**Seeing the natural world: a tension between pupils' diverse conceptions as revealed by their visual representations and monolithic science lessons**

> What you look hard at seems to look hard at you ... Unless you refresh the mind from time to time you cannot always remember or believe how deep the inscape in things is.
>
> (Gerard Manley Hopkins in his journal, early March 1871)


## Abstract

In this paper we report on drawings of the natural environment produced by a sample of 13-14 year-olds. One of our interests is in the extent to which these young people see the world in the way rewarded in science lessons. With rare exceptions, school science generally assumes that for any scientific issue there is a single valid scientific conception so that alternative conceptions are misconceptions. The drawings reveal a plurality of ways in which the natural environment is portrayed and we conclude that there is scientific as well as other worth in this diversity. We argue that schools need to take account of this diversity; many pupils will not be interested in a single, monolithic depiction of the natural world in their school science lessons.

## Introduction

When teachers or researchers ask subjects about their understandings of anything, subjects respond by presenting ‘representations’ (Bruner 1964). These representations may be words or mathematical symbols, drawings, physical constructions or even gestures. In the language of Buckley *et al.* (1997) and Gilbert and Boulter (2000) such representations can be viewed as expressed models – that is, representations of phenomena placed in a public domain. These expressed models are presumed to be generated from mental models – i.e. the personal cognitive representations held by individual subjects. The only way for a researcher to understand a subject’s mental model of a particular phenomenon is by eliciting one or more of their expressed models of that phenomenon.

There are many ways of gathering information about subjects’ understandings of scientific phenomena. However, despite the richness and variety of the methods used by science educators, it remains the fact that most of these methods rely on subjects either talking or writing about science. Such methods include oral interviewing of students, gathering students’ written responses, recording students’ spontaneous conversations and getting students to construct written concept maps.

However, another fruitful, and non-verbal, approach is to ask subjects to draw certain objects and there is a long tradition of this approach being used outside of science education (e.g. Luquet, 1927/2001; Goodenough, 1926; Kellogg, 1969; Kress, 1997; Anning and Ring, 2004) and a growing tradition of it being used within science education in a variety of setting (hospitals, schools, scientists’ laboratories) since

Gellert's pioneering work (e.g. Gellert, 1962; Guichard, 1995; Rennie and Jarvis, 1995; Tunnicliffe and Reiss 1999, Kozma, 2003).

In this paper we will report on the drawings produced by a sample of pupils in a study that looked at how pupils 'see' the natural environment. One of our interests is in the extent to which these pupils, all of school age, see the world in the way rewarded by conventional school science. There has been a long debate in the science education literature about the extent to which the various conceptions held by pupils of scientific phenomena are to be seen as misconceptions or alternative conceptions. With rare exceptions, it is generally held that there is a single valid scientific conception so that alternative conceptions are misconceptions. We argue that just as post-modernism has led many to the abandonment of the notion that there is but one way of understanding events (seeing the world), so these drawings reveal a plurality of ways in which the natural environment is portrayed and that there is scientific worth in this diversity. We argue that schools need to take account of this diversity; many pupils will not be interested in a single, monolithic scientific depiction of the natural world.

**Methods and sample**

We worked with nine primary and four secondary schools in England to allow us to obtain data from five year 1 classes (5-6 year olds), four year 5 classes (9-10 year olds) and four year 9 classes (13-14 year olds). In each class, teachers were asked to select a sample of six pupils to represent the range of abilities in the class and, if possible, to include both boys and girls. Each young person was interviewed on three occasions about nine natural objects (mushroom, squirrel, daisy, grass, cloud, ant, pigeon, oak tree, pond) using either a drawing of the object, a photograph of the object or the name of the object as the probe. These objects were decided upon by consideration of those objects with which the pupils would be familiar, likely to be in their home or school environment and likely to be represented or present on out-of-school visits.

At the end of the third interview, the pupils were asked “to do a drawing showing all these objects” and to remind them what these were an A1-sized sheet with the names of the objects on was provided for them to see (Figure 1). Pupils had about 10-15 minutes to produce their drawings which were on A4 paper. A supplementary part of the study looked at equivalent Brazilian pupils but here we focus on the 23 year 9 English pupils from whom drawings were obtained (one boy present in the other parts of the study was not present when the drawings were obtained).

One of the schools from which our year 9 data come is a large, state (i.e. non-fee-paying) community college for female and male 12-19 year-olds on the outskirts of a major town on the south coast. The area has problems with employment and housing and the school’s intake comes from a range of abilities and social backgrounds. The science department is well staffed and all the pupils carry out practical science in well-equipped laboratories. There was not much evidence of biological illustration in the laboratories. There are extensive school playing fields but no tradition of working outside on the natural world was evident. The second school is a state school for female and male 11-16 year-olds on the outskirts of a small town. Although the school was somewhat bleak, with concrete corridors and Spartan laboratories, it had a hedge outside and was surrounded by fields. The third school is a fee-paying (i.e. independent, non-state) school in central London that only takes girls from the ages of 11-18 years. It is highly regarded for its science teaching, and practical and investigative science is taught in relatively small groups to interested and engaged girls who mostly come from privileged home backgrounds. The science laboratories are full of pupils' work and biological materials from living animals and plants to posters. There are, though, minimal outdoor areas except playing fields; however the school organises numerous excursions. The fourth school is a state school for 11-18 year-olds and is on the outskirts of a thriving Thames valley town set in pleasant suburban parkland. The school has high academic standards and a strong tradition of achievement in science. It is the favoured choice of many parents seeking single-sex education for their girls in the area. It has well equipped science laboratories with an array of pupils' work and other posters on the walls. The grounds did not seem to form the focus of much work in science but the teachers were interested and engaged in taking pupils on fieldtrips in both science and geography.

In analysing the drawings we have been influenced by classic studies of children's drawings (notably Luquet (1927/2001)) as well as by the developing field of visual literacies (e.g. Kress and van Leeuwen 1996; Mirzoeff 1998; the journals *Journal of Visual Culture* and *Visual Communication*). We accept that there is great cultural specificity to visual language (Kress and van Leeuwen; 1996); we have not, for example, involved the authors of the drawings discussed here in the interpretations of the drawings. So what we present is our analysis, principally informed by our interests as science educators in improving school science education.

Thomas and Silk point out that:

> Pictures that present structural information can be further subdivided into those that provide information about the structure of the object (often termed *object-centred* representations) and those that present information about the spatial relations of objects in a scene (often termed *array-centred* representations).
>
> (Thomas and Silk, 1990: 89)

We are interested both in how the pupils arrange the objects on the page and on how they depict the objects themselves. The techniques we use are therefore based on those that have been used by art historians for generations, though we also find that digital manipulation of the drawings (not reported here) can be used to help investigate their compositions.

**Findings**

It is worth emphasising that these drawings are the products of memory and imagination: none of the objects (except possibly clouds viewed from a classroom window) was present when the drawings were produced. We focus initially on the ways the pupils depict the relationship between the objects. A fundamental distinction can be made between those pupils who represent the objects independently as isolates and those who indicate some sort(s) of interconnections between them. At the most extreme, fully 14 of the 23 pupils present drawings in which the nine objects are arranged as separate icons in a virtual 3 x 3 chequerboard (e.g. Figure 2).

Figure 2 is noteworthy in a number of ways in addition to the isolation of the objects. We are not especially interested in this study in aspects of the drawings that can be said to be ‘wrong’ – such as the shape of the leaves of the daisy and the positions of the legs on the ant. However, some of the ‘mistakes’ are perhaps more interesting. The tail of the squirrel is one that, to put it loosely, any squirrel might be proud of. What we think is going on is that pupils seize on defining (salient) characteristics of objects. A squirrel is ‘defined’ by its bushy tail, along with a small number of other features such as the propensity to hold/store nuts (iconically acorns) and, as shown in Figure 2, a tendency to stand on its hind legs. Kress and van Leeuwen (1996) state that:

> *Interest* guides the selection of what is seen as the criterial aspects of the object, and this criterial aspect is then regarded as adequately or sufficiently representative of the object in the given context. In other words, it is never the ‘whole object’ but only ever its criterial aspects which are represented.
>
> (Kress and van Leeuwen, 1996: 6)

‘Interest’ though, must not be thought to be an individualistic state of mind. The salient criterial aspects, we would argue, are largely determined by the ways in which powerful others have previously chosen to (re)present the object in question. In the case of squirrels the choice of ‘bushy tail, sitting on hind legs, possibly holding a nut’ by the manufacturers of toy animals and those who portray squirrels in cartoons and elsewhere allows even a child much younger than the ones with whom we worked here instantly to recognise the portrayed animal, rendering it familiar, comfortable, comforting. As a result, a feature of a squirrel, its tail, becomes almost emblematic of the animal. One could imagine that if one played a game in which features of animals were called out and children had to identify the animal in question, in England the feature ‘thick tail’ would probably be likely to elicit ‘squirrel’ or ‘fox’.

One point of interest is whether the girl who drew the squirrel in Figure 2 thought she was producing, in the photographic sense, an ‘accurate’ drawing of a squirrel or not. Luquet (1927/2001), talking about children typically several years younger than the ones in our study, famously concluded:

> Whereas adults are committed to *visual* realism, children are proponents of *intellectual* realism. For adults, any drawing, if it is to provide a resemblance, must be a kind of photograph of the object, reproducing all those details, but only those details, which can be seen from where the object is viewed, and with the shape they form from that viewpoint. In short, the object has to be depicted in perspective. For children, however, a drawing can only be a good likeness if it includes all of the actual details of the object, even if they are not visible either from the location from which they are observed or from any other viewpoint.
>
> (Luquet, 1927/2001: 102)

We would like to go beyond Luquet in suggesting that whereas he says that for a children’s drawing to be successful it must include “all of the actual details of the object”, what we think may be of importance is not ‘actual’ as understood by some comparison with ‘actual’ squirrels in the real world nor even perhaps ‘actual’ as understood by comparison with the portrayal of squirrels in toys and cartoons but possibly 'actual' as understood by a mental model which some children may know not to be 'real' (i.e. photographically realistic). In other words, the child may be drawing what it knows is a caricature, a visual representation designed to highlight certain features. After all, the child knew that we were friendly researchers – the drawings having been obtained on the fourth occasion that each child met one of the researchers. If we are right, we would suppose that the children would, on average, produce more visually realistic drawings (in Luquet's sense of the term) had they found themselves in an examination situation where they knew that accurate depictions of reality were wanted (provided that they were motivated to do well in the examination).

There are a couple of other points worth making about Figure 2. First of all, all the objects are named. Indeed, the girl who drew Figure 2 has used precisely the words provided in Figure 1. In one sense this is hardly surprising: the sheet shown in Figure 1 was visible as she drew. But why did she find it necessary to write the objects' names? Unless she is particularly modest about the quality of her drawing, it is hardly likely that she believed that we needed the names to distinguish her nine representations. It is interesting that there isn't an especially close relationship between the positions of the objects in Figures 1 and 2, though the oak tree and pond are at the bottom of both. It might conceivably, therefore, be that naming the objects served as a checklist so that each object was drawn, but only once. However, this doesn't seem very likely given that the author of the drawing was 14 years old and 8 months of age. Another, more likely in our judgement, possibility stems from the fact that in English science lessons it is typically the case that pupils are required to 'label their drawings' (the phrase is one that each of us has used in our teaching many times). So it might be that the objects in Figure 2 are labelled because the girl saw the exercise as being a science exercise that she wanted satisfactorily to complete.

The final feature of Figure 2 to which we would like to draw attention is the roots of the oak tree. Unless an oak tree has been dug up or blown down one can't see its roots. Nor was it the case that either the drawing of the oak tree or the photograph that we used in our research showed roots. What we think is going on is that the author of Figure 2 is drawing an oak tree (or a generalised tree) as often depicted in school science textbooks. In such textbooks (oak) trees are most likely to be illustrated in the context of ecosystems, photosynthesis, transpiration or root structure and function. Indeed, the drawing of the oak tree in Figure 2, with its roots and a selection of leaves, one of them in the process of falling to the ground, would be suitable to illustrate any of these biology topics.

A very different representation of the nine objects is seen in Figure 3, also drawn by a girl (aged 13 years and 10 months). Here we see a single tableau, not nine unconnected objects. Indeed, despite what some would regard as a lower level of artistic skill than that shown in Figure 2, the author has arranged her scene carefully. The right hand side of the drawing is dominated by an oak tree; balancing this we have a cloud (top left) and a pond (bottom left). Furthermore the cloud is drawn smaller than the pond, a feature, in compositional terms, that fits well with the naturalistic depiction of the crown of the tree as larger than its base.

The oak tree in Figure 3, unlike its counterpart in Figure 2, lacks roots and individual leaves. However, all the other objects are related to it, albeit some more intimately than others. The closest relationship is with the pigeon and the squirrel who sit, separately, looking in different directions and not at each other, on the only two braches depicted. The squirrel looks towards us a trifle unhappy, perhaps at being perched so high, particularly as it is shown sitting in a way that would not be very stable if it was a person. The squirrel's tail in its lateral depiction shows a characteristic feature of children's drawings, one that Luquet (1927/2001) calls 'folding out' or 'rabattement':

> … we encounter an absolutely impossible kind of perspective in the case of a novel technique which I term 'folding out' or 'rabattement', a procedure which is applied from the outset to the supports of objects, such as the feet and legs of animals and furniture and the wheels of vehicles. This involves folding out each of these supports as though they were connected to the object by hinges around which they can be turned.
>
> Luquet (1927/2001: 110)

The naturalistic setting in Figure 3 is presumably the reason why two mushrooms are depicted. Though this may not seem a very major difference between Figures 2 and 3, it is the case that Figure 2 has only one of each object, with the possible exception of grass which, anyway, none of our 23 children depicted as an individual plant, whereas Figure 3 boasts a second mushroom of the same sort (something like the poisonous fly agaric (*Amanita muscaria*) – a fairly archetypical mushroom for all its dangers).

The interrelationships among the objects in Figure 3 means, almost inevitably, that their relative sizes are more naturalistic than in Figure 2. It is as if Figure 2 has nine scales, one for each object, whereas Figure 3 has one scale. However, the scale in Figure 3 is not a linear one. Although it might be claimed that perspective has been used so that the fore-grounded ant and the distant cloud are drawn with appropriate dimensions, the oak tree is definitely too small relative to the pigeon, squirrel, mushrooms and daisy. It is as if the scale in Figure 3 is a logarithmic one that serves mainly to preserve the relative dimensions of the objects.

One more difference between Figures 2 and 3 is perhaps less interesting and that is that Figure 2 has been drawn in pencil while Figure 3 has been drawn in blue biro. This makes it harder for the author of Figure 3 to indicate textures and tones. In Figure 2, on the other hand, the pencil has successfully been used to indicate the blackness of the lower side of a cloud heavy with rain, the furriness of a squirrel's tail and something of the gnarled texture of the bark of an oak tree.

In summary, Figures 2 and 3 differ principally as indicated in Table 1.

One final point worth making about Figure 3 is a similarity it shares with Figure 2, namely how the pond is depicted. Both these ponds have other objects within them. In Figure 3 there are two lily pads and a fish. It is more difficult to see precisely what is present in the pond in Figure 2. It is clearly fringed by tall plants; there are two lily pads and it possible that one of them has a frog on it; and there are two wavy lines which conceivably indicate waves or pond weed. Twenty one of the 23 children drew a pond and 20 of these ponds were fringed with plants and/or contained living organisms within them. It is as if the word ‘pond’ does not mean ‘a small area of freshwater’ but is more akin to ‘wood’ in that a wood is a collection of organisms (principally trees) and other things; so a pond is a small watery freshwater habitat that acts as a home for other organisms. Our list of nine objects did not contain any organisms that would realistically be found in ponds, with the exception of grass that might fringe a pond. The children, therefore, supplied their own organisms: lily pads, fish, reeds, frogs (complete with eggs and tadpoles) and in one case a water insect (probably a pond skater) and a small duck.

Our final drawing is shown in Figure 4. Again it is by a girl (aged 14 years and 1 month) and again it shows the various objects in relationship. There are a number of its features that are particularly worth highlighting.

First, Figure 4 is even more realistic than is Figure 3. In Figure 4 we have three clouds (clouds are rarely solitary), a clump of four mushrooms and three daisy flowering heads arising from a single base. We can also see that the pigeon has mass by the way it weighs down the bough on which it perches. There seems too to be a successful attempt to indicate the way in which grass occurs both in clumps (see the five jagged outlines near the base of the picture) yet also in a swathe of continuous vegetation.

The author of Figure 4 has also wrestled more overtly with the problem of perspective and scale. She has chosen to indicate distinct leaves on the oak tree. Indeed, some 324 individual leaves have been drawn, many with the typical crenulations found in the common oak (*Quercus robur*) that is native in the UK and featured in many nature books and school biology textbooks. However, the fact that she has drawn the leaves individually so that they are recognisably oak leaves means that, from a realist perspective, they are too large. Indeed, the problem of the representation of the oak tree leaves was something with which the semi-professional artist who did our drawings wrestled, eventually deciding to show them individually in precisely the same way in which the author of Figure 4 did (Figure 5). (Note that the author of Figure 4 had not seen the drawing in Figure 5; the names of the objects were the probes when she was interviewed.)

Figure 4 also comes up with an effective way of illustrating both the habitat and the size of ants. An ant colony is indicated and then, in a way never found in the pictures of professional artists but beloved by certain science illustrators, a cone of magnification allows us to see a single ant in sufficient detail to appreciate its eyes and mouthparts in addition to its legs, antennae, head, thorax and abdomen that are also shown in Figure 2 and 3.

Finally, Figure 4 is one of only four of the 23 drawings to use more than one colour (three others use just one colour, as in Figure 3). Kress and van Leeuwen note “It is difficult to go into detail about the meanings of the different colours. The literature on the emotive meanings of colour is quite inconsistent (Kress and van Leeuwen, 1996: 266) while Costall points out that “Children’s use of colour in their drawings is a neglected topic of research” (Costall, 2001: 162).

In Figure 4 various intensities of the green of chlorophyll are indicated in the grass, the oak tree leaves, the flowering stems of the daisies and the plants in and around the pond. The sky is a faint blue, the central florets of the daisy are yellow, the ant is grey-black and the pigeon a pale brown, but perhaps it is the squirrel that is most interesting. Its colour is dark brown with a suggestion of red. The result is certainly closer to the red squirrel (*Sciurus vulgaris*) that is native in the British Isles than its North American counterpart, the grey squirrel (*Neosciurus carolinensis*). And yet it is the grey squirrel that is far more likely to be seen in Britain today, and for all of the lifetime of the person who drew Figure 4. Indeed, the red squirrel is becoming increasingly rare and there are no red squirrels (save in wildlife collections) within more than 100 miles of where these children live whilst the grey squirrel and the rabbit (*Oryctolagus cuniculus*), another introduced species, are the two most commonly seen mammals in the British countryside.

**Discussion**

It is not the case that the pupils who represent the nine natural objects independently necessarily show less scientific detail in their drawings, nor do they typically demonstrate poorer drawings skills. Rather, as we have earlier noticed in a study that looked at the drawings made by pupils of what is inside themselves (Reiss *et al.*, 2002), some pupils portray items in isolation from other items even though in ‘reality’ the items are intimately connected. In some of the drawings in this study clouds are no more likely to be near the top of the page than are mushrooms while some objects are drawn at right angles to others, indicating that fitting a tall object (a tree) into an available empty space on a page is more important than showing its position in its natural setting.

An issue related to the degree of interconnectedness between the objects is the scale with which they are drawn. The pupils who represent the objects independently are less likely to show realistic representations of sizes than are the pupils who indicate interconnections. At the same time, it is clear that scale is normally used (when it is used) to indicate relative not absolute sizes, though in a small number of cases conventions are used, to excellent effect, to indicate that ants or oak leaves, in particular, are, in reality, smaller than shown.

Among the drawings that show interconnections between the objects, the most common relationship implied is one of two or more natural objects sharing a habitat or of one organism acting as a habit for another. For example, squirrels are often shown in the oak tree and ants in the grass. Ponds are especially interesting in this regard as they are often drawn showing insects, ducks, water lilies, marginal plants and fish; that is, ponds are depicted as communities of organisms. This contrasts with clouds, the drawings of which never contain organisms though the clouds are sometime shown producing rain and, in one case, receive water by evaporation from beneath.

Interestingly, while ecology teaching in England and Wales (and many other countries) stresses food chains and food webs, few feeding relationships are depicted in the drawings and those which are show antediluvian herbivory (in particular, squirrels eating acorns). To a certain extent, a not inconsiderable number of the drawings can be seen as child-like manifestations of peaceful mediaeval, Renaissance or so-called primitive (art brut) representations of a paradisiacal Garden of Eden. This irenic quality is reinforced by the fact that the facial expressions of the animals often show smiles, a feature which we suspect derives at least in part from a Disneyfication of the environment but may indicate a sense of hope.

## Conclusions and implications

There are two main ways in which our results can be interpreted. One way is simply to say that some students have a better understanding of these nine objects than do others. We could produce some sort of a hierarchy of scientific knowledge presuming, for example, that students who show interconnections between the objects have a better understanding than ones than those who don't. However, we are reluctant to assert that this is all there is to it. In ecology, autecology, in which a single species is studied in detail, has had a long history of being as reputable as synecology, in which the interconnections of species in communities are studied (Chapman and Reiss, 1999). The second way is to accept that there is a range of ways in which students can validly portray these natural objects.

We are attracted to this second interpretation, for all that we believe that pupils do need to understand the relationships between objects in the environment, since we are concerned at the continued reluctance in Europe for students to choose to study science beyond the age at which it is compulsory. We suspect that curricula and teaching approaches need more genuinely to engage with today's students. To a considerable extent, the image presented of science in schools is of a single, secure body of reliable knowledge. In an increasingly diverse, post-modern world we are not surprised that many pupils find such an account boring. The drawings we are analysing suggest that there is no one way in which pupils see the natural world and raise the possibility that there is more than one scientifically/educationally valid way in which the natural world may be seen.

A possible way to illustrate the assertion that there is more than one scientifically valid way of seeing the world is to imagine a particular wood and then think of the ways in which a scientist might study it. There are many:

> For a start, a biologist would be most interested in the organisms in the wood, a climatologist would study such things as insolation, rainfall, aspect and wind and a geologist would focus on the underlying rocks and the consequences of these for the soil.
>
> Further, there are a great variety of ways in which just the biologists might work in such a wood. Even eschewing such obvious niche-specific roles occupied by those who define themselves as microbiologists, botanists, mycologists and zoologists, our wood will be full of ecologists, anatomists, biochemists, physiologists and even such difficult to classify creatures as Oliver Rackham, interested in the history of the wood as revealed by a variety of different approaches including dendrochronology, field archaeology and the study of place names (Rackham, 1976). Indeed, we can subdivide further: our ecologists will include population biologists (counting the numbers of individuals within species and organising these individuals by age classes), ecological geneticists (concerned with any relationships between genomes and differential fitnesses), autecologists (each occupied with the ecology of a single species), synecologists

> (attempting to unravel the interrelationships between species), conservation biologists (concerned to prevent, through careful management based on thorough monitoring, the loss of species from the wood) and so on.
>
> (Reiss and Tunnicliffe, 2001: 125-6)

We are not suggesting that students should be introduced overtly to post-modernism in their science lessons. But we do believe that school science too often fails to connect with the diversity of pupils' lives (Osborne and Collins, 2000; Reiss, 2000; Calabrese Barton and Osborne, 2001). Furthermore, school science, for all that it might hold to the Popperian notion of falsifiability – and thus the ultimate provisionality of scientific knowledge – is almost invariably embedded (? mired) in the notion that if only we control our variables a bit more carefully and tighten up on our data collection methods, we will be able confidently to confirm or refute our hypothesis. Our point is that the diversity of viewpoints that frontier science can accept is too often missing from school science: school ecology provides a fine and accessible platform from which to rethink the typical taught notion of a unitary conception of science. School science has the potential to aid in individualisation, not require homogenisation. However, unless school science takes account of this plurality of viewpoints we predict that many students will continue to conclude that school science is not for them.

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**Table 1 Differences between the drawings in Figures 2 and 3**

| **Characteristic** | **Figure 2** | **Figure 3** |
|---|---|---|
| *Composition* | Nine unrelated objects | One naturalistic composition |
| *Realistic depiction of relative sizes of objects* | Limited | Considerable |
| *Number of times each object is represented* | Once | Once or twice |
| *Medium* | Pencil | Blue biro |

## Figure captions

### Figure 1

The A1-sized sheet, with the names of the nine objects used in this study, that children were given sight of when asked to do their drawing.

### Figure 2

One of the drawings produced by a 14 year-old, showing the nine objects.

### Figure 3

The drawing produced by a 13 year-old, showing the nine objects.

### Figure 4

The drawing produced by a 14 year-old, showing the nine objects.

### Figure 5

The drawing of the oak tree produced by an artist and used as one of the probes in the study.