Case Study

# An International Study of Young Peoples' Drawings of What Is Inside Themselves

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What do young people know of what is inside them and how does this knowledge depend on their culture? In this study a cross-sectional approach was used involving a total of 586 pupils from 11 different countries. Young people, aged either seven years or 15 years, were given a blank piece of A4-sized paper and asked to draw what they thought was inside themselves. The resultant drawings were analysed using a seven point scale where the criterion was anatomical accuracy. However, we also tentatively suggest other ways in which such drawings may be analysed, drawing on approaches used in the disciplines of visual design and visual culture.

*Key words:* Biology education, Mental models, International study, Anatomy, Drawings.

## Introduction

In this study we report on young peoples' understandings of their own internal structures in eleven countries. This is part of a larger on-going study in which 54 countries have agreed to participate. The eleven countries analysed here – Australia, Brazil, Denmark, Ghana, Iceland, Northern Ireland, Portugal, Russia, Taiwan, Uganda and Venezuela – were identified partly because they were among the first to send us the data we requested and partly because they were identified by us as representing a good geographical and cultural spread.

As discussed in more detail below, seven year-olds and 15 year-olds were asked to draw what they thought was inside themselves. We chose seven year-olds on the grounds that in just about every country the great majority of seven year-olds have begun school, and 15 year-olds on the grounds that in many countries a high proportion of 15 year-olds are still in formal education yet, are near to the end of their compulsory schooling.

As far as young peoples' knowledge, as revealed by drawings, of what is inside themselves goes, perhaps the most thoroughly studied organ system is the skeleton (Caravita & Tonucci, 1987; Tunnicliffe & Reiss, 1999a). There have been a number of research reports and papers looking at other organ systems that have often reported valuable data (notably Nagy, 1953; Gellert, 1962; Mintzes, 1984; Carey, 1985; Fleer, 1994; Bàguena & Oliván, 2000; Bandiera & di Macco, 2000; Cuthbert, 2000; Selles & Ayres, 2000; Selles *et al.*, 2000; Zogza & Gritsi, 2000). However, we are unaware of any work that systematically, simultaneously and quantitatively examines:

(i) how knowledge, as revealed by drawings, of human internal structure depends on pupil age;
(ii) how such knowledge differs between the various human organs and organ systems;
(iii) how similar or different such knowledge is from country to country.

Our study is intended to begin to address these three issues. As we discuss below, it was as we carried out a quantitative and anatomically-focused analysis already developed for a study on English pupils and undergraduates (Reiss & Tunnicliffe, 2001) that we realised that the analysis only allowed us to interpret part of the information present in each drawing

As we have reviewed elsewhere, there are many ways of gathering information about pupils' understandings of scientific phenomena (Tunnicliffe & Reiss, 1999a). Most of these methods rely on pupils either talking or writing about science. Such methods include oral interviewing of pupils (Osborne & Gilbert 1980), gathering pupils' written responses (Leach *et al.*, 1995), recording pupils' spontaneous conversations (Tunnicliffe & Reiss, 1999b) and getting pupils to construct written concept maps (Novak & Musonda, 1991).

In this study we decided to use an approach which relied less on words. While we do not assert that drawings are necessarily superior to other ways of elucidating understandings, they do have certain worthwhile features. One advantage is the comparative ease with which a rich mass of data can be obtained. In addition, there is perhaps a certain appropriateness in asking subjects to represent (albeit in two dimensions) anatomically their own anatomy. In the language of Buckley, Boulter & Gilbert (1997), such representations can be viewed as the expressed models – that is, representations of phenomena placed in the public domain – of the young people. These expressed models relate to (but do not equate with) the mental models – i.e. the private and personal cognitive representations – held by the same young people. Finally, drawings are particularly suitable for large international studies, given the diversity of languages used.

## Methods

Biology educators from around the world (generally just one per country) were approached and invited to participate in the study. Once they had accepted, they were e-mailed or posted a detailed 12 item protocol. The principal details of this were as follows:

- Identify suitable schools. Try to obtain at least 20 drawings done by seven year-olds and at least 20 drawings done by 15 year-olds, preferably at least ten drawings at each age range being done by girls and ten by boys. The schools to be used should be 'typical' ones for your country so far as this is possible. Try and ensure that you have a representative spread of children with regard to such factors as wealth (are the schools in unusually poor or unusually rich districts?), ethnicity (are certain racial groups not present in the school?), selection/access (is the school fee-paying?) and gender (do both boys and girls go to the school?)
- You will need approximately 15 minutes with the class. Take in enough white A4 paper (approximately 296 x 210 mm) for each child in the class to have one sheet and for you to have some spare. Take in pencils and pens too, or check with the teacher in advance that there will be enough of these for each pupil to have something with which to draw.
- When you speak to the pupils tell them the following – in whatever language is most appropriate. Try not to add extra instructions. We want all the countries to have data collected under the same conditions, so far as this is possible.
  a. I would like each of you to do a drawing of what you think is inside yourself.
  b. This is not a test or an examination but please don't copy each other's work.
  c. You can have as long as you like but I imagine 10-15 minutes should be long enough.
  d. This is part of a research project involving lots of children of your age from many countries around the world.
  e. Please write your name clearly at the top of the page.
  f. Please also write how old you are in years.
  g. Please also write whether you are a girl or a boy.
- If any pupils ask you any questions, try to say 'It's up to you' unless it simply needs you to clarify something you have already said. If a child tells you that they can't draw, tell them not to worry and that we are interested in what they think is inside themselves not in whether they can draw well.
- If any drawings have labels on them that are not in English, please do a photocopy of the drawing and write an English translation on the photocopy.
- Write just a few lines about each school. For example: 'Smallwood School has about 700 pupils, both boys and girls, aged from 11 to 16 years-old. About 80% of pupils are White. The remainder are mainly Asian. Pupils do not need to pay fees to attend and the school is situated in a rural village. The school has a good reputation among parents and academically is fairly typical for a school in England.'
- Write a few lines about what children at each age group have studied about what is inside themselves. For example: 'By the time they are 15 years old, pupils at Smallwood School have studied the Science National Curriculum in England and Wales since the age of five. Biology is taught each year as part of Science and quite a bit of time is spent on the skeleton, digestive system, the circulatory system, the urinogenital system and gaseous exchange system. Some time, but less, is also spent learning about the nervous system and how muscles work. The only bits of the endocrine system that are studied are the functions of the hormones insulin and adrenaline. Most teaching is done by teachers drawing on the blackboard and by pupils copying from textbooks.'

## Results

Our first approach to the analysis of the drawings was to use a method we had already developed for a study on English pupils and undergraduates (Reiss & Tunnicliffe, 2001). A seven point ranking system was employed reflecting different levels of biological understanding (Figure 1) using the operational definitions given in Figure 2. The scoring system we used gives as little credit as possible to the 'artistic' quality of the drawing and is as unambiguous as possible to score. There was no consideration of pupils' ages in determining the scoring system or the actual scores.

Having agreed on the level (i.e. 1 to 7), we then, for each of the eight organ systems, decided whether or not the drawing met the criterion for that organ system. If it did, we recorded the appropriate capital letter (S for skeletal, G for gaseous exchange, etc.). If it did not, we then decided whether or not at

| | |
|---|---|
| *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 (e.g. 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 to anus). |
| *Level 6* | Two or three major organ systems indicated out of skeletal, gaseous exchange, nervous, digestive, endocrine, urinogenital, muscular and circulatory. |
| *Level 7* | Comprehensive representation with four or more organ systems indicated out of skeletal, gaseous exchange, nervous, digestive, endocrine, urinogenital, muscular and circulatory. |

***Figure 1*** *The system used to score the biological quality of each drawing.*

least one organ was present on the drawing for that organ system. If one was, we recorded the appropriate lower case letter (s for skeletal, g for gaseous exchange, etc.). Each drawing was therefore effectively scored a total of 17 times, once for the overall level, once for the presence or absence of each organ system and once for the presence or absence of at least one organ in each organ system. Each drawing was scored independently by two of the authors. In excess of 95% of cases, the two scorings were identical. In those cases where the scorings differed, the two same authors discussed each such case until agreement was reached.

To illustrate our analysis, Figure 3 shows a drawing by a 15 year-old female Australian. The drawing is scored 5 D sgndumc. In other words, it has (as defined by us) one satisfactory organ systems, i.e. the digestive system, and contains organs in the following seven organ systems: skeletal, gaseous exchange, nervous, digestive, urinogenital, muscular and circulatory.

Before analysing the data, two of the authors read through the reports on the schools used. In some cases there was felt to be significant doubt that the schools contained a representative spread of children. The most frequent problems were either that one sex was under-represented or that children from more privileged backgrounds were over-represented. No such data are included in this paper.

Table 1 shows for the 11 countries in this study the mean levels attained by the seven and the 15 year-olds together with standard errors of the mean. As one would expect, 15 year-olds almost always score very significantly higher than seven year-olds within all countries. A not so significant increase was found in Iceland ($0.001<p<0.01$) and no significant increase ($p>0.05$) was found in Taiwan. In addition, results suggest that countries may vary in the degree to which pupils progress in their knowledge over these eight years. The apparent lack of progress in Taiwan may result from the high average scores achieved by the seven year-olds and the high standard error of the mean for this age group. In Taiwan, first grade (six year-old) children are taught about the alimentary canal, about the gaseous exchange system and about excretion. It is clear from their drawings that many Taiwanese seven year-olds have an impressive knowledge of these organ systems (leading to a high mean score) while some (like the typical seven year-olds in many other countries) do not (leading to a high standard error of the mean).

Table 2 shows that gender differences are generally small and rarely significant. However, four of the 22 t-tests do reveal significant differences at the 5% level and in each case males produced drawings that on average scored higher than those produced by females: Ghana (15 year-olds); Iceland (15 year-olds); Russia (15 year-olds); Taiwan (seven year-olds).

In all countries, for each of the eight organ systems, only a minority of drawings – whether by seven year-olds or 15 year-olds – show the organ system drawn sufficiently completely to be classified by us as an organ system. At the same time, there are statistically very significant differences between the eight organ systems in terms of how well they

| | |
|---|---|
| *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 (e.g. optic nerve). |
| *Digestive system* | Through tube from mouth to anus and indication of convolutions and/or compartmentalisation. |
| *Endocrine system* | Two endocrine organs (e.g. thyroid, adrenals, pituitary) other than pancreas [scored within digestive system] or gonads [scored within urinogenital system]. |
| *Urinogenital system* | Two kidneys, two ureters, bladder and urethra or two ovaries, two fallopian tubes and uterus or two testes, two epididymes 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. |

***Figure 2*** *Definitions of each organ system.*

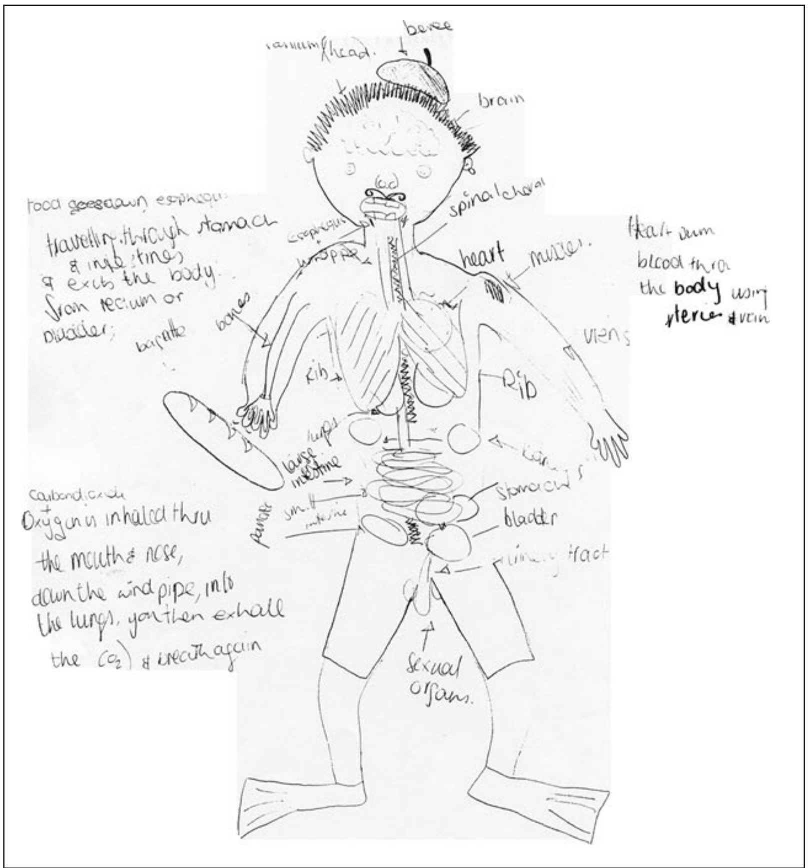


***Figure 3*** *A drawing by an Australian 15 year-old female which is scored 5 D sgndumc according to the method described in the text.*

**Table 1** Comparisons between levels attained by seven and 15 year-olds in each country; sem = standard error of the mean; n = number of pupils in each age group for each country; t = value of a t-test comparing seven and 15 year-olds within each country; p = value of significance.

| | *Level attained by 7 year-olds* | | | *Level attained by 15 year-olds* | | | | |
|---|---|---|---|---|---|---|---|---|
| *Country* | *Mean* | *sem* | *n* | *Mean* | *sem* | *n* | *t* | *p* |
| Australia | 2.70 | 0.167 | 30 | 4.53 | 0.236 | 15 | 6.33 | <0.001 |
| Brazil | 3.91 | 0.094 | 21 | 4.65 | 0.150 | 20 | 4.18 | <0.001 |
| Denmark | 2.55 | 0.145 | 31 | 4.39 | 0.186 | 23 | 7.80 | <0.001 |
| Ghana | 1.85 | 0.082 | 20 | 4.50 | 0.181 | 22 | 13.34 | <0.001 |
| Iceland | 1.92 | 0.095 | 38 | 2.53 | 0.177 | 31 | 3.04 | <0.01 |
| N. Ireland | 3.50 | 0.136 | 20 | 4.85 | 0.196 | 20 | 5.66 | <0.001 |
| Portugal | 2.48 | 0.179 | 31 | 4.24 | 0.136 | 17 | 7.83 | <0.001 |
| Russia | 1.00 | 0.000 | 24 | 2.38 | 0.317 | 24 | 4.34 | <0.001 |
| Taiwan | 3.68 | 0.253 | 42 | 4.16 | 0.131 | 37 | 1.68 | <0.1 |
| Uganda | 1.81 | 0.117 | 31 | 3.22 | 0.226 | 27 | 5.54 | <0.001 |
| Venezuela | 2.27 | 0.149 | 22 | 3.32 | 0.173 | 40 | 4.39 | <0.001 |

**Table 2** Comparison between levels attained by females (F) and males (M) in each country; t = value of a t-test comparing females and males within each age group within each country; p = value of significance.

| | *Mean levels attained by 7 year-olds* | | | | *Mean level attained by 15 year-olds* | | | |
|---|---|---|---|---|---|---|---|---|
| *Country* | *F* | *M* | *t* | *p* | *F* | *M* | *t* | *p* |
| Australia | 2.73 | 2.71 | 0.06 | >0.5 | 4.83 | 4.30 | 1.17 | <0.5 |
| Brazil | 3.82 | 4.00 | 0.99 | <0.5 | 4.63 | 4.67 | 0.15 | >0.5 |
| Denmark | 2.54 | 2.67 | 0.39 | >0.5 | 4.44 | 4.36 | 0.19 | >0.5 |
| Ghana | 1.80 | 1.90 | 0.60 | >0.5 | 3.89 | 4.92 | 2.87 | <0.01 |
| Iceland | 1.86 | 1.96 | 0.58 | >0.5 | 2.13 | 3.00 | 2.86 | <0.01 |
| N. Ireland | 3.50 | 3.60 | 0.34 | >0.5 | 4.60 | 5.10 | 1.32 | <0.5 |
| Portugal | 2.77 | 2.28 | 1.36 | <0.2 | 4.18 | 4.26 | 0.29 | >0.5 |
| Russia | 1.00 | 1.00 | - | | 1.60 | 3.67 | 3.32 | <0.01 |
| Taiwan | 3.00 | 4.00 | 3.18 | <0.01 | 4.20 | 4.11 | 0.31 | >0.5 |
| Uganda | 1.83 | 1.77 | 0.26 | >0.5 | 3.00 | 3.50 | 1.07 | <0.5 |
| Venezuela | 2.44 | 2.15 | 0.87 | <0.5 | 3.10 | 3.58 | 1.37 | <0.2 |

are represented. Generally, the best drawn organ systems are the digestive system, the gaseous exchange system and the skeletal system. At the other extreme, very few of the drawings show the muscular system, the endocrine system or the circulatory system. When it comes to organs rather than entire organ systems, the majority of the drawings contain some organ (nearly always the heart) in the circulatory system and many also contain some part of the digestive and/or skeletal system.

Differences between countries are difficult to categorise but are intriguing. For example, a number of the drawings completed by pupils in Uganda showed babies (e.g. Figure 4). Some of these drawings, including that in Figure 4, were completed by seven year-olds so we don't presume that these pupils themselves were pregnant. Rather we presume that unborn babies are drawn because the pupils live in countries where fecundity is high and so a high proportion of women are pregnant.

In some countries, a high proportion of the drawings show not a single body but a scattered series of drawings, each of one organ system or part of the body. Figure 5 shows such a drawing produced by a 15 year-old male in Ghana. We assume that such drawings reflect the way that pupils have learnt in school. Presumably such pupils have been introduced separately to the various organs systems or parts of the body. However, they have either never been helped to put these various parts together into a single whole or have not succeeded in so doing. The result, if we take drawings like that in Figure 5 at face value, is that pupils don't see their insides as a single mutually adapted and functioning whole but as an accumulation of isolated parts. Figure 5 betrays no understanding on the part of the pupil about the relative positions of the various parts of his body. Perhaps as importantly it does not suggest that the pupil has a model of physiology in which the products of digestion are used to build up muscles which contract as a result of innervation.

It was as we compared the drawings produced in the various countries that we began to review the way in which we analysed the drawings. For a start, it has been shown that if English primary school children are asked to 'Draw the bones that are inside your body' they produce significantly better (in the sense of anatomical more accurate) drawings of the skeleton than if they are asked to 'Draw what you think is inside your body' (Khwaja & Saxton, 2001). This is not especially surprising but shows that our original assumption that the drawings provided quite a reasonable measure of pupils' knowledge about their internal structure is an oversimplification. Similarly, we have pointed out the extent to which many people (including undergraduates) who undoubtedly know something about their reproductive organs nevertheless choose to omit these from their drawings (Reiss & Tunnicliffe, 2001).

Perhaps more fundamentally, in some countries quite a high proportion of the drawings display feelings or thoughts while in other countries none do. At least in part this may be due to differences in language. In some countries it may have been that the instruction 'I would like each of you to do a drawing of what you think is inside yourself' was heard by at least some pupils as 'I would like each of you to do a drawing of what you think

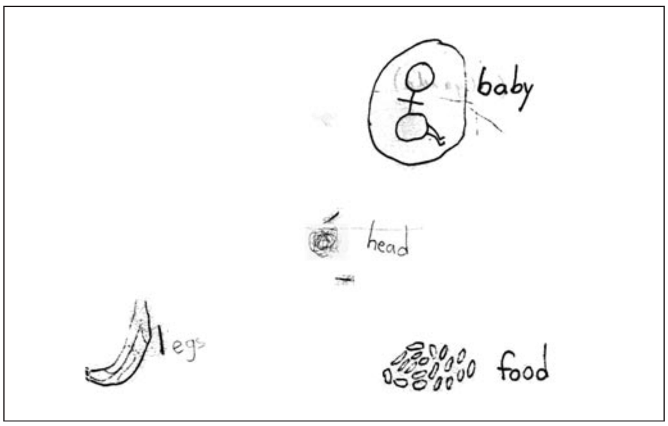


***Figure 4*** *A drawing by a 7 year-old Uganda female showing a baby within her drawing of herself*

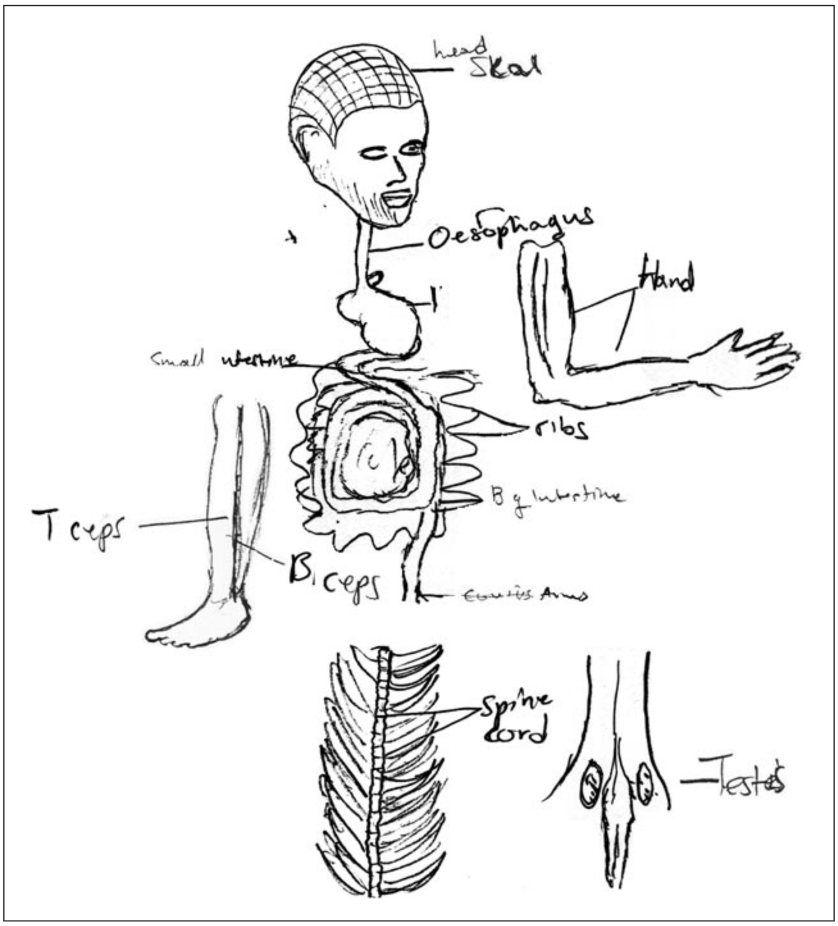


***Figure 5*** *A drawing by a 15 year-old male in Ghana that shows not a single body but a scattered series of drawings of parts of the body.*

inside yourself'. Figure 6 shows a drawing by a 15 year-old female in Taiwan. While the pupil has produced such conventional anatomical labels as 'cell', 'blood' and 'nerve' (all in Chinese) and 'heart' and 'mind' (in English), she has also identified 'future' and 'money' (in Chinese) as being inside herself. It is clear that our anatomical analysis fails to capture at least some of what this pupil, and others like her, were trying to convey.

Similarly, Figure 7 shows a drawing by a 15 year-old female in Venezuela. Above a heart pierced by an arrow, she has drawn another heart which appears torn in two – though a reductionist might suggest that this is merely a representation of the septum separating the left and right sides of the heart! Alongside this upper heart the pupil has written 'My happiness will be complete with Richard'. On the scoring system provided in Figures 1 and 2 this pupil only scores 2c. But it seems extremely likely that she is not attempting to produce an anatomical representation of her insides. Rather, she is using her drawing to illustrate, symbolically, what is currently of particular importance inside her, namely her affection/love for Richard.

Finally, and even more extremely, consider the two drawings shown in Figures 8 and 9. Each of these is drawn by a Russian 15 year-old and is in splendid colour. Figure 8 is drawn by a female. At the top right under the heading 'School year' it seems to show a smiling demon in front of a boiling cauldron. Below and to the right, above the heading 'Holidays', it shows a girl with a catapult partly hidden behind her back looking away from a broken pane of glass. Figure 9 is drawn by a male. It shows a figure floating on a cloud with a halo, playing a flute above a beautiful scene of mountains and water. Whatever was going on in the minds of these two young


***Figure 6*** *A drawing by a 15 year-old female in Taiwan that not only shows anatomical structures but also 'money' and 'future' (labelled in Chinese).*

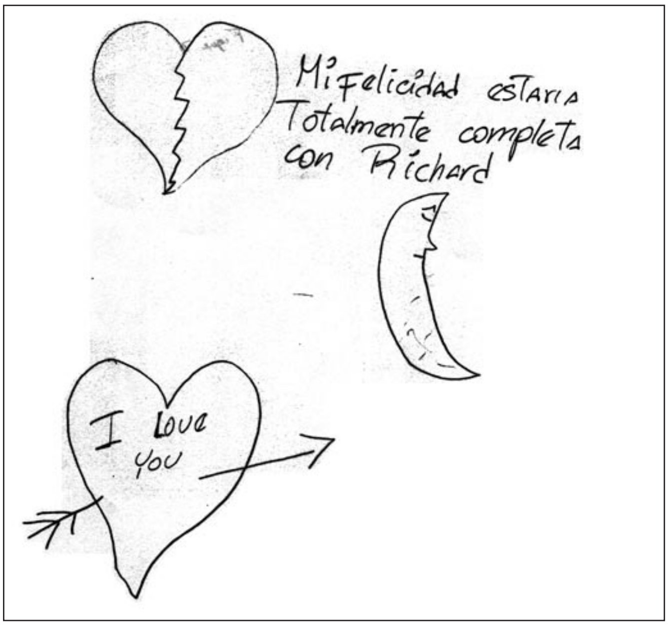


***Figure 7*** *A drawing by a 15 year-old female in Venezuela that indicates her emotions.*

***Figure 8*** *A drawing by a Russian 15 year-old female when asked to draw what is inside herself.*

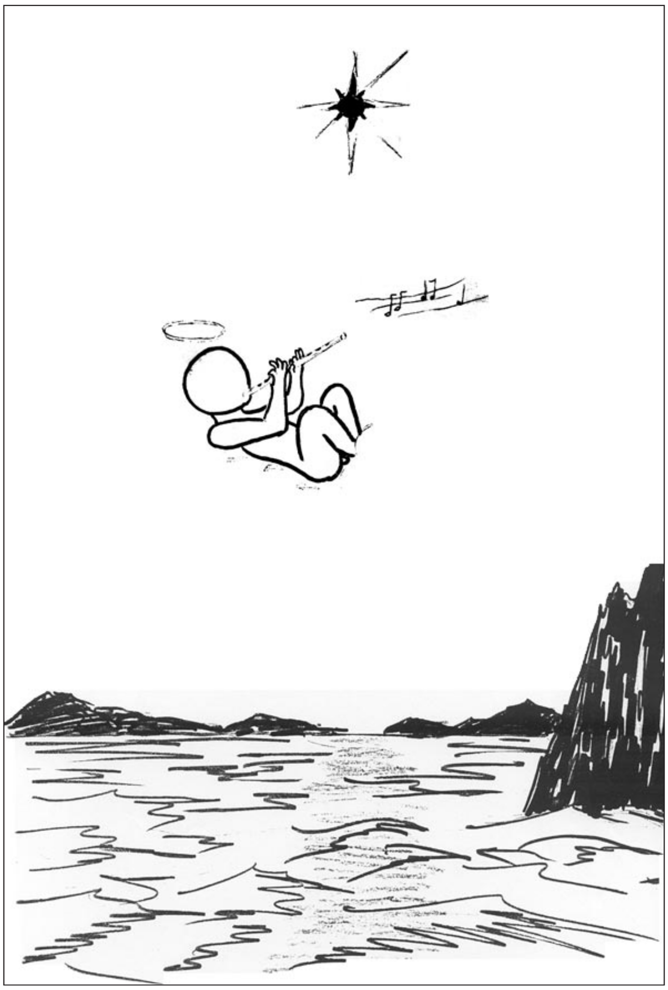

***Figure 9*** *A drawing by a Russian 15 year-old male when asked to draw what is inside himself.*

people when they drew their drawings clearly had little to do with conventional school biology!

## Discussion and educational implications

By simply asking young people of different ages to draw what is inside themselves, a considerable amount of valuable research material can be gathered. Analysis shows that by the time the subjects we studied were seven years old, they frequently had a broad knowledge of their internal structure, being aware of a wide variety of organs. However, they had little appreciation of how organs exist as related structures within organ systems. Dishearteningly, for science educators, while the 15 year-olds had a better knowledge of their internal organs, most of them still revealed little understanding of their organ systems.

Science curricula can build upon and extend the knowledge that pupils bring to science classes. It seems that as young people age they first learn that they contain certain individual organs. They then realise that these organs are situated in specific locations. Then they come to know that certain organs are joined together in functional units, for example the oesophagus is joined to the stomach. In some cases pupils then learn that a number of organs are joined into a whole organ system. From a teaching point of view this means that rather than, as often is the case at present, teaching pupils from the start about whole organ systems and then going into more detail about constituent organs – essentially a model of disassembly – we might do better to begin with individual organs and then help children learn that these are assembled into functional systems. This would be a model of assembly.

The findings reported here strongly suggest that a reductionist frame of analysis for the drawings omits much that is of interest. We are still unclear about how best to interpret some of the drawings, though it does seem clear that many pupils, particularly in some countries, use their drawings to reveal the emotions that they feel they have inside them as well as (or sometimes instead of) what anatomical structures they know they have inside themselves.

We are attracted by the possibility that a richer way to interpret some of these drawings may be to use the approaches developed by Gunther Kress and Theo van Leeuwen in their *Reading Images: The Grammar of Visual Design* (Kress & van Leeuwen, 1996) and by a number of authors working in the field of visual culture (e.g. Mirzoeff, 1998, 1999). These approaches pay close attention to such features as the layout, size, use of colour, style, imagery and use of metaphor in a visual representation. As yet such approaches have been little used in science education (but see Jewitt *et al.*, 2001). It may be, though, that these analytical frameworks provide fruitful avenues for science educators to explore.

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