 children (aged 7 or 8), 98 year-2 children (aged 9 or 10) 324 year-3 children (aged 11 or 12) 521 year-4 children (aged 13 or 14) , 439 year-5 children (aged 15 or 16), 50 year-6 children (aged 17 or 18), 22 year-7 teachers' school students (aged 18 to 25), and 45 year-8 Biology undergraduates (aged 18 to 25) and are depicted on Table 2.

Table 2. Year of attendance at Brazilian schools organised under the criteria based on pupils' performance, age groups, corresponding grades and n = number of students in each age category.

Year	Age	Grade	n
0	4 to 6	K – II, K – III	242
1	7 or 8	1st , 2 nd	80
2	9 or 10	3rd , 4th	98
3	11 or 12	5th , 6th	324
4	13 or 14	7th , 8th	521
5	15 or 16	9th , 10th	439
6	17 or 18	11th	50
7	18 to 25	teacher's school, 12th	22
8	18 to 25	Undergraduates 1st year	45

RESULTS

Data analysis.

A total of 8415 drawings were collected. Scoring from the drawings in order to assess the different levels of biological understanding attained by the students was done by the first two authors by following criteria developed in the ranking protocol formulated by Tunnicliffe, (1999), Tunnicliffe Reiss, (1999a, b). Few disagreements over scoring were discussed by the authors until a conclusion was reached.

The response variable considered is the level attained by the students in the scoring process of the drawings. Thus, every drawing was scored by following a scale ranging from 1 to 7 according to the criteria established and represented on Table 3.

Table 3. Skeleton composition ranking protocol

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

Age group and type of animal being drawn, i. e. fish [type 1], human [type 2], rat [type 3], and bird [type 4] were taken into consideration. The distribution of the probability of variable response (level) was considered as multivariate of parameters. The total number of the types of animals [i. e. fish, human, rat, bird] being drawn was 6,879 and the probabilities of attaining levels 1 to 7 as p1 to p7 were subjected to an estimative. The distribution of cumulative levels was modelled as this variable and is from an ordinal type under the relationship

(Model 1): logit (Pr(y </= r))= á r + â x^t (1)

where: r = level attained in the scoring process
â = regression vector parameter
x^t = variable vector [age group, gender group and animal being drawn

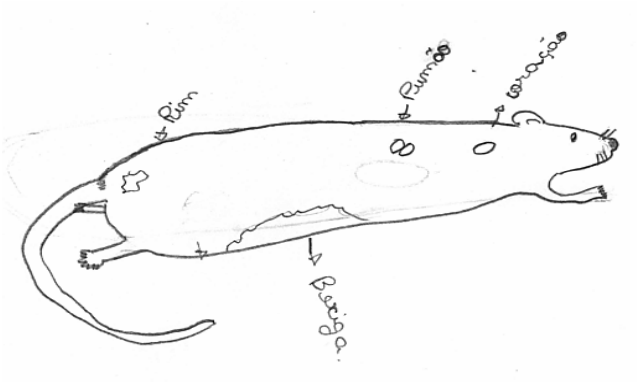

Figure 1. Drawing of a rat by a 2-yr-old female scored as level 1 (i. e. no bones)

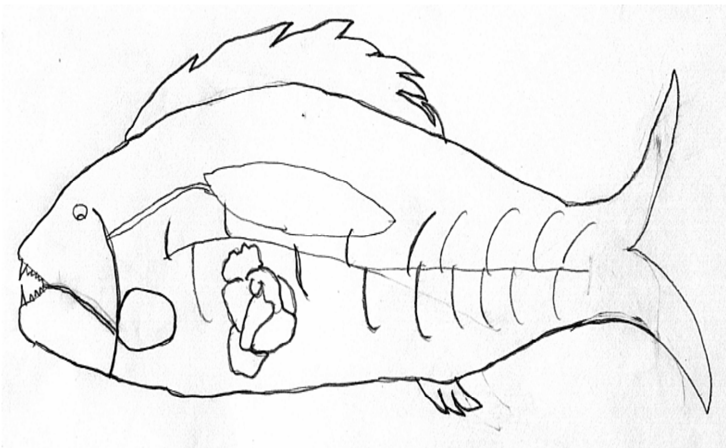

Figure 2. Drawing of a fish by a 1-yr-old female scored as level 2 (i. e. bones indicated by simple lines or circles).

Figure 3. Drawing of a rat by a 0-yr-old (reception) male scored as level 3 (i. e. bones indicated by "dog bone" shape at random or throughout body). The label "osso" (bone) was added by a supply teacher after the drawing was completed.

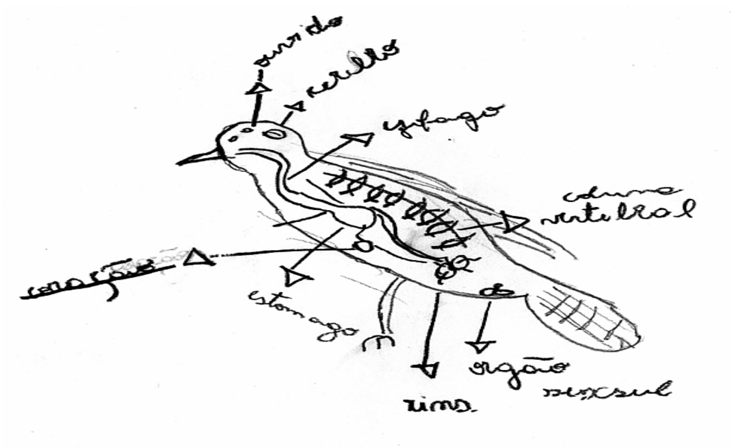

Figure 4. Drawing of a bird by a 3-yr-old male scored as level 4 (i. e. one type of bone, the "coluna vertebral" (backbone), is in its appropriate position).

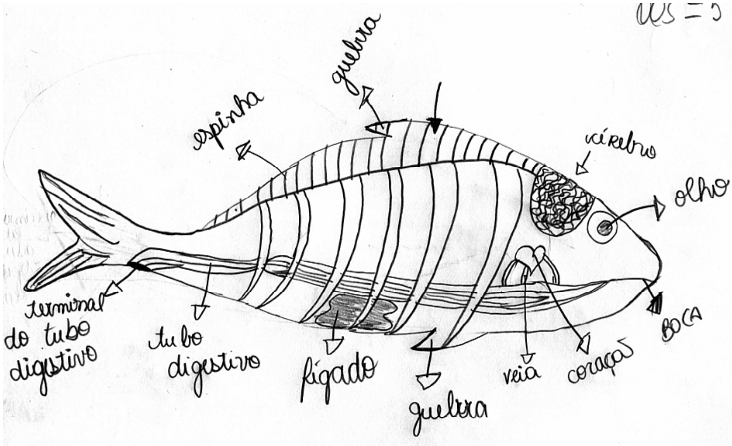

Figure 5. A drawing of a fish by a 4-yr-old female scored as level 5 (i. e. at least two types of bones, "espinha e desenho de costela" (backbones and ribs), are indicated in their appropriate positions.

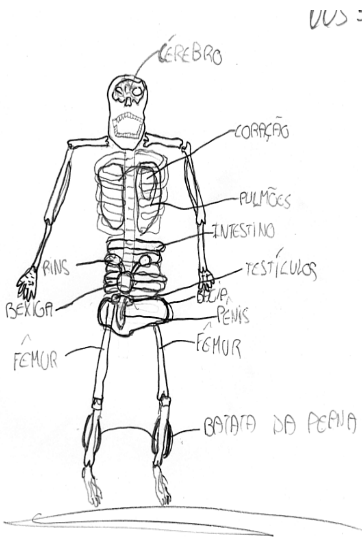

Figure 6. Drawing of himself by a 4-yr-old male scored as a level 6 i. e. definite vertebrate skeletal organisation is showed (i. e. backbone, skull and limbs and/or ribs).

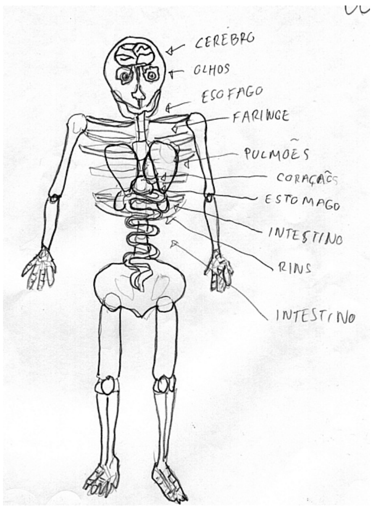

Figure 7. Drawing of himself by a 5-yr-old male scored as level 7 (i. e. comprehensive skeleton (i. e. connections between backbone, skull, limbs and ribs).

Data were entered into Statistica 5.0 (StatSoft Brazil Ltda) for further basic analysis. All statistical tests are 2-tailed. The parametric test multivariate generalized linear model was used for group comparisons and kind of animal (FAHRMEIR; GEHARD, 2001)

The significance of the student age

As common sense would indicate, older students attained higher levels than younger in general. For instance, the level attained by students drawing the rat skeleton increases in percentage from 2% (level 4) for year 0 students to 4.5% for teachers' school students (yr 7) or for Biology undergraduates (yr 8). Besides, only few students from yr 7 or yr 8 attained levels 5 and 6.

Further analysis confirmed that older students attained higher levels than younger. The average level attained increases slightly when students are drawing themselves (human beings) from 1.81 for yr 0 students to 2.7 for yr 7 students but not for yr 8 (Biology undergraduates) students (Table 4).

Table 4. Levels attained by students from different ages when drawing themselves. Levels equate to the 1-7 scale for understanding of the skeleton as described in the text. Yr 0 students are reception pupils (aged 4-6), yr 8 are first year undergraduates specialising in Biology. *Sem* is the standard error of the mean; *n* is the number of students in each age category.

Year	Mean level	Median level	*Sem*	*n*
0	1.81	2	0.05	206
1	2.0	2	0.15	60
2	1.66	1	0.11	75
3	1.87	1	0.07	324
4	2.17	2	0.06	485
5	2.29	2	0.06	366
6	2.15	2	0.17	39
7	2.7	2	0.55	10
8	1.66	1	0.27	27

Table 5. Levels attained by students from different ages when drawing the rat.

Year	Mean level	Median level	*Sem*	*n*
0	1.71	2	0.04	242
1	1.64	1	0.09	80
2	1.41	1	0.06	98
3	1.63	1	0.06	393
4	1.83	1	0.06	521
5	1.71	1	0.06	439
6	2.02	1	0.22	50
7	2.04	1	0.36	22
8	2.27	1	0.25	45

Table 5 presents the same data as in Table 4 – for the rat; the same data are presented in Table 6 for the woodpecker, and, the same data are presented in Table 7 as in Table 6 – for the corbina (fish). In each case the mean level attained with relation to the age increases very little.

Table 6. Levels attained by students from different ages when drawing the woodpecker.

Year	Mean level	Median level	Sem	n
0	1.65	2	0.04	224
1	1.62	1	0.10	69
2	1.35	1	0.08	76
3	1.55	1	0.06	360
4	1.58	1	0.05	520
5	1.48	1	0.06	378
6	1.16	1	0.09	49
7	2.23	2	0.32	22
8	1.77	1	0.19	43

Table 7. Levels attained by students from different ages when drawing the corbina (fish).

Year	Mean level	Median level	Sem	n
0	1.76	2	0.05	187
1	2.16	2	0.10	70
2	1.91	2	0.09	94
3	1.94	2	0.05	385
4	2.18	2	0.04	483
5	2.35	2	0.07	357
6	2.03	2	0.16	38
7	3.0	2	0.43	11
8	2.23	2	0.27	31

The significance of the animal being drawn

It was noticed that only at age 7 (teacher's school students) ranging from 18 to 25 years old had a better level of understanding according to the animal being drawn, whereas other ages do not differ between themselves, Table 8.

Table 8. Mean levels attained by students from different ages when drawing specific animals. Levels equate to the 1-7 scale for understanding the skeleton of these vertebrates.

Year	Rat	Bird	Fish	Human
0	1.71	1.65	1.76	1.81
1	1.64	1.62	2.16	2.0
2	1.41	1.35	1.91	1.66
3	1.63	1.55	1.94	1.87
4	1.83	1.58	2.18	2.17
5	1.71	1.48	2.35	2.29
6	2.02	1.16	2.03	2.15
7	2.04	2.23	3.0	2.7
8	2.27	1.77	2.23	1.66

Model (1) was re-done without the range of ages and gender evaluating the type of animal. Thus, there is only a statistical significance to explain the levels attained by age 7 students according to the type of animal being drawn. Figure 8 represents the levels of understanding attained only by the age 7 group.

By inspecting the levels of understanding expressed in the drawings observed for rat and human as well as for fish and bird, i. e. these types of drawings cluster together 2 by 2. Therefore, the levels attained for the rat drawings were about 40% for level 1, about 37% for level 2 and only 23 % for other levels. For the human drawings the levels attained were 50% for level 1, 35% for level 2 and the remaining 15% for other levels. For the bird drawings the level attained were 24% for level 1, about 38% for level 2, 9% for level 3 and the remaining 29% for other levels. At last, for the fish drawings the levels attained were 19% for level 1, about 35% for level 2, 9% for level 3 and the remaining 37% for other levels. Figure 9 represents the levels of understandings attained by ages 1 to 8 (except 7)

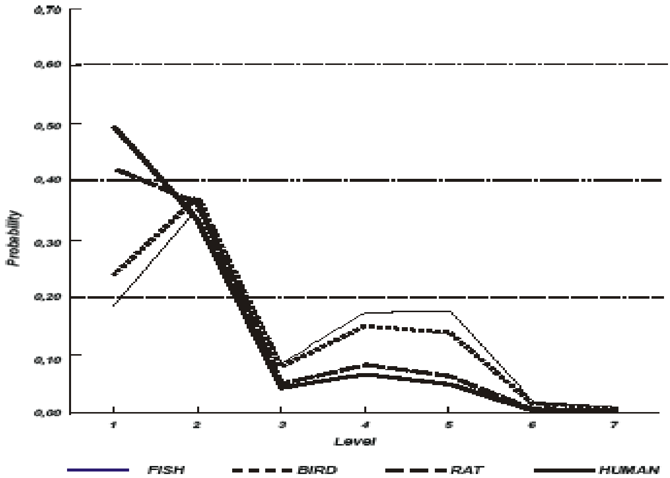

Figure 8. Levels of understanding attained by teacher's school students (age 7) when scoring for fish, bird, rat and human.

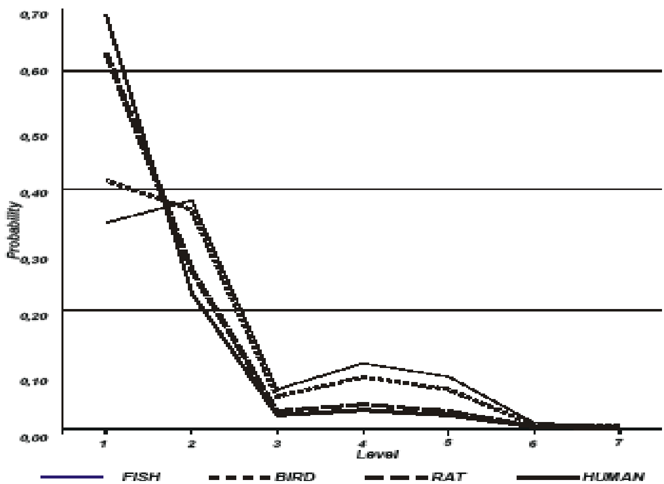

Figure 9. Levels of understanding attained by students (age 1 to 8) except age 7 when scoring for fish, bird, rat, and human.

By inspecting the levels of understanding attained, again one notices a similar trend as depicted in Fig. 8, i.e. a clustering of 2 by 2 rat with human and fish with bird where the levels attained were very close. Thus, the levels attained for the rat drawings were about 62% for level 1, about 27% for level 2 and 11% for other levels. On the other hand, human drawings attained 70% for level 1, 22% for level 2 and the remaining 8% for other levels. The levels attained for bird drawings were 41% for level 1, 38% for level 2, 7% for level 3 and the remaining 14% for other levels. Finally, for fish drawings 35% attained level 1, about 39% for level 2, 9% for level 3 and the remaining 17% for other levels.

In summary, the statistical approach applied for the analysis of the data revealed that there is no noticeable significant differences between age groups 1 to 8, with modest mean levels growing, except for age 7 which presents a distinct level of understanding. Besides, all drawings representing the animals are significantly different between themselves concerning the levels attained. However, the levels attained for the drawings of rat and human are higher than those for fish and bird, perhaps indication a closer identification with the former vertebrates (Fig.9). In conclusion, no statistical significance was found for the levels attained either by gender or age when scoring for the four vertebrates, between ages 1 to 8, except for age 7 in relation to the type of animal.

Discussion

Three previous cross-sectional studies, to our knowledge, discussed how children's drawings of the skeleton developed establishing basic transitory categories (CARAVITA; TONUCCI, 1987, GUICHARD, 1995 and TUNNICLIFFE ; REISS, 1999[a]). As the categorizations depicted present similarities as well as differences, that prompted the authors to carry out a research replicating a previous study using a common methodology in a different culture to a developing country, in this case, southern Brazil.

One out of 10 yr-7 students and one out of 27 yr-8 students reached level 6 with respect to the human drawing; one out of 22 yr-7 students sand two out of 45 yr-8 students reached level 6 with respect to rat drawing; zero out of 22 yr-7 students and zero out of 43 yr-8 students reached either level 6 or 7 with respect to the woodpecker drawing; and zero out of 11 yr-7 students and one out of 31 yr-8 students reached level 6 with respect to the fish drawing. What somewhat is curious is that five out of 342 yr-3 students, four out of 474 yr-4 students, and one out of 366 yr-5 students reached level 7 when drawing themselves. It was expected collectively that many more students would draw a skeleton, stressing the connections between backbone, skull, limbs, and ribs (e.g. Figure 7).

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 levels 6 or 7. Further analysis revealed that when students are drawing themselves, the average levels attained increases slightly and even diminish for Biology students. The same trend is noticed for the drawings of the rat and fish, except for the bird. However, for almost the same range of ages another study (TUNNICLIFFE; REISS, 1999a) has demonstrated a noticeable rise in the mean levels achieved for the drawings of themselves (i.e. the students) for the rat, starling, and herring.

Capturing the expressed models, i. e. representations of phenomena placed in the public domain Gilbert (1997), Greca Moreira (1997), Borges (1999) on how bones and skeleton of animals develop and expand throughout other educational settings in representative selected areas in Brazil should be a collaborative goal in itself, and the subject for future investigations. In conclusion, in spite to the fact that this kind of research was carried out in other countries with European traditions, it is still fundamental to know what Brazilian students think about bones & skeletons. Researchers pursuing this goal would be able to suggest science teachers new didactic interventions on the topic. It is fundamental that the practice of "observing with meaning" is taught from pre-school onwards i. e. the skeleton as a functional unit related to muscles and movement (TUNNICLIFFE; SCOTT, 2007). The latter concepts are highly relevant when discussing 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 students.

Brazil, a post-colonial country, is only 500 years old and as a whole, in its short history, suffered all sorts of strategies of cultural omission and marginalization (MACEDO, 2004). The authors hypothesize that building regional science curricula, organized under concepts as autopoiesis (TRIVELATO, 2005) and integrating cultural local knowledge and popular experiences and values of the social groups involved would bring meaningful improvement for Biology learning & teaching at all levels.

Educational implications

Our study has educational implications for science teachers.

• We suspect that although many students usually get good marks on their formal elementary science and biology examinations, they do face a serious difficulty into seeing how the many pieces of the skeleton fit together (LUCAS, 1995; BRAUD, 1998).
• A study of the bones of hen, cat or even a puzzle grow pieces by students since pre-school years could help students have a grasp of what constitute a skeleton (TUNNICLIFFE; UECKERT, 2007).
• Fortunately, there are children's books about human skeletons as well as for adolescents (LOWERY, 1993; ROWETT, 1999) that provide integrated accounts.
• Nowadays, there are educational approaches that could contribute for a better understanding and grasping of human skeletons through class and home activities aiming into constructing a model of the backbone and spine, using spools of different sizes and a thread, for example (VANCLEAVE, 1995), refreshments straws and plasticine (BRAUD, 1996) assembling of cardboard cut-outs of skeletons parts with pins and staples, simulating movable and fixed joints (KEIM, 1989; SANTOS, 1996, MORENO et al. 1997).
• Another possibility is to ask children, as part of their regular homework, to draw the skeletons of any whole fish or chicken they eat specially during their barbecued meals what are very popular in Brazil.
• A last approach is to make far intensive use through visits

to human and animal skeleton displays presented in Natural History and integrative museums which offer rich informal learning experiences for free in Brazil (SILVA JR., 1995; TUNNICLIFFE, 1999; TUNNICLIFFE, 2000).

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