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What's in the body? Children's annotated drawings

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ABSTRACT

This paper presents a study of children's ideas of the body's internal structure. Children between four and 13 years (N = 170) individually produced drawings. During each drawing session the children explained their drawings to a facilitator and added written labels either by themselves or, if they were too young to write, with the facilitator's help. The results provide an updated comprehensive picture of children in different age groups and their views on the internal structure of the body. The type and numbers of organs drawn are similar to those documented in previous studies. However, in comparison to recent studies, the children drew more organs, the brain was indicated almost as often as the heart, and the Valentine heart was frequently used as a symbol. In contrast with previous research, children drew connections between organs. This result calls for caution regarding conclusions made from decontextualized questions. The importance of providing children with the opportunity to clarify their drawings is emphasised since it otherwise becomes a question of the researcher's interpretation. The connections they draw, and explanations they give to their drawings, have interesting implications for understanding children's ideas, and hence both for teaching and learning and for science education research.

KEYWORDS

Biology education; early years; children's drawings; human body; internal organs

Introduction

Research on children's interpretations of natural phenomena was initiated by the early works of Piaget (1989) and has subsequently been developed in the psychology of learning and various domains of science education. The human body and how it functions is one such domain. Various authors have explored children's understanding of organs and organ systems (e.g. Carvalho et al., 2004; Reiss et al., 2002; Rowlands, 2004), in efforts to determine the nature of children's understanding and gaps in their knowledge of the human body. Previous studies of these important phenomena have generally been investigations covering children ranging from four years old to university age. Many of them have used children's drawings to explore their understanding, in some cases in conjunction with interviews. Many of the studies involving children in different age groups are between two and five decades old. Therefore, there is a need for an updated study that includes children in different age groups. Furthermore, considerable information has been gained, as reviewed by Garcia-Barros and Martínez-Losada (2011), but several important gaps in our knowledge of children's understandings of the human body's structure and functions require attention to be able to address their pre-knowledge. Key aspects of these matters are outlined in this introductory section.

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First, we define organ and organ system, as understood in this paper. An organ is part of an organism, which is typically self-contained and has a specific vital function. Generally, an organ is defined as a collection of tissues joined in a structural unit. Examples of organs are heart, lungs, brain, eyes, stomach, spleen, bones, pancreas, kidneys, liver, intestines, skin, and urinary bladder. Organs may be internal, such as the heart and lungs, or external, such as the skin and genitals. Functionally related organs often act cooperatively as organ systems. In humans, 10 organ systems are commonly recognized: the skin (the largest), skeletal, muscular, nervous, endocrine (hormonal), digestive, respiratory, circulatory, excretory, and reproductive systems (Encyclopædia Britannica, 2017; Fischbarg, Ehlers, and Hjortdal, 2006).

Numbers of internal organs shown in children's drawings are closely correlated to the age of the child, reflecting increases in children's knowledge with age (Glaun and Rosenthal, 1987). Reiss and Tunnicliffe (2001) developed a 7-level scale for scoring children's drawings in this respect, which has been subsequently applied in several studies (Dempster and Stears, 2014; Óskarsdóttir et al., 2011). The participants and methods used in previous studies in which children's drawings of the human body have been examined are listed in Table 1, while the numbers of organs shown in drawings by children of various ages, and the mean scores of their drawings, according to Reiss and Tunnicliffe's scale are presented in Table 2. Results concerning the positioning of the organs and if misplaced organs are included in the results are not clearly articulated in some of the studies (Gellert, 1962; Glaun and Rosenthal, 1987; Eiser and Patterson, 1983).

The organs indicated in children's drawings are often related to their own experiences and cultural connections (Dempster and Stears, 2014; Óskarsdóttir et al., 2011; Reiss et al., 2002). Table 3 summarises the frequencies that internal organs have been found in children's drawings in previous studies. The overview presented in Table 3 shows some striking similarities in the lists of indicated organs. The most commonly drawn organs are bones, brain and heart, with some variation in order of frequencies. The frequent presence of bones and the heart in children's drawings can be explained by the fact that these organs can be experienced by our senses: all children can feel bones and the heart may both be felt beating and heard (Dempster and Stears, 2014; Glaun and Rosenthal, 1987).

However, the cultural context appears to influence children's awareness and knowledge of the body, and hence features of their drawings. For example, brains may have been frequently depicted in drawings examined by Óskarsdóttir et al. (2011) proposed to be partly because of an ongoing media campaign encouraging Danish children to use helmets to protect their brains. In contrast, digestive organs were commonly present in drawings by South African children analysed by Dempster and Stears (2014), possibly because the children were strongly aware of them as they had experienced hunger.

Table 1. Participants and methods used in previous studies of children's understanding of the human body that included analyses of their drawings.

	Gellert (1962)	Eiser and Patterson (1983)	Glaun and Rosenthal (1987)	Reiss and Tunnicliffe (2001)	Óskarsdóttir et al. (2011)	Dempster and Stears (2014)
Participants	American hospitalised children aged 4–16 years. N = 96	British children (6, 8, 10 and 12 years old). N = 104	Australian children aged 5–11 years. N = 210	British students aged four to 20 years. N = 158	Nordic 6-year-old children, before formal learning. N = 119	South African children: 3–15 (mean 7) years old. N = 233
Instrument	Questionnaires and drawings combined with individual interviews.	Drawings combined with individual interviews.	Drawings combined with individual interviews.	Analysis of drawings using seven-level scoring scale.	Drawings Analysis with modified Reiss and Tunnicliffe scale.	Drawings Analysis with Reiss et al.'s (2002) scoring scale.

Table 2. Mean numbers of internal organs in drawings by children of indicated ages recorded in previous studies, and mean scores for their drawings.

	Gellert (1962)	Eiser and Patterson (1983)	Glaun and Rosenthal (1987)	Reiss and Tunnicliffe (2001)	Óskarsdóttir et al. (2011)	Dempster and Stears (2014)
Age groups	Mean No.	Mean No.	Mean No.	Mean Score	Mean Score	Mean Score
4–5	3.3			Level 2[a] (2.00)		
5–6	3.3	2.96	3.4			
6–7			4.18	Level 3[a] and Level 4 (3.71)	Two organs in appropriate position	
7–8	4.2	4.31	5.5	Level 4[a] (4.27)		Level 4[a] 3.6 (range: 1.0–6.0)
8–9			8.5			
9–10	9.0					
10–11		5.85	8.7	Level 4a(4.41)		
11–12	10.3	6.92				
12–13						
13–14	14.0			Level 5[a] (4.67)		

[a] Level 1 No representation of internal structure.
Level 2 One or more internal organ (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 (e.g. stomach and a bone 'unit' such as the ribs) in appropriate position, but no extensive relationship indicated between them.
Level 5 One organ system indicated. (Reiss and Tunnicliffe, 2001, 386)

Table 3. Organs indicated (in decreasing frequency) in children's drawings examined in previous studies.

Study	Indicated organs
Gellert (1962)	Bones, blood vessels, heart, blood, brain, intestinal tract, lungs, kidneys, and stomach
Eiser and Patterson (1983)	Brain, heart, bones, blood and lungs
Glaun and Rosenthal (1987)	Bones, heart, blood, blood vessels, brain, stomach, lungs, oesophagus, muscles, intestine, kidneys, liver, nerves
Cuthbert (2000)	Heart, brain, bones, lungs, stomach, kidneys, ribs, muscles, intestines, liver American children, 7–11 years old (N = 348)
Reiss and Tunnicliffe (2001)	Heart, some portions of the skeletal system, brain, lungs and stomach The same organs and frequency order were recorded in the international study by Reiss et al. (2002)
Óskarsdóttir et al. (2011)	Brain and heart. These organs were also observed by Bartoszeck, Machado, and Amann-Gainotti (2011) in drawings by five-to 11-year-old Brazilian children (N = 396)
Dempster and Stears (2014)	Digestive organs, bones and the heart

According to Nagy (1953), younger children do not typically distinguish between internal and external attributes. Gellert (1962) notes that 'to some children "their inside" included everything covered by the skin; to others, it referred to the content of the trunk only' (300). However, Dempster and Stears (2014) suggest that the use of external attributes might be due to the children's limited knowledge of internal ones: instead of drawing nothing, they may choose to draw external attributes. In addition, Óskarsdóttir et al. (2011) points out that the concept *organ* may need further explanation for most children.

Previous studies have found that children of various ages do not draw connections between organ systems (Cuthbert, 2000; Dempster and Stears, 2014; Óskarsdóttir, 2006; Óskarsdóttir et al., 2011; Reiss and Tunnicliffe, 2001; Reiss et al., 2002). Reiss and Tunnicliffe (2001) found that students had little understanding of how organs exist as related structures within organ systems. Similarly, in an international follow-up study, a minority of drawings by both 7- and 15-year-old children showed any organ system sufficiently completely (Reiss et al., 2002). Accordingly, the children included in the study by Óskarsdóttir et al. (2011) generally drew the skeleton as simple lines or circles, and the bones were rarely connected. Further, most of the drawings showed no

connections between the organs. The most common connections, if any were present, were between the heart and veins.

Several authors have noted that children drew the heart like an icon of a Valentine heart (Crider, 1981; Garcia-Barros, Martínez-Losada, and Garrido, 2011; Reiss and Tunnicliffe, 2001). A possible explanation for this is that books often use this kind of representation (Óskarsdóttir et al., 2011) and children make re-representations of those drawings. Reiss and Tunnicliffe (2001) drew similar conclusions and asked themselves if the children thought this is what the heart looks like, or if it was a symbolic interpretation originating from cartoons, advertisements or cards. Another proposed explanation is that certain organs or organ systems are difficult to draw or visualize, and/or there is limited space to draw a whole organ system (Prokop and Jana, 2006).

To further problematize the interpretations of children's drawings, Reiss et al. (2002) state that some children put a lot of effort into their choices of colour, size, layout, style and use of metaphor in visual representations, which may reflect their feelings or emotions about what is inside their bodies, rather than necessarily their ideas about anatomical structures. Moreover, according to Reiss et al. (2002) the effects of credit for the artistic quality of drawings has generally received little attention in science education.

In overall conclusion, substantial information about the nature of children's understanding of organs and organ systems has been acquired from analyses of their drawings of the human body. However, further knowledge is required to enhance teaching about the human body, improve children's understandings of its structure and functions, and address their pre-knowledge. More information could potentially be acquired by asking children to clarify what they are drawing. Thus, the aim of the study presented here was to acquire more detailed knowledge of children's ideas of the structure of the human body by asking 4- to 13-year-old children to draw what they think is inside the body within the outline of a body, and comment on their drawings.

We specifically addressed the following questions.

- What organs do children represent?
- What understanding of the internal human structure is revealed in children's annotated drawings?
- What impact does the context of the question have on what children draw?
- How can children's clarifying comments contribute to the interpretations of drawings?

Methodology

Participants and data collection

The empirical study's participants were 170 children (89 girls and 81 boys) aged between four and 13 years from different pre-, preschool class and primary schools. They were divided into eight age groups (Table 4), each with an approximately equal gender distribution. Their schools, some urban and some rural, are located in the southern part of Sweden. Data were collected in two phases, referred to as Phase 1 and Phase 2. All children volunteered to participate and their parents gave their informed consent.

In Phase 1, volunteering students from a teacher-education program collected annotated drawings by children they taught during their training period. In Phase 2, experienced teachers taking an in-service course collected annotated drawings by their own pupils. The involvement of many data collectors can be seen as a weakness, but the students and teachers (hereafter facilitators) were familiar to the pupils, which can be seen as a strength. In both phases, the facilitators were instructed to obtain structured observations by neutral probing, asking no leading questions, noting the total time of the drawing session, taking notes during the session and writing reflections after each session. In addition, specific forms were constructed to help them remember what information to collect.

Table 4. Mean time spent on task and mean number of internal organs represented by indicated age groups.

Age (years)	Total number	Mean time on task (min)	Mean number of internal organs
4–5	22	10.8	2
6	12	19	4.3
7	13	17.5	5.1
8	27	18	5.1
9	28	14.5	6.4
10	24	11.5	6.5
11	34	12	7.3
12–13	10	1.5	7.2
	170		

At the beginning of each session in Phase 1, the participating child was introduced to the task. Each child was sequentially given two non-gendered human body outlines (Enochson et al., 2015). On the first sheet the child was requested to 'Draw and tell me what's inside the body' (Drawing 1), whereas advised by Óskarsdóttir et al. (2011), the mention of the concept organ was intentionally avoided. Subsequently, the first sheet was collected, and the child was given a new sheet and requested to 'Draw the pathway a sandwich and a glass of water takes in the body' (Drawing 2). The children had access to a pencil and crayons of different colours. Each session lasted 10–20 minutes (Table 4). The facilitator was instructed to follow the child's own performance rather than posing a predetermined set of questions. Nevertheless, the facilitator had to note the child's understanding of his/her choice of pictorial convention (Welzel and Roth, 1998) when asked clarifying questions during the drawing session (Brooks, 2009; Ehrlén, 2009). However, in some cases the facilitator saved the questions until directly after the child had finished, to avoid the child losing concentration during the drawing process. For the children who could not write, the facilitator labelled the organs during the data collection. In some cases, the facilitator also had to complement, clarify the children's notes on the drawings. Notes on what happened during the session were written down immediately after the child had finished.

The procedure was the same in Phase 2, except that some questions were added based on experiences from Phase 1 regarding issues that needed further clarification. Facilitators were asked to find out if a drawn Valentine heart was meant as an icon or a realistic representation, how to interpret bones, blood vessels and nerves represented in just one part of the body (e.g. the arm) and reasons why external attributes like eyes, nose and ears had been included (if represented in the drawings).

Analysis

Focus for the analysis was to find out children's conceptions of the structure of the internal body, therefore a content analysis of the children's annotated drawings was used. Content analysis of drawings allows both qualitative investigations of what is drawn and quantitative investigations of how often it appears (Merriman and Guerin, 2006). Since we were interested in the total number of internal organs the children were aware of, we counted organs indicated in both Drawings 1 and 2 (each item only once). Their identity, number, and position in the body outline were considered. The correctness of the positioning of the internal organs was assessed in a relatively generous way considering the young age of some of the children. However, the organs had to be placed approximately correctly and in correct position relative to each other to be considered correctly placed in the body outline. For example, if the brain was placed in the head but drawn relatively small relative to the space available in the head it was anyway considered correct; if the heart was placed in the stomach area it was considered misplaced; if an intestine was drawn above the stomach, it was considered incorrectly placed, etc. Furthermore, to complement and support

the researchers' interpretations of the drawings, the facilitators' notes from the sessions were considered in the analysis. In addition to the internal structures, many children spontaneously indicated external characteristics (e.g. skin and hair), which were included in the analysis but not counted as internal organ.

Other important considerations include the judgement of details and realism in the drawings. The youngest children in the study could not have been expected to draw internal organs realistically. However, since the organs were labelled on the drawings, by the children themselves or the facilitator, they could be easily identified. Drawings with no texts clarifying the featured items were discarded and were not further considered. Moreover, we registered if the heart was represented as a Valentine-type icon, since this is an issue discussed in previous studies. To increase the reliability of the analyses, the entire qualitative dataset was analysed several times by three independent coders. In most cases, the number of organs, their positions and connections identified by the different coders were the same. In a few cases, where there was disagreement, the data were reanalysed until agreement was reached. For transparency, representative drawings are shown, by children of both genders, spanning the participants' age range, displaying both relatively few and relatively large numbers of features.

Differences in time-on-task and number of portrayed external organs across the children's ages were analyzed with respect to three age groups: preschool (below 6 years of age), preschool class and junior primary school (6–9 years) and senior primary school (10–13 years). Since the data were not normally distributed within each of the age groups, the non-parametric Kruskal-Wallis test was performed. Satistically significant results were followed by post-hoc Dunn's multiple comparisons using Bonferroni correction. An alpha level 0.05 was used for statistical significance.

Results and discussion

Time spent on task and quality of the drawings

The average time children spent on the task was 13,4 minutes and varied most among the four- to five-year olds (4–20 minutes). However, the statistical analysis of time-on-task revealed significant differences across age groups ($H(2) = 49.3$, $p < 0.001$). Post-hoc Dunn's test indicated that the children in the preschool class and junior primary school (ages 6–9) group had higher time-on-task values (mean 17.3 minutes) than the children in both the preschool group (ages 4–5, mean 11 minutes) ($p < 0.001$, adjusted by Bonferroni correction) and senior primary school group (ages 10–13, mean 10 minutes) ($p < 0.001$, adjusted by Bonferroni correction). This is possibly because they were more committed to and curious about the task.

The detail and realism in the drawings produced varied strongly even within the age groups. Examples of drawings selected to show the variation and numbered according to ages of the children that drew them, are presented in Figure 1.

The 11- to 13-year-old children, who could be expected to be most artistically skilled, tended to draw the organs rather sketchily (Figure 1(i)) while the drawings produced by children aged five to seven in many cases were very carefully designed and included many details (Figure 1(c, d, f)).

Organs and their indicated positions in the drawings

Numbers of organs represented by the children in this study are consistent with the numbers recorded in earlier previous studies with similar data collection arrangements (Tables 1 and 2). The participating children aged six to eight years (Figure 1(e–g)) depicted on average 5.5 internal organs, while those in studies by Gellert (1962), Eiser and Patterson (1983) and Glaun and Rosenthal (1987) Gellert (1962), depicted three to five on average. It is important to emphasize that the number of organs varied greatly even within age groups, as illustrated by Figure 1(a–d). However, Óskarsdóttir et al. (2011) found that children of the same age depicted

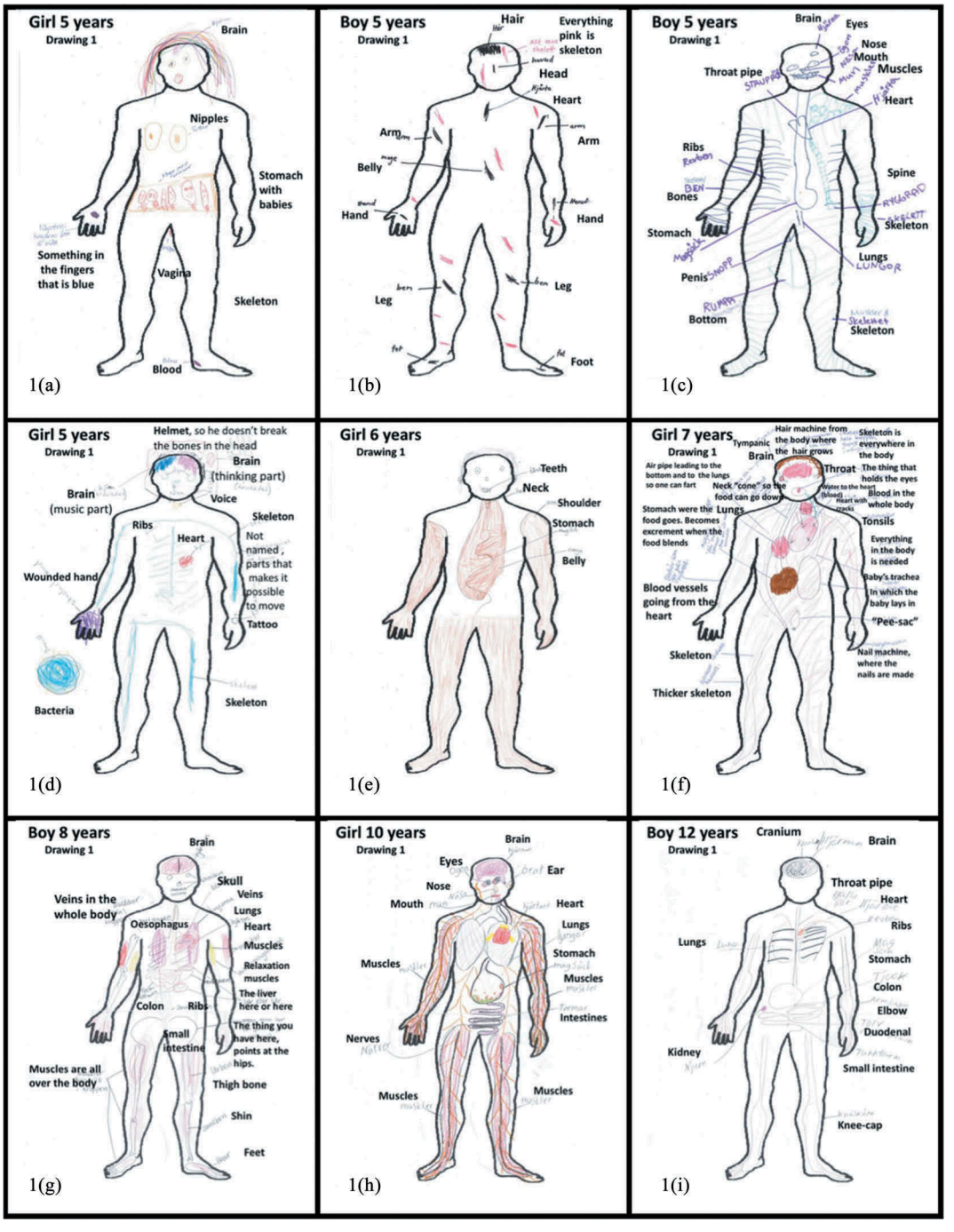

Figure 1. Children's Drawings of What's Inside the Body.

just one or two organs in the correct place. The discrepancies may be at least partly due to differences in methodology. In this study, children were given two tasks and we included both drawings in our analysis, which may have increased overall numbers of represented organs. In addition, in our study and the cited studies by Gellert, Eiser and Patterson, and Glaun and Rosenthal, each child sat alone with the facilitator during the data collection, while in the study

by Óskarsdóttir et al. (2011) the children may have been less engaged because a whole class addressed the task simultaneously. Moreover, comparing numbers of organs found in this and previous studies is not straightforward for at least four other reasons. Firstly, the context of participating children affects the outcome and, for instance, in Gellert's study the children were hospitalised. Secondly, there were differences in the tasks. In the present study, and studies by Gellert (1962), Eiser and Patterson (1983) and Glaun and Rosenthal (1987), but not the other cited studies, the children both drew and orally expressed themselves. Thirdly, studies involving use of Reiss and Tunnicliffe's scoring scale focused on organ systems rather than the number of organs drawn. Fourthly, it is not always clear what the total number of organs includes, for example whether or not misplaced organs and external attributes (discussed below) are included in the analysis.

The children were asked to draw what is *inside* the human body, but many of them (about 40%) also drew external attributes and structures such as a mouth, eyes, ears, nose, and hair. The youngest children also drew other external attributes such as neck, arm, hand, nails, skin, nipples, a wound with blood and belly button (Figure 1(a, b, e)). This is an issue that has been noted in some previous studies (Reiss and Tunnicliffe, 2001; Óskarsdóttir et al., 2011), but not extensively discussed. The inclusion of external attributes could be due to difficulties for the children to distinguish what the concept *organ* means (Óskarsdóttir et al., 2011). Further, the meaning of the concept *inside* might be unclear (Gellert (1962), especially for the youngest children, as indicated by Figure 1(a, e). A possibility is that the children drew these attributes to compensate for lack of knowledge about internal organs (Dempster and Stears, 2014), or in fact generate them for aesthetical reasons, to make their drawings 'look nice' (Änggård, 2005). Actually, the older children gave interesting explanations in their comments, for example that they found it difficult to separate the outside from the inside in certain cases since, for instance, 'the eyes' are both outside and inside the body referring to the optic nerve (Figure 1(h)). Furthermore, the boundary of the mouth as an internal or external body part is not entirely clear.

The statistical analysis revealed significant differences across age groups for number of portrayed internal organs ($H(2) = 44.3$, $p < 0.001$) and number of portrayed external organs ($H(2) = 14.2$ $p = 0.001$). Concerning the number of internal organs, the number they drew increased with age (Figure 2). Thus, the preschool group (age 4–5) depicted fewer internal organs than the preschool class and junior primary school group (age 6–9) ($p < 0.001$, adjusted by Bonferroni correction) and the senior primary school group (age 10–13) ($p < 0.001$, adjusted by Bonferroni

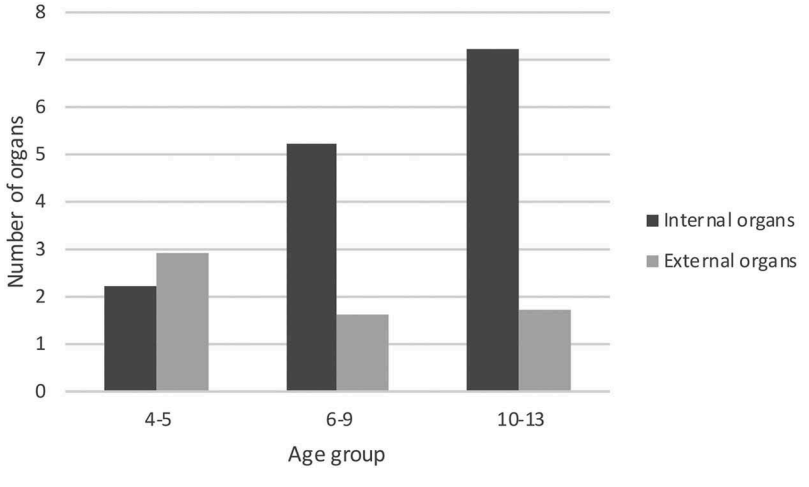

Figure 2. Mean Number of Organs Indicated in the Drawings.

correction), while the preschool class and junior primary school group depicted fewer internal organs than the senior primary school group ($p = 0.001$, adjusted by Bonferroni correction).

With respect to the number of external organs, Dunn's post-hoc test showed that children in the preschool group (ages 4–5) portrayed more external organs than the children in both the preschool class and junior primary group (ages 6–9) ($p = 0.019$, adjusted by Bonferroni correction) and the senior primary school group (ages 10–13) ($p = 0.01$, adjusted by Bonferroni correction).

The sharpest increase in numbers of internal organs represented was between ages 4–5 years (slightly less than 2) and 6–9 years (more than five organs). The increase in the number of drawn organs may be an indication of what the children had been taught at school or informally gained knowledge. Further, a contributory factor for the sharp age-related rise in our study may be that 6- to 8-year-old children spent the longest time on the task, on average. The time spent on task could reflect strong engagement, which may explain the sharp increase in knowledge at this age, or simply the younger children's need for more time to draw and communicate. Moreover, the drawing task may have appealed more to younger children than to older ones, although this interpretation is not supported by Figure 1(b), in which a boy simply indicated rather than drawing various body parts.

The heart, brain, skeleton, stomach, blood and lungs were the six internal organs most frequently indicated by the children (Figure 3). The brain as the second most frequently indicated organ is in accordance with Óskarsdóttir et al. (2011), but is in contrast with findings from Gellert (1962), Glaun and Rosenthal (1987), and Reiss and Tunnicliffe (2001). Lungs were indicated by some of the younger children, but more commonly by children aged seven and older. The children often only used the word 'intestines' when referring to the digestive tract beyond the stomach. Small intestines and colon were also mentioned, most often by the older children. Liver and kidneys were indicated by children aged 10–13 years more often than by younger children. These patterns are generally consistent with those observed in previous studies (Table 3), with some variation in frequency order.

Other organs, such as pancreas, caecum, vocal cord and tonsils, were mentioned by very few children. Some children also mentioned: nerve fibres, bacteria that make you sick, good and evil bacteria, different parts of the skeleton, vitamins that make the body feel better, brainstem and earwax.

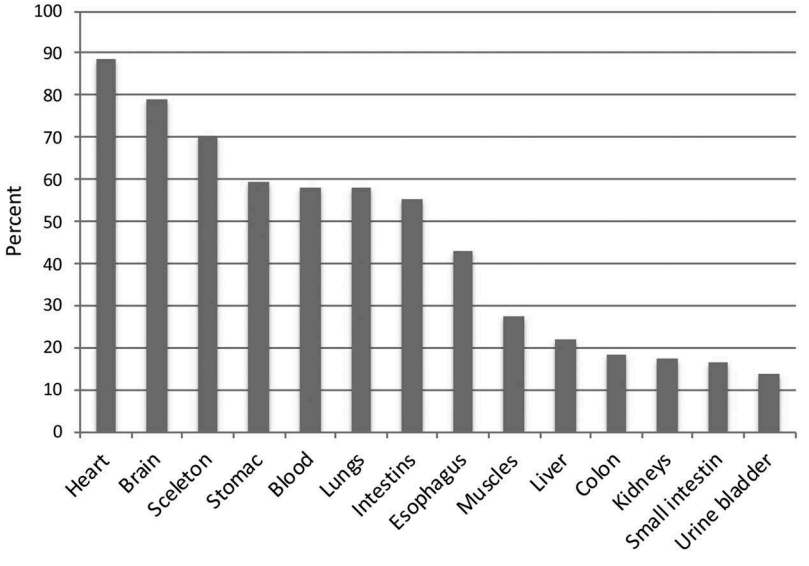

Figure 3. Percentages of Indicated Internal Organs in Drawing 1 and 2.

Interestingly, although the heart was the most commonly indicated internal organ, the brain was indicated almost as often. In fact, the six-year-old children represented the brain more often than the heart (Figure 4). There was also an unexpected and unexplained decrease in the proportion of 10-year-olds that represented the brain.

Children seemed to recognize the brain's importance from the age of six and find it the easiest organ to place in the correct position. As postulated by Óskarsdóttir et al. (2011), this may be at least partly based on children's own experiences, as many children learn to ride a bike at about this age, and everyone must use a helmet to protect the brain (see annotation in Figure 1(d)) in Scandinavia. Moreover, children's awareness might also be influenced by current discussion of the importance of the brain in the society. Finally, the children appeared to be aware of the positions of most of the internal organs that they indicated. If lungs were indicated they were mostly drawn in correct positions, but in a few cases only one of the lungs was indicated. Difficulties in placing the stomach and intestines (<10%) were essentially connected to the organ's vertical relationships. The organs that were least frequently indicated were the kidneys, liver and bladder, but were correctly placed when indicated.

Interpretations of the children's drawings

The heart was relatively often represented by an iconic Valentine heart (Figure 1(c, d), most frequently in drawings of the youngest children, about 40 % of the four- to nine-year-olds. This representation decreased among the older children (Figure 5). The heart was also frequently represented in this manner by children who participated in previous studies (Crider, 1981; Reiss and Tunnicliffe, 2001; Garcia-Barros, Martínez-Losada, and Garrido, 2011). Reiss and Tunnicliffe (2001) discussed uncertainty about whether this representation is symbolic or represents what children really think. However, statements by the children in the present study clearly indicated recognition that it is a symbolic representation of the heart," She *draws the heart as a shape of a heart but directly comments it and says that it does not look like that inside of the body"* (Facilitator's note, girl, 10 years old). Moreover, most of the children explained that they used the Valentine heart representation as a symbol because it is easy to draw. However, we cannot exclude that the perception that the heart looks like a Valentine heart is possible, especially among the youngest children (Crider, 1981).

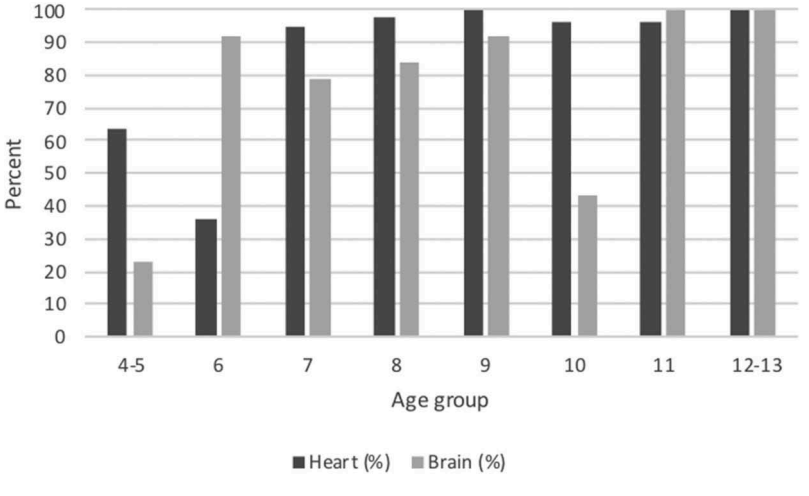

Figure 4. Percentages of Children in Each Age Group who Represented the Heart and Brain.

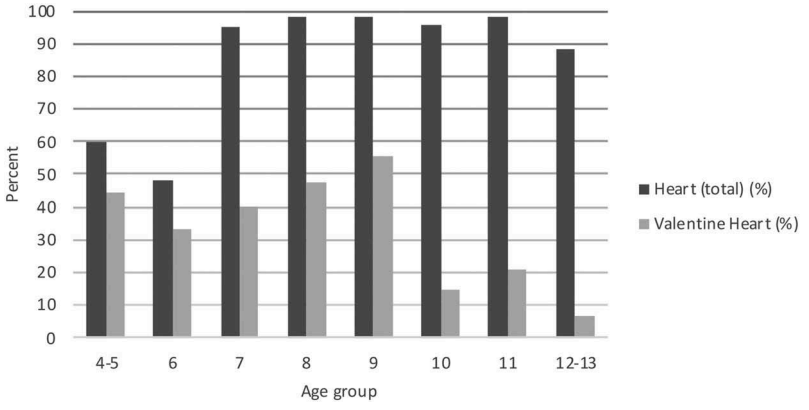

Figure 5. Percentage of Children in Each Age Group who Represented the Heart with a Valentine Heart.

Several previous reports have emphasised the lack of connections between organs in children's drawings (Dempster and Stears, 2014; Reiss and Tunnicliffe, 2001; Reiss et al., 2002; Óskarsdóttir et al., 2011). We were therefore interested in comparing Drawings 1 and 2 in this study (Figure 6). In Drawing 1, the children were asked to draw what is inside their bodies without any further directions. However, in Drawing 2, the request to indicate the route of food and drink through the body contextualized the task. The common lack of connections between the organs was only partly confirmed in our study. In Drawing 1, this was observed primarily in the drawings of the younger children (Figure 6), while more than 50% of the children between 8–10 years connected organs into more or less complete systems (drawing 1) without a given context (Figure 1(f–i)). Interestingly, when the children were given a contextualised task, to draw the passage of food and drink (in Drawing 2), most of the children included connections between the organs, and this contextualization effect was most pronounced among the youngest children. One of the facilitators commented that, *'The child knows that there are organs in the body and that the organs cooperate'* (Facilitator's note, girl, 10 years old). Other comments that are not quite scientifically correct also express some kinds of connections, e.g. *'Air pipe leading to the bottom and to the lungs so one can fart'* (Figure 1(f)). This differs from the finding by Reiss and Tunnicliffe (2001). In their study the participants were not aware of how organs were organised as functional systems. Given the previously reported deficiency of indicated connections between organs, even when children have been specifically asked to draw organ systems,

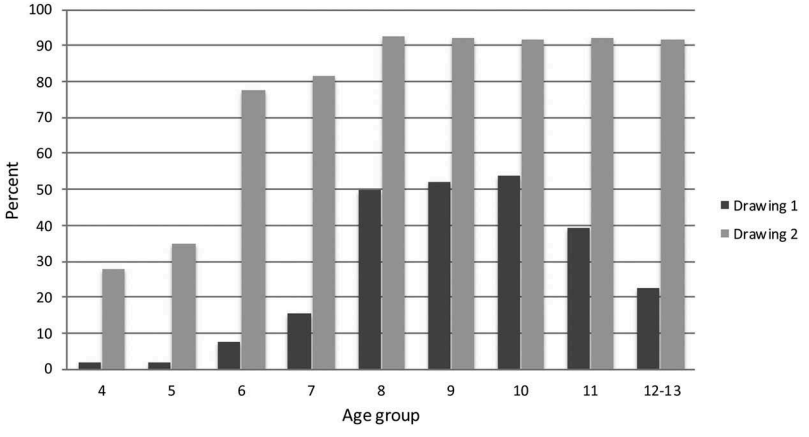

Figure 6. Percentages of Children in Each Age Group who Indicated Connections Between Organs in Drawings 1 and 2.

this is a noteworthy finding. Table 5 summarises the types of connections made in Drawing 1. However, it must be emphasised that they did not draw complete organ systems but made connections between parts of them, such as between the heart and blood vessels, or trachea and lungs. Although, the same child may have drawn several connections, the overall analyses in Figure 6 counts one connection per child.

The number of drawn systems increased with age, except amongst the 11-year old children. The skeletal system and the circulatory system were the most commonly drawn. This is possibly due to the result that the most frequently drawn organs are part of these systems. Since the context had an impact on the number of connections that the children drew, the significance of the context was also investigated. Therefor, the number of digestive organs that the children drew with and without context were investigated (Table 6).

The number of digestive organs increased as the question (Drawing 2) became more specified. Among the 11–13-year old children there is a small decrease in number of drawn intestines. This can possibly be explained by the fact that some children became more specific when the task was put in a context. Instead of merely drawing intestines some of them drew the duodenum, small intestines and colon. Besides this, there was only one discrepancy in Drawing 2, the intestines, drawn by a six-year old. Another noteworthy difference refers to the liver which 15 of the 11-year-olds drew in Drawing 1 but only 5 of them in Drawing 2. This result implies that the older children focus on gastrointestinal tract and not on the glands such as the liver, the gall bladder and the pancreas. Also, the result points to the fact that children can do more when the question is posed in a context. Hence results obtained from decontextualized tasks such as the task in Drawing 1 and in many other previous studies may be discussed. Overall, this indicates that both context and instruction influence the results and lack of knowledge may not be the reason why children do not draw something. Other methodological considerations and implications of the results are discussed in the following section.

Table 5. Connections made in drawing 1. Given in order of magnitude where 1 corresponds to the most common connection in the age group.

Age	Circulatory system	Skeletal system	Digestive system	Muscular system	Respiratory system	Nervous system
4–5	2	1				
6	1	2	3			
7	3	1	2	4		
8	1	2	3	4		5
9	2	1	3	5	4	6
10	2	1	3	5	4	6
11	2	1	3		4	
12–13	2	3	1	4	4	3

Table 6. A comparison of depicted digestive organs in a decontextual (Drawing 1) vs. a contextual task (Drawing 2). (Given in % of each age group).

Age	Mouth		Oesophagus		Stomach		Intestines	
Drawing	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
4–5	**9%**	27%	**5%**	27%	**32%**	41%	**0**	0
6	**33%**	67%	**17%**	42%	**50%**	83%	**17%**	8%
7	**0%**	39%	**31%**	54%	**46%**	69%	**23%**	31%
8	**0%**	22%	**11%**	41%	**37%**	63%	**15%**	22%
9	**18%**	39%	**11%**	26%	**68%**	82%	**18%**	36%
10	**17%**	29%	**29%**	63%	**67%**	83%	**38%**	50%
11	**12%**	41%	**32%**	65%	**62%**	82%	**50%**	41%
12–13	**10%**	50%	**30%**	90%	**90%**	100%	**50%**	60%

Conclusions and educational implications

Several authors have concluded that many children lack understanding of organ systems, even if they are aware of component organs. For example, Reiss and Tunnicliffe (2001) mention that students may know that they have bones, but their drawings do not generally show a skeletal system. However, whether this is due to lack of knowledge is debatable. It may simply reflect the difficulty of drawing the inside of a human body on a single sheet of paper, especially in the limited space and time the children were given. Furthermore, it is challenging to transform the internal three-dimensional structure of a human body into a two-dimensional drawing. The different parts of the inside of the body must be superimposed somehow, which is far from straightforward. For example, drawing muscles, the blood system and skeleton in the same drawing and include all the different organs is challenging, even for a skilled adult artist.

The complexity of the systems poses further challenges. The children realized that they could not possibly draw a complete blood or skeleton system, for example, so many of them depicted elements, e.g. the skeleton in one arm or a leg and explained that they knew that the skeleton was present in other parts of the body, but they just drew it in one part to avoid crowding of organs. Thus, a lack of organs or systems may be due to illustration difficulties rather than lack of knowledge and children may use creative strategies to overcome these problems if given the opportunity.

Thus, in accordance with Brooks (2009), Ehrlén (2009) and Wiegerová and Andrea (2017) our study highlights the importance of letting children comment upon and clarify their drawings. Also, we claim that our methodology enables a deep interpretation of children's drawings and re-evaluation of their level of correctness. We suggest that this approach can make valuable contributions to the development of science education research: a conclusion that has been previously expressed but seems to have been forgotten. As stated by Glaun and Rosenthal (1987):

> A limitation of earlier research has been an over-reliance upon drawings as means of eliciting concepts about the body interior. The present study sought to extend previous research by improving methodology. To this end, the use of drawings was combined with an interview, designed to elicit the child's description of the interior of the body. (Glaun and Rosenthal, 1987, 64)

In summary, our overall results show that many children have an unexpected level of knowledge of the internal organs. They might not indicate a higher number of organs, but they appear to know their positions much better than reported in previous studies. The brain is specified almost as often as the heart, and most of the children gave clear indications of the Valentine heart as a symbolic representation. However, the most noteworthy finding is the high frequency of indicated connections between organs into organ systems in both drawings. This finding is in contrast with earlier studies.

Implications for teaching

One may ask why the issue of organs being internal or external is of interest within the field of teaching and learning biology. In accordance with Simons and Keil (1995), we believe that young children have a framework of causal explanations without detailed mental models of underlying mechanisms. Therefore, a primary transition from abstract to concrete is required. To help young children, we need to explain and concretize what is happening inside the body. This is of importance, particularly for teachers of the youngest children. In fact, abstract to concrete progression may capture important features of how knowledge develops within biological. However, it might be difficult to distinguish between deficiencies in drawing abilities and the level of knowledge development. This is where the importance of annotation comes in. Gelman and Wellman (1991) stress that children's awareness of the distinction between inside-outside is an important stepping-stone for children's understanding. Their results show that four-year-old children already understand the importance of

non-obvious features. The significance of concrete experiences is also emphasised by Marton and Pang (2006) within the framework of perceptual learning. They claim that children's initially vague perceptions can become more differentiated by teaching them to paying attention to features and to discern differences. An awareness of this is valuable knowledge for teachers when they interact with younger children during their learning process

Finally, as noted by Ainsworth, Prain, and Tytler (2011), children's drawings are valuable tools in both educational research and practical teaching. By letting the children draw and explain their drawings we can open new windows to the understanding of children's ideas about the internal structure and processes of the human body. In addition, annotated drawings can provide teachers with valuable insights into children's current knowledge that are helpful for planning pedagogic exercises to improve understanding of body structure and functions and a way to respect children's knowledge and to challenge them.

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No potential conflict of interest was reported by the authors.

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