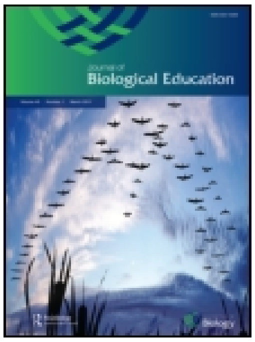

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Trends in children's concepts of vertebrate and invertebrate

Martin Braund

Children link backbones with movement but see them as large and inflexible. These and other findings are used to argue for a better understanding of structure and function

Introduction

Traditionally, biological education in the UK has placed a significant emphasis on taxonomy. Recent revisions to the National Curriculum in England and Wales (DfE, 1995), whilst reinforcing the dominance of human biological processes in teaching, have retained significant elements associated with classification. For example, teachers of children in Key Stage 2 (aged between 7 and 11) are required by the programmes of study to *'relate work on the variety of life to the reasons for classifying living things'* (p.9) and to teach the use of keys. Teachers of children in Key Stage 3 (aged between 11 and 14) are required to develop classification further by asking children to *'classify living things into major taxonomic groups'* (p.18).

Abstract

Schoolchildren's ability to classify animals as vertebrate or invertebrate has been found in previous studies to be weak. Typically vertebrates are regarded as large animals with obvious heads and limbs whilst invertebrates are seen as shapeless, legless animals that crawl. Little is known about the conceptions held by primary aged children or about the ways in which ideas vary with age.

This paper reports the results of a cross-age study carried out with children aged between 7 and 15. Children's classification of photographic examples of animals and the attributes of vertebrates and invertebrates they associate with examples have been analysed so that trends in thinking can be shown.

The youngest children seem preoccupied with shape, form, and size. A very strong idea held by children at all ages is that any animal that coils or flexes cannot possess a backbone. Children also seem to regard a backbone as a wide, straight structure.

Many of the minority of children who classify animals like a snake, seal, and fish correctly as vertebrates seem to have some first-hand experience of internal structure.

The paper uses the trends identified to suggest a number of experiences that could be included in the school science curriculum to redress the situation and argues for more classroom work relating structure with function.

Key words: Children's concepts, Vertebrate, Animal form, Trends in ideas.

Research on the ability to classify animals into major taxa has revealed that children in secondary schools have significant problems in this area of Biology (Ryman, 1974a, 1974b; Trowbridge and Mintzes, 1985; Braund, 1991). In particular the concept of vertebrate seems to be applied, in a very restricted sense, to animals with very definite heads, limbs, and a distinct outline (Trowbridge and Mintzes, *ibid.*). The same work shows that children tend to associate the concept of invertebrate with a crawling habit or to animals with flattened and amorphous bodies. Cross-age studies have revealed that these 'alternative conceptions' are very persistent across the age range 11–14 (Braund, *ibid.*).

Relatively little is known, however, about the concepts held by children of primary school age, the detailed ways in which they attribute vertebrate and invertebrate characteristics, or how these develop and change with age. The study reported here explores these areas with a view to providing comment on effective ways of enhancing teaching.

In this paper the collective term 'invertebrate' is used throughout. It should be noted, however, that the term has no taxonomic validity and that its use in secondary education is not recommended (IOB, 1989).

Outline of the study

Children in six National Curriculum year groups were chosen for the study (Y3, Y4, Y5, Y6, Y8, and Y10).

Chronological ages ranged from 7 years and 6 months for the youngest children in National Curriculum Year 3 (Y3) to 15 years and 6 months for the oldest children in National Curriculum year 10 (Y10). The primary and secondary schools used draw pupils from a similar mix of social backgrounds and most of the children from the primary school will transfer at 11 to the secondary school used in the study. Mixed ability in the samples was maintained by using the entire intake for each year group in the primary school, and by ensuring that equal numbers in the secondary school samples were drawn from all the school's ability sets for science in Y8 and Y10.

The study design is based on the well established technique in science education research of 'interviewing about instances'. A full description of this approach and advice on ways of using it unobtrusively and effectively with children can be found in Osborne and Freyberg (1985, p.8 and pp. 160-161). Children were shown a series of colour photographs of animals in the order listed in table 1 and asked to say whether they thought the animal possessed a backbone or not, and then to explain their reasoning. Children in the primary school were interviewed one at a time and their responses recorded in writing by a researcher, whilst children in the secondary school wrote their responses on to prepared sheets. Supplementary questions were also asked to elicit any involvement with, or interest in, animals outside the confines of school.

Results

Correct classifications of the different examples shown as vertebrate or invertebrate have been scored as percentages of the whole sample for each age cohort, and these data are presented as table 1.

In much educational research children's ideas have been presented and analysed as 'alternative frameworks'. This term can be traced back to the work of Driver and Easley (1978) and are described by Watts (1983) as *'a person's imaginative efforts to describe and explain the world'*. Although they have been used to describe conceptions in biology, they are more commonly identified in research dealing with perceptions associated with the physical world e.g. notions of gravity, force, energy, etc. Since the ideas represented in this study are really perceptions of characteristics of animals that children relate best to their view of vertebrate or invertebrate, I shall refer to these as specific 'attributes' instead of using the term 'framework'.

The identification of these attributes and the tracking of the frequency with which these are applied in the different age cohorts forms the basis of analysis and the discussion of trends across the age range studied. These data are shown alongside illustrative examples for each attribute and are provided as tables 2 and 3.

Table 1 Percentage of pupils in different year groups correctly identifying animals as vertebrate or invertebrate

	Percentage of pupils in each year group correctly identifying examples					
	Y3	Y4	Y5	Y6	Y8	Y10
Examples presented	*n*=14	*n*=19	*n*=17	*n*=14	*n*=25	*n*=26
Elephant	87	95	94	100	100	100
Fish	13	58	41	21	68	77
Gerbil	73	79	82	79	100	100
Ant	87	84	71	93	100	85
Bird	53	74	94	86	96	96
Child	100	100	100	100	100	100
Seal	67	68	71	29	84	85
Spider	53	68	71	93	80	100
Tortoise	40	32	47	14	36	38
Snake	13	26	12	21	28	46

Trends in the classification of examples as vertebrate or invertebrate

Children had no difficulty in classifying the human example as a vertebrate and were also successful with the elephant and gerbil. The picture of the bird caused problems for the youngest children in Y3 and Y4. Inspection of the attributes given by individuals suggests that this is associated with the notion that birds either have softer bodies, or do not have such a pronounced curvature to their backs. This idea of curvature associated with the possession of a backbone also appears strongly in children's drawings of vertebrates (Braund, 1996). Children, for example, tend to accentuate the curvature on their drawings with heavy shading or exaggerated, curved shapes.

The lower success rate at classifying the seal, fish, tortoise, and snake as vertebrates seems to mirror the results of previous studies (Trowbridge and Mintzes; Braund, *op. cit.*), and supports the notion that children associate vertebrate animals with recognizable limbs and heads.

A more detailed examination of the attributes given for each animal suggests that the notion of flexibility in movement underpins much of children's thinking. For example, a greater proportion of children in Y5 and Y6 than in other years appreciate that a fish must have flexibility of movement, but still think that this flexing (lateral motion) precludes the possibility of a backbone. At these ages children also tend to think that the fish is too thin to accommodate a backbone. These ideas are less prevalent in the secondary aged children but about a quarter of Y10 children continue to think a fish is an invertebrate. The idea that lateral

Table 2 Table showing the most common attributes used by pupils to justify animals classified as 'vertebrate'

		Percentages of attributes given by each year group					
		Y3	Y4	Y5	Y6	Y8	Y10
Attributes	**Illustrative examples**	(*n*=14)	(*n*=19)	(*n*=17)	(*n*=14)	(*n*=25)	(*n*=26)
Movement	*'It needs a backbone to swim, run, move fast.'*	11	27	36	38	23	30
Support	*'The backbone holds it up. It needs one to stand up.'*	26	27	14	14	23	39
Flexibility allowed	*'The backbone lets it bend and move its legs/fins.'*	0	1	12	7	2	5
Articulation	*'It has to have one for the legs/fins to attach to.'*	0	0	4	7	8	1
Shape	*'Because it has a curved back.'*	11	22	9	10	10	1
Size	*'It's big enough for a backbone.'*	20	10	3	10	4	1
Form (Hard/soft)	*'It has a hard body – not soft.'*	19	0	0	0	0	0
Generalizations	*'All mammals/fish (vertebrates) have backbones.'*	4	0	1	3	13	11
First-hand experience	*'I've cut open a fish and seen bones, I saw a skeleton in a museum.'*	4	12	9	5	9	6
Secondary knowledge	*'I saw a TV programme about it.'*	2	6	8	5	4	3

Table 3 Table showing the most common attributes used by pupils to justify animals classified as 'invertebrate'

		Percentages of attributes given by each year group					
		Y3	Y4	Y5	Y6	Y8	Y10
Attributes	**Illustrative examples**	*n*=14	*n*=19	*n*=17	*n*=14	*n*=25	*n*=26
Movement	*'It has to crawl so it cannot have one.'*	15	5	13	9	13	2
Flexibility	*'It has to bend when it moves. It has to coil up'.*	10	11	19	25	11	28
Shape	*'It is flat/not a curved shape.'*	18	26	26	29	16	16
Size	*'It is too long or too thin for a backbone.'*	15	26	11	12	11	6
Form (hard/soft)	*'It doesn't have a backbone because it's too soft.'*	20	6	6	3	5	1.5
Generalizations	*'It's a reptile and they don't have backbones.'*	0	5	3	3	22	6
Other means of support	*'It doesn't need a backbone because it has legs.' 'The water will support it.'*	0	0	0	0	4	12
First-hand experience	*'You can squash an ant – it has no bones inside it.'*	2	2	2	2	0	0
Secondary knowledge	*'I read something in a book about it.'*	0	0	2	3	1	6

movement and flexibility may occur but that a backbone cannot allow for this seems to be a persistent one.

Changing ideas relating to flexibility in motion could also account for the variation in performance for the seal, but the rapid improvement from Y6 (29 per cent correct) to Y8 (84 per cent correct) seems more to do with the increased frequency with which these children generalize from class taxa *(the seal is a mammal and all mammals have backbones)*. It is interesting to note that this tendency to generalize is mostly confined to the mammal taxon and is rarely used for the superordinate concepts of vertebrate or invertebrate.

Virtually all children at each age classifying the tortoise as an invertebrate regard the shell as replacing the backbone for support; the improvement from Y6 to Y8 is due principally to an increase in those who realize that there is a backbone in addition to the shell. Children are still likely, however, to mention an additional supporting function for the backbone (e.g. *'to hold the shell up')*.

The snake proves, as in previous studies, to be the most problematic as a vertebrate in the eyes of children of all ages. There are two main attributes associated with children's mis-classification to note here. The first is the idea that a snake is too long or too thin to accommodate a backbone. This idea is most frequent in the primary aged children. The second is that the snake must curl up and that a backbone cannot accommodate this. As for the fish, this idea seems very persistent and is still common amongst the oldest secondary aged children as an inspection of the data in table 3 reveals.

One other point to note here is that children who were most successful at associating the snake, seal and fish with the concept of vertebrate, i.e. those who 'bucked the trend', were often those who referred to some first- or second-hand knowledge of structure for example:

> *'My dad and me found a dead fish's skeleton on the beach'* (Year 3)
> *'I've seen a picture of a snake in a book – it had a bone in it'* (Year 5)
> *'We went to a museum and saw inside a whale'* (Year 8)

The importance of informal learning occurring outside school should not be undervalued here. Other studies (Braund, 1991, *op. cit.*) have found that children who were poor in many areas of science, yet outperformed expectations on classification tasks, often had some out-of-school use for classification e.g. fishing, bird-watching.

The data in table 1 reveal that children had less of a problem recognizing the invertebrate nature of examples used in the study than they did for some vertebrate examples. An inspection of the attributes used, however, shows that their reasoning may not necessarily be 'scientific' in the sense of a knowledge of internal structure. Primary aged children seem preoccupied with the outline shape of the body. The responses below are typical and occur frequently in each age cohort from the primary school sample.

> *'The spider has two bits... it (the backbone) can't fit in between'*
> *'The ant has a sort of zig-zag shape...'*

Secondary aged children are more likely to generalize *('the ant's an insect and they don't have backbones')*, or to consider that other means of support make a backbone unnecessary *('It's got lots of legs to hold it up... so it doesn't need a backbone')*.

Trends in attributes associated with the concepts of vertebrate and invertebrate

An analysis of attributes featuring in the different age cohorts of this study and presented in tables 2 and 3 has been used to identify trends with age. The key features in these trends are summarized in the progression boxes shown as figure 1. The boxes show only the most common attributes identified at each age.

The youngest children in the study (at Y3) tend to associate invertebrates with soft bodies and a small overall size. They are less preoccupied with the inherent flexibility of an invertebrate body but nevertheless still make a link between a backbone and movement.

The idea that shape and size indicate presence or absence of a backbone (e.g. a curved shape linked with vertebrates as stated earlier) persists until the age of around 12. The notion that some animals are too thin, too long or oddly shaped and cannot therefore accommodate a backbone, seems to indicate that children see backbones as both wide and straight as well as being inflexible. The youngest age groups (Y3 and Y4) show some appreciation of function for backbones in terms of support, though this seems to regress in the older primary years. Support becomes a very strong feature of the attributes provided by secondary aged children, but surprisingly few seem aware of other skeletal functions such as the need for articulation with limbs or for muscle attachment.

As might be expected, as children learn more taxonomic classifications, these are increasingly evident in the attributes supplied. An inspection of individual responses revealed that the taxonomic terms most commonly generalized are mammal, insect, and reptile. The latter was, however, more often than not misused, being attributed to invertebrates.

The youngest children in the study (Y3 and Y4) were much more likely to apply one or two dominant attributes to all examples offered, whereas the older primary aged children often applied different attributes to each example. The secondary aged children relied more on generalization, taught or book based information, or merely stated that they *'just knew it has/hasn't got a backbone'*.

Implications for teaching – improving the experience of structure and function

The programmes of study for Key Stages 2 and 3 (DfE, 1995 p.9 section 2f and p.17 section 2g) require children to be taught that the skeleton provides support and movement in humans but, as for other biological concepts, next to nothing is said about structure and functioning in the rest of the animal kingdom. There is no mention of skeletal functions in the programme of study for Key Stage 4 (ages 14–16). There is a worrying paucity of experience related to the non-human, non-flowering plant living world as represented in the National Curriculum. Surveys of the use of animals in schools (Lock and Millett, 1991; Reiss and Beaney, 1992) indicate that children's first-hand contact with 'real' animals has been on the decline for some years. Zoological programming on television in the last 10 years has tended to focus on behavioural and ecological aspects rather than on structural or

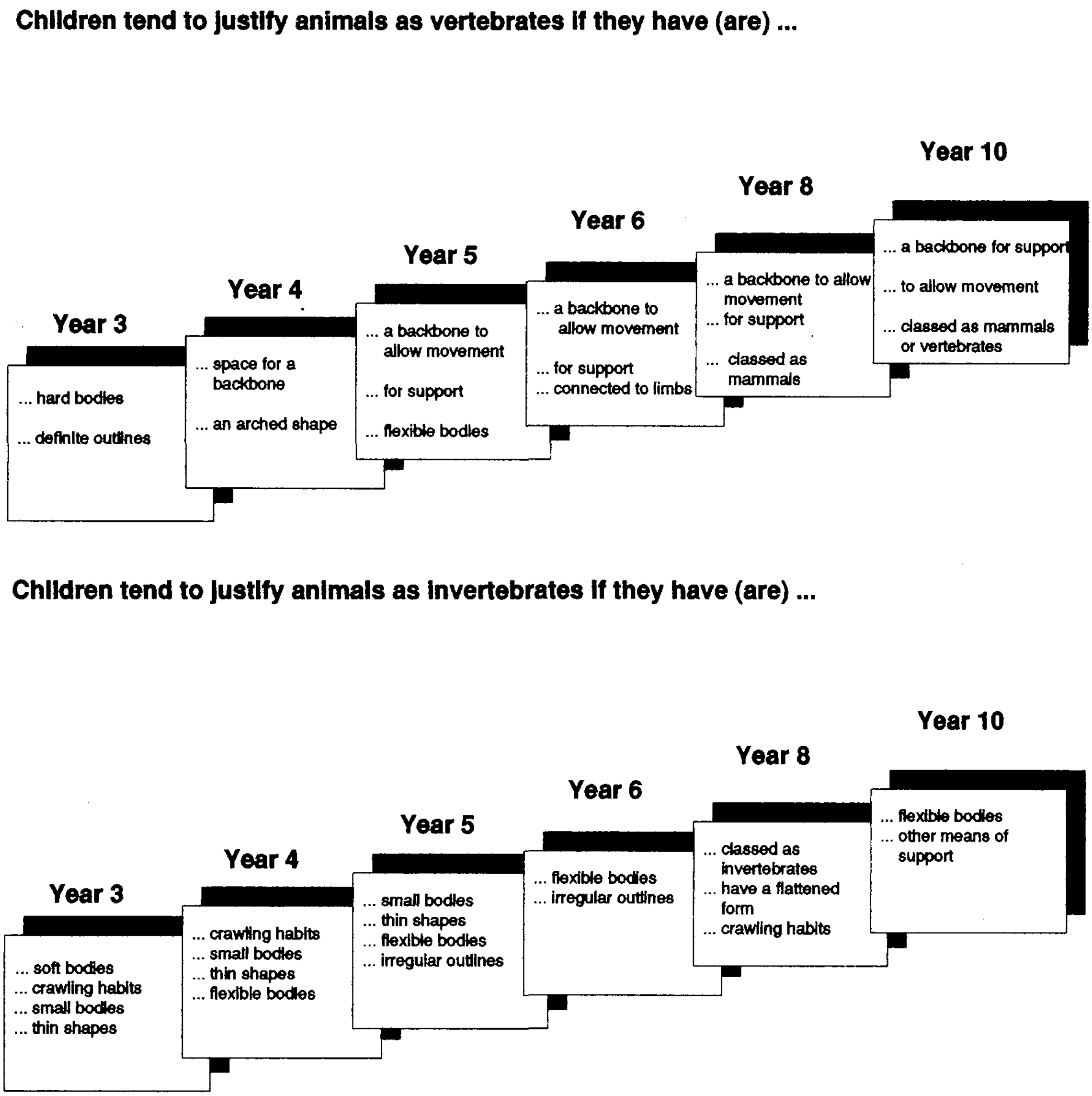

Figure 1 Progression in children's ideas about vertebrate and invertebrate animals.

functional considerations. We also have to remember that the increased processing of foods means, for example, that the children today rarely eat fish with bones. Considering these factors together, it seems that there is a real need to both widen and deepen children's knowledge and understanding of the structure and functioning of animals.

Children at every age in this study had little problem in communicating enthusiastically and (in terms of their own perceptions) knowledgeably about backbones and their functions. Follow-up questioning, probing children's outside interests relating to 'animals', showed that the most perceptive children (and successful in terms of correct classification) were, however, often those who had accessed information from other sources than school. These were commonly children whose parents provided the stimulation of visits to museums and zoos or engaged in birdwatching or fishing. It could be proposed that 'contact with nature' might be enough to improve awareness, for example, children living in rural surroundings might out-perform those from urban settings on classification tasks, but there is evidence to suggest that this cannot be assumed (Tema, 1989).

The weight of evidence from this and previous studies would seem to suggest that the knowledge base of children in UK schools in this area is at best sporadic and influenced by external, non-school interests. The question for teachers and curriculum developers, therefore, must be one of how experience can be improved equitably for all children. Since science is a relatively new area for primary school teachers to tackle and their own background knowledge in this area may well be weak (OFSTED, 1995), this question applies to both teachers and learners. The rest of this section considers some curriculum experiences that might help make redress.

This study has shown that although children increasingly associate a backbone with providing for movement, they have problems in equating this with flexibility in movement and seem to think that it requires a broad back able to accommodate a substantial structure. What experience can be provided to help children relate backbones to flexibility and articulation in movement, and to appreciate a wider range of structure and functioning in the animal world?

Most children can be made aware of the flexibility of their own backbones through stretching, bending, and twisting exercises in PE lessons. These could be extended to simulating the leaping, jumping, and crawling movements of a number of other vertebrates. Children should be made aware of the need to keep backbones supple but not to overload them. Good posture and sensible lifting techniques could be taught to help reduce the potential for back problems in later life. Consequently a useful link with health education can be made here.

The notion of flexibility could be extended by making model backbones from whole milk straws threaded on to a fishing line to represent a nerve cord, and comparing these with 'backbones' made from milk straw segments representing vertebrae so that children can understand how flexibility in the structure can be achieved. Diagrams and pictures in library books can help to provide older children with a number of examples of 'seeing inside animals'. Books in the *Dorling Kindersley Eyewitness* series (see, for example, Page, 1991) are excellent for this. Matching skeletons with animal outlines could provide another useful activity. It would also be beneficial for children to see video clips of animals moving in X-ray vision so that the arching and flexing and sideways movements of the bones can be seen clearly. There is also a need for both mainstream and educational filmmakers to return to the sorts of programme that go beyond the populist image of 'spectacular animals in threatened habitats'. A fine example of this 'functionalist' genre was evident in the 1972 BBC series 'Animal Design' (Sparks, 1972).

More examples of real animals in schools and a better use of those that are encountered would also help. Lock (1993) has called for an increase in the number of investigations using animals in secondary classrooms so that an understanding of structure and functioning can be enhanced. More recently Cassidy and Tranter (1996) have provided advice on the classroom use of suitable examples from many phyla. A common topic taught in primary schools, 'minibeasts', provides an almost universal 'invertebrate experience' for many children. A closer look at structures such as jointed legs, segments, and a muscular foot (as in snails) would help children appreciate how movement can still occur in animals with strong exoskeletons but without backbones.

The moratorium on change in the National Curriculum seems to usher a quiescent phase for curriculum development in the UK. The research presented here adds weight to the argument that children's experiences, in an area in which they show natural interest, are somewhat constrained. Each revision of the Science National Curriculum is essentially a pruning exercise removing what some see as the less essential parts of scientific knowledge. It is to be hoped that members of the biological sciences community will post warning notices, lest further revisions result in an even poorer understanding of the living world being made available to future generations.

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