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Contexts of meaning: young children's understanding of biological phenomena

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Contexts of meaning: young children's understanding of biological phenomena

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The present study reported here explores the composition of young children's contexts of meaning. Specifically, the major concerns involve identifying (*a*) potential underlying beliefs that may influence the construction of concepts, (*b*) cognitive processes that contribute to the construction of concepts and meaning, (*c*) variables that affect conceptual development, and (*d*) variables that may influence the construction of meaning. Using earthworms as objects of discussion, 10 children in Grade 1 (6 years) to Grade 3 (8 years) were interviewed during 30–45 minute sessions. From the data, a typology of children's thinking was developed that included: general categories of knowledge; mental processes; frameworks of belief, emotions, values and aesthetics. The components of this typology contribute to young children's construction of meaning about biological phenomena.

Introduction

In order to understand more fully how children create meaning or make sense of their environment, we need to look at the complexity of their thinking. To date, most research in children's knowledge of science has focused on identifying specific concepts. However, a few researchers have explored children's concepts from the wider perspective of conceptual ecology (Hewson 1988, Posner and Strike 1989) based on Toulmin's (1972) notion of the interaction of individuals and their environment. The basic assumption of conceptual ecology is that people's knowledge is adapted to their cultural and intellectual environment. Beliefs and conceptual knowledge come together to help children interpret their personal environment. Gilbert *et al.*'s (1982) description of 'children's science' approaches the notion that children's beliefs act as guiding frameworks for the interpretation of phenomena. Such beliefs help children interpret the world in a way that serves further to construct a coherent world view.

The framework of conceptual ecology suggests that each individual's knowledge is particularly meaningful to that person in his or her own environment. Other researchers, such as Gregory Bateson and Jerome Bruner, have suggested wider frameworks for looking at what is meaningful. Bateson (1979) refers to context as a 'story' or 'pattern [of connectedness] through time... [and that] nothing has meaning except [as] seen ... in some context' (pp. 16–17). Bruner (1986) and Bateson (1972) both include the notion of multiple perspectives as a dimension of human knowing and interaction. An even wider sense of context is created when we consider the idea that many perspectives can be incorporated into how children understand

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and create meaning of their world. This more global sense of contexts of meaning serves as the focus for the present study, in which the nature of young children's contexts of meaning is explored.

Background

The constructivist view of children's learning in science, as described by numerous researchers (Barbour 1985, Driver and Bell 1986, Gilbert *et al.* 1982, Novak 1987, Osborne 1985, Pines and West 1986, Pope and Gilbert 1985), contends that individuals construct their own knowledge in ways that are personally meaningful. Such meaningful knowledge constructions contain varying degrees of naive concepts and idiosyncratic information. However, the general view of cognitivist researchers is that meaning is semantic (see Bloom 1990 for a more complete treatment). From this point of view, meaning is conceptual.

To date, the research on children's cognitive struture has focused primarily upon descriptions of specific concepts held by children and the general characteristics of children's understanding. The cognitivist perspective of children's understanding in science has received thorough treatment by a number of researchers, including Carey (1986), Champagne and Klopfer (1984), Driver and Bell (1986), Gilbert *et al.* (1982), Novak (1987), Osborne and Wittrock (1983), Pines and West (1986), Resnick (1983). Although a more complete treatment is available from the previous sources, Osborne and Wittrock (1983) have summarized the essential aspects of cognitivist thinking:

> (1) Children have meanings for words and views about how and why things in their natural environment behave as they do from a young age.
> (2) The views and meanings held by children are sometimes uninfluenced by considerable exposure to science teaching.
> (3) When children's views change as a result of new learning experiences they sometimes change in ways unanticipated by teachers or curriculum designers (p. 495).

Although the majority of the research that looks at the conceptual structures of children has focused on the physical sciences, an increasing number of researchers are working with children's understanding of biological concepts. Of particular interest in regard to the present study are Bell (1981) and Trowbridge and Mintzes (1985, 1988). The major emphasis in each of these studies focused on how children classify animals and what attributes they use as important characteristics of animals. Children were found to have highly stable, but restricted concepts of animals. In general, the attributes children consider characteristic of animals were common to living things or were restricted to mammals.

Researchers' descriptions of children's concepts of animals are intriguing in that such descriptions point to the consistency and extent of idiosyncratic concepts. Yet, the current literature falls short in exploring the full complexity of children's ideas about living organisms. Such complexity has to do with the nature of meaning and the nature of how children construct meaning. The present study explores how young children construct meaning while looking at and talking about earthworms. Specifically, the major concerns involve identifying (*a*) potential underlying beliefs that may influence the construction of concepts, (*b*) cognitive processes that contribute to the construction of concepts and meaning, (*c*) variables that affect conceptual development, and (*d*) variables that may influence the construction of meaning.

Method

During the winter and spring of 1988, 10 children in Grades 1–3 in a school in Ontario were interviewed during 30–45 minute sessions. The sessions centred on having the children observe, manipulate, and talk about live earthworms. In each case, the interviewer allowed the children to explore the earthworms on their own while discussing their observations and ideas. In addition, the children were asked questions that (*a*) probed into each individual's ideas and questions, and (*b*) followed an agenda of a few major areas of relevance to this investigation. All interviews were tape-recorded and transcribed. Although the children's names are fictitious, they have been arranged according to grade level. Grade 1 children's names begin with 'A', while Grade 2 names begin with 'B' and Grade 3 names begin with 'C'.

Results

The problem of trying to understand how children think from the perspective of cognitive ecology is complex. A wide variety of thinking processes, concepts, beliefs, values, emotions, and all sorts of semantic and episodic information come into play when children interact with natural objects (earthworms, in the present study). Almost every utterance in each interview contains information relevant to the study of children's cognition. However, the forthcoming presentation of the results will attempt to organize and condense the data into a more easily comprehensible and manageable form. The major focus will centre around an evolving typology generated from the data. This typology establishes a profile of the psychological components that interact in the process of the construction of meaning.

The typology contains four general componential divisions with associated components and subcomponents: (*a*) knowledge, including semantic knowledge (which contains classification and categorization) and episodic knowledge; (*b*) mental processes, including inferring, perceiving, describing, explaining and comparative processes (which involve generating metaphors and analogies, comparing and discriminating); (*c*) frameworks of belief, including anthropocentrism, anthropomorphism, and zoomorphism; and (*d*) emotions, values and aesthetics. Although the typology can be expanded to include new components, in its present form it serves as a basis for exploring the context of young children's learning and knowledge of biology.

Discussing each component of the typology separately is artificial. As will be seen in the data, there is a great deal of interaction between the various components. Children use metaphors in the midst of inferences, along with knowledge claims, or as descriptors that mark a particular belief. For the sake of clarity, however, the results will be presented in sections that correspond to each of the major divisions of the typology. At the same time, links with other divisions and between components will be described as necessary.

Children's knowledge

Discriminating between a child's knowledge and the products of various mental processes is difficult. A child may make a particular knowledge claim about worms, but whether such a claim is actual semantic knowledge directly associated in memory with the worm, or whether the claim is inferred from semantic knowledge associated

with other animals, is not always known. For example, Amy responds to a question about what is inside of the worm by saying: 'Blood, sometimes there's a little bit of bones, a little bit of blood and skin and bones, little ones; well, he really has blood and this gushy stuff; well, it usually has a lot of blood...' Worms do have blood, yet it is not readily visible like the red blood of many other animals. Does Amy 'know' that worms have blood or has she inferred that worms have blood? Immediately after mentioning blood, she goes on to say that they have bones, as well. Worms do not have bones, yet many other animals do. In the case of Beth, when asked what helps worms move, she said, 'I think they have muscles, little muscles, teeny weeny muscles help them move like we do'. In a similar way, Beth has inferred that worms have muscles like humans.

In another instance near the beginning of the interview, Amy uncovers some worms and says, 'one's bigger, it looks like that's the father and that's the mother and that's the baby... that one's much younger...'. Here Amy has made an inference based on her knowledge of humans (anthropomorphism) or of other animals (zoomorphism). Such statements by Amy suggest that she is actively inferring much of what appears as knowledge about the worm. On the other hand, Amy responds to a question about what worms eat by saying:

> Well, I don't know, but birds, I know that birds [eat worms]. You know what? Usually when my grandma and grandpa have a lot of worms in the garden there's about 200 birds on the lawn... Yesterday I saw a bird with a worm, or a twig, I didn't see it I just saw it tearing something. I was right behind it on the sidewalk, just walking along singing a song.

She did not answer the original question, but she did know that birds eat worms. Such a knowledge claim is reinforced by episodic knowledge of an actual event in which she thought she saw a bird eating a worm. Clearly, such a claim (birds eat worms) is associated in memory with her knowledge of worms. In a similar way Becky claims, 'I know they help gardens... [R: how do they help gardens?]... my mom told me but I don't remember'. In this case, she knows they help gardens, but cannot remember why.

A major component of semantic knowledge concerns the way in which objects (animals) are categorized or classified. When two of the children claim worms are snakes, they associate different information with the same category. Amy focuses on similar visual characteristics, even though two differences (size and colour) are noted. Adam focuses on visual characteristics, as well as other similarities, such as in habitat, in what they do, and in the lack of a specific anatomical structure:

> ...some worms look just like a snake... [R: what's the difference...?]... worms are just a small snake [R: how are they alike?]... well snakes live in the ground and do the same things. Worms can't hurt you. Worms are just smaller, but they're the same thing. Worms don't have ears... [R: what about snakes?]... snakes don't have ears... [several minutes later]... did you know that worms probably are just baby snakes?

Even though differences are discussed, each child groups worms and snakes together.

In another case, Cindy makes a categorical statement that worms are reptiles. However, differences in characteristics lead to a dilemma between membership in the reptile category or membership in an alternate category (mammals). Without any direct questioning, Cindy talks about worms:

> I think they are mammals, but they don't have any hair, and I don't think they are reptiles. Yeah, I think they are reptiles, but I don't think they lay eggs. I think they are

> both. They don't have any hair, but their young are born alive, so they are part mammal and they don't have any hair so they are part reptile, okay? and part dinosaur too. Well dinosaurs deliver young and they didn't have any hair so they are like dinosaurs (laughs) actually we don't know dinosaurs laid them alive or whatever...

She solved her dilemma by mutual inclusion in the two (three, including dinosaurs) different categories. Her associations and inferences show a rich, although incomplete, collection of knowledge. Her struggle with the rules (characteristics for class inclusion) of classification is an example of her active attempts to construct meaning.

As we have seen in the case of Amy, episodic knowledge appears to play a role in the establishment or, at least, in the reinforcement of semantic knowledge. In other instances, the role of episodic knowledge is less clear. When Andy was asked if he had ever seen earthworms before, he responded with, 'um-hum, on my driveway dead... [R: how come?]... because the car ran over them. I've seen them on the sidewalk...'. More commonly, other children's experiences with seeing worms have to do with gardens. For example, Alex's explanation is typical of other children: 'I've picked up a lot and put them in our garden...'. Many of the children who had experiences with worms in gardens also knew from their 'moms' that worms were helpful for plants, however all but one child could not remember why. For example, Cindy explains:

> Well, let's see if I can remember this, they go through and they make holes in the dirt so water can get in and the plants in it will live. I think that's right... They just wiggle through and make a little hole in there... okay I'll show you, see if this was smushed down tight like it normally is in a garden, then the water can't get through the little holes 'cause they are too small....

Cindy's explanation demonstrates a more complex conceptual understanding. An understanding that appears to have an experiential (episodic) basis.

The interaction between the information and concepts contained in semantic memory and the experiential knowledge contained in episodic memory appear to produce a meaningful framework of knowledge for at least some of the children. Some concepts appear to be constructed from everyday personal experiences. While in other instances, everyday experiences appear to be associated in ways that reinforce or confirm concepts. The fabric of everyday experiences and the fabric of conceptual knowledge are interwoven to produce a richer and more complex context of meaning. However, the picture of the context of meaning is still incomplete. As we saw in some of the previous examples and as we shall see in the following section, children are actively processing information and constructing new knowledge while producing a more dynamic context of meaning.

Children's mental processes

At the beginning of the previous section, the difficulty in establishing whether a particular concept was associated with worms was shown. In some cases, it appears that children actively make inferences about worms from knowledge associated with other exemplars. Although these inferences may be an obstacle when one is attempting to identify a particular conceptual structure, the act of inferring, along with other cognitive processes, allows us to glimpse the active construction of

knowledge. For instance, Cindy ponders a question about worms, then proceeds to infer an answer:

> I wonder if snakes have veins that do the same things, like same insides but different outsides? They have to use the same muscles like to push forward. I was just wondering why is that worm mov[ing] the same way. So it should have the same veins because, our veins look like that....

The framework she establishes for her question is quite interesting. She conjectures (infers) that the visibly different outsides of worms and people may contain similar unseen structures on the inside. Then within this framework, she asserts (and infers) that another structure (muscles) exist and function in the same way in both worms and humans (comparative process). This assertion about muscles, that appears to arise from her perception of the moving worm, is used as a basis for her conjecture that worms and humans have similar veins. What we see here is an active process of knowledge construction involving: (*a*) perceiving, (*b*) questioning, (*c*) inferring, (*d*) conjecturing, (*e*) asserting and (*f*) comparing.

In another instance, Cindy sees something unusual about a worm, which expands into a constructive process:

> ....what's wrong with that, it's all red at the front. Is that where its hearts are or something?' Cause there's little red dots or something...[R: what else is inside the worm?]....You know it probably has stuff like we do like when something hurts us we curl up and they probably do that too, and having so many hearts I don't know what's going to happen. [R: they have many hearts you think?]...yeah, have you heard about that? They have like seven so that if they get cut off, like that one, they have another heart so they can live, and so many people are using them for fishing....

In this excerpt, the complex interaction of a variety of typological components goes beyond the mere construction of knowledge to a larger sense of the construction of meaning. Her initial perception of the red on the worm is framed in the notion that something is wrong. Then she appears to associate the red with blood and does associate the colour with the presence of the hearts. As in the previous example, Cindy goes on to make a structural comparison to humans. However at this point, she refers to the human reaction to pain as a basis for inferring causality to why worms curl up. Her inference is cast in a framework of anthropomorphism. Later in the excerpt, a framework of anthropocentrism guides another type of causal inference. She reasons that because worms have seven hearts (actually five) they can survive being cut in half, and such a capability makes them good for fishing. This sense of creating meaning appears in the richness and variety of associations. In a way, Cindy can identify with the worm as a creature that feels pain and reacts to it in a way that is similar to her own reactions to pain. In addition, worms are good for fishing because they can survive being cut up, and therefore are useful to people.

The same sort of complexity in the construction of meaning can be seen as Adam observes a worm:

> ....look how another one of these things squirm around on this [picks up worm] [R: what does it feel like?] They feel like stickers when they've been licked and sticky. You see how this one's squirming?.... He just pulls himself back and then he just pulls the back part forward and then pulls the front forward, and that's how he works. Want to know how they know which is the front of the worm when you go fishing?...that's the front part, because it has a little hole...that's where they put the hook in....

The use of metaphor, another component of the typology, appears in the above sequence. The metaphor compares the way a worm feels to stickers. As Adam

continues to observe the worm, he goes on to describe its movement. His account provides a fairly accurate description of the movement protocol. However his interpretation of the action uses the explanation of 'pulling' for all movements. Having to discriminate between the front and back parts of the worm in his description, appears to prompt another association or inference about why there's a little hole in the front. His functional explanation makes an anthropocentric connection to the worm's value in fishing.

Children use metaphors in their descriptions and interpretations of worms. In fact, most of the metaphors evident in the data relate to observations the children make. Fifty per cent of the metaphors related to the visual or tactile perceptions of the earthworms. Action metaphors occur about 32% of the time. Other metaphors refer to certain belief frameworks (anthropomorphism) and to imagined transpositions and actions.

A more complex and dynamic metaphor which initially involves what might be referred to as an anthropomorphic transposition and later becomes a functional metaphor can be seen in an excerpt from Amy's interview:

> [R: do you think it would be nice to live in that ground?] It would be muddy. You'd get yourself dirty all the time and your mother would go, 'get up here and get your clean clothes on! You're always squirming around in that dust patch!' [R: oh worms wear clothes do they?] I wonder if their skin is really clothes for them?

At first, she puts herself in the position of living in the ground like the worm. Getting her clothes dirty is the central issue. Then 'clothes' become a functional metaphor of skin acting as clothes. The more imaginative and playful use of metaphor in the beginning leads to the development of the metaphor as a serious functional question. The elaboration involved in the first use of metaphor affects her context of meaning which leads to the metaphoric question. This context appears to encompass notions of cleanliness, function, and family. Such contexts of meaning influence the way worms, in this instance, and the natural world, in general, are understood.

Another interesting and similar use of metaphor appears in Cindy's response to a question about what the heart does:

> I don't know about my body (laughs). Well I don't know about my worm body (laughs). It moves the same way so it probably has the same inside, so it has one vein down the middle and then little ones going out....

She appears to transpose herself into the position of the worm: imagining herself as the worm when she talks about 'my body'. This transposition is followed by a comparison of movement between the human body and the worm, which then acts as the basis for inferring similarities in the circulatory system. It cannot be determined whether or not such a transposition facilitated the processes of comparing and inferring, though such a relationship is plausible. However, the context of meaning characterized by the imagined transposition encompasses a sense of subjective identification with the worms beyond that of a more objective observation.

In addition to metaphors, the children frequently utilize other types of comparisons. Three fundamental types of comparisons are commonly found: (*a*) perceptual, (*b*) prior knowledge and (*c*) inferred. Perceptual comparisons deal with visual and tactile similarities. For example, the animal most commonly compared to an earthworm is a snake. Nine of the ten children in the present study make such a comparison. For example, Amy states that, 'they both look the same', while Andy

specifies that they look like snakes 'because they are long and squirmy' and Alex thinks they 'move like snakes'. In most cases, the comparisons with snakes are clearly visual.

Comparisons based on prior knowledge (episodic or semantic) and those based on inferences are often used in conjunction with one another. These two types of comparisons are also difficult to distinguish from each other. Cindy's response to whether worms can 'talk' to each other demonstrates both types of comparisons: 'dolphins can and whales can and fish can and we can, probably they [worms] can...'. If 'talking' means auditory communication, we can assume that she has some prior knowledge of dolphins, whales and humans communicating in such a way. However, when she includes fish in the list of animals that talk, it is unclear as to where she got that information. Besides not knowing exactly what she means by fish talking, we are not sure whether she 'learned' such an idea previously or inferred it? Her reasoning that other animals talk leads to an obvious inferred comparison that worms can talk as well.

Other types of comparisons focus on making discriminations. For example, as Cathy explains that worms remind her of centipedes, she says, '.... well they're long and stretchy, they don't have legs...'. She goes on to say, '.... well they are sort of like snakes, well, snakes don't have legs and they sort of inch around, well, worms don't have designs on them and snakes do...'. In the first part, even though worms remind her of centipedes, she notes that worms do not have legs. This discrimination may have led her to dismiss the centipede comparison and try the snake. Yet, even with the snake comparison, Cathy sees that snakes can have markings on them, but worms do not.

In general, metaphors and other comparisons appear to facilitate the construction of new knowledge and add to the complexity of children's understanding. In the midst of inferring new comparisons, we have seen how some knowledge is constructed. From an early age, children are actively involved in constructing new knowledge. Comparative inferences and metaphors appear to be among the important processes involved in knowledge construction.

The thinking processes evident in the children's talking about worms are important in understanding how children create meaning of their world. Such processes are not selective in the sense that they deal with only 'scientific' content. Children's thinking is dynamic. Metaphors, comparisons, inferred relations, stories and fables are all brought into the particular context of thought, which is the context of earthworms in the present study. Additional influences or components of the contexts of meaning involve what might be called a framework of belief, as well as emotions, valuation, and aesthetics. In the following section, the framework of beliefs will be discussed in more detail.

Framework of beliefs

Defining children's belief frameworks is difficult. Many potential beliefs are omitted in the present paper because of the high inferences required. Only three components of children's belief structures are discussed: (*a*) anthropocentrism, (*b*) anthropomorphism and (*c*) zoomorphism. Each of these components requires fairly low inferences during data analysis.

Anthropocentric statements refer to the utility of worms or other animals and natural objects for human purposes. Adam's statement about the hole in the worm

being there so that people can put hooks in them is indicative of a human-centred view. In another situation, Adam is comparing snakes and worms and says, '... worms can't hurt you'. Such a statement does not directly show the utility of worms, but it does centre upon a favourable relationship with human beings. When Andy says, 'I only like the one [worm] at the end of my fishing rod', he is demonstrating a common utilitarian view of worms. Another common, but different, utilitarian view of worms is expressed by Bonnie: 'All I know is they are good for the flowers.' Such human-centred views provide a means of students to connect meaning to worms. Worms are useful to their experience as human beings. On the other hand, the notion that other animals are dangerous to people and worms are not is another way of attaching meaning to animals and other natural objects.

The 'morphisms'—anthropomorphism and zoomorphism—are common belief components that place the attributes of humans or other animals upon worms. Before exploring the morphisms in more detail, it is worth noting that many children refer to worms as he or she. Such use of pronouns is difficult to establish as an example of anthropomorphism, since 'he' or 'she' may only be simple artifacts of everyday language.

The distinction between anthropomorphic and zoomorphic statements is occasionally unclear. In some cases, children's statements are classified as zoomorphic when they may be anthropomorphic. Such zoomorphic classificatiions are meant to err on the side of generality, since humans share many characteristics with other animals. Zoomorphic and anthropomorphic statements potentially have a number of similar subcategories: (*a*) structural, (*b*) behavioural, (*c*) functional and (*d*) social (the latter two do not appear in common in the present study). However, intentional, cognizant and emotional categories of statements are uniquely anthropomorphic.

The transferring of attributes is fairly common among all the children. Such transferences provide a strong way to create more meaningful understanding. For instance, take the notion of 'trying' that appears as an intentional anthropomorphic statement of several children. 'Trying' opens up a connection to children's personal experiences. They know what it is like to try to move, climb, or get away. A distinct example of the connection to personal meaning appears in Cindy's behavioural anthropomorphic statement: '... when something hurts us we curl up, they probably do that too ...' She understands what it is like to feel pain. Her reaction appears to be to curl up. Her expectation from seeing worms curl up is that they do it as a reaction to being hurt. The (structural and behavioural) zoomorphic statement by Beth, 'wagging its tail', is another connection to a greater context of meaning. Even though worms do not have tails, they appear to have tails. Tails are long, roundish and pointy, just like the shape of a worm. Furthermore, tails wag; that is what tails do. Children have experienced 'tails' by watching and playing with dogs and cats. Features or attributes, such as tails, have a great deal of meaning attached to them.

Beliefs, as discussed in the present paper, provide a framework for creating meaning. Beliefs overlap and interact with other components, such as inferring, comparing, semantic and episodic knowledge, emotions, values and aesthetics. The meanings attached to specific attributes become associated with the knowledge of other animals or natural objects to create an even greater context of meaning around the specific object. Such beliefs can guide mental processes, such as the making of inferences that reinforces the particular belief and embellishes the context of meaning.

Emotions, values and aesthetics

As seen in the discussion of anthropocentrism, children place certain values on worms, e.g., they are good for fishing, gardens and flowers. However, values extend beyond anthropocentric beliefs and bcome intermingled with emotions and a sense of aesthetics. In fact, when children's statements are examined it is difficult to separate emotions or aesthetics from values. For example, Adam's statement that 'the fatter ones are pretty', demonstrates a certain aesthetic appreciation for the fatter worms and, at the same time, the statement is laden with values. Emotional statements are also value-laden, such as when Andy says, 'it's disgusting, when you feel them'. Such intermingling of emotions, values and aesthetics creates a strong connection to the information involved with specific objects. At the same time, emotions, values, and aesthetics affect the context of meaning.

The context of meaning is coloured by the personal qualities of emotions, values and aesthetics. For Andy, the context of meaning surrounding earthworms has a particular quality of aversion: '... disgusting, squirmy yuckies, not very nice yuck, funny way'. On the other hand, Adam's view of worms is more appreciative: '... really neat, pretty, isn't that neat'. However, most of the children seemed to have mixed emotions, values and aesthetic views of worms. In fact, Amy's views change from aversion to appreciation: 'don't really like, squirmy, weird, squirm, feels neat, neat, weird little place, pretty funny, I like these little worms'. No matter which qualities are present, the children have a direct and personal connection with earthworms; a connection which is emotional, valuative, and aesthetic. Such strong, personal connections are extremely meaningful.

Discussion

The various components of the typology interact in ways that create personal contexts of meaning for each child. Such contexts of meaning are not strictly scientific in nature, nor are they strictly logical or rational. Instead, the contexts contain a wide variety of associations to different types of information, beliefs, emotions, values and aesthetics.

Contexts of meaning are often indicated by context markers (Bateson, personal communication 1975) or triggers (Bruner 1986). For instance, as discussed previously, the statement, 'wagging it's tail', marks a context of meaning about 'tails' and their structure and function. In the same way, heads, eyes, hunting, and so forth, point to or trigger further meaning. Heads and eyes orient the child to worms. The head and eyes deal with knowing the world, they are the essence of being alive from the child's point of view. If a worm is alive, it has to have a head and maybe eyes. The action of hunting provides a way to interpret the behaviour of worms. When the worm is moving its 'head' around, it looks as if it is 'hunting' and hunting is what 'animals' do. The metaphors generated by the children mark different contexts of meaning. For example, the metaphor that worms move like 'slinkies' contains meaning about how slinkies function and 'behave'. In similar ways to metaphors, other typological components, such as beliefs, emotions, values and aesthetics, all trigger or mark greater contexts of meaning.

Contexts of meaning are dynamic and ever-changing arrays of information embedded in a variety of emotions, values, aesthetics and beliefs. The action of various processes (inferring, comparing, perceiving, etc.) continuously alter the content and meaning of these contexts. Such contexts of meaning are highly personal

because of the influence of invidual (episodic) experiences, emotions, values, beliefs, and so forth. Various context markers, such as 'tails', may trigger similar meaning in different children, but in the the larger context, in the present case 'worms', each child's meaning is quite individualized and different.

If we consider children's context of meaning in the spirit of 'alternative' frameworks by not judging their 'correctness', we can begin to see how children construct and modify concepts along with associated meaning. For example, the children in the present study may not have had any concepts of how earthworms move, yet as they examined the worms in front of them the children described what they saw. The descriptions used other concepts available to them, such as 'pulling' as an explanation for how the worm was able to make one part of its body move and then another part move. Some children made metaphoric associations with objects, such as slinkies. Other children inferred that worms must have muscles, because humans have muscles. In most cases, children actively sought out associations with their own experiences and previous knowledge.

Emotions, values, aesthetics and beliefs also affect the associative processes or, at least, affect the meaning attached to the newly constructed or modified concepts. For instance, worm movement takes on an intentional quality when Bonnie says, 'he's trying to crawl down', and a familiar human behavioural quality when she says, 'they crawl over everything and get comfy'. On the other hand, a zoomorphic comparison, such as Curtis' 'slither like snakies', sets up an associative pathway to the child's knowledge of snakes and accompanying context of meaning.

Contexts of meaning expand and change as they overlap and interact with other contexts. Individual concepts do not occur in a vacuum, but in a complex arena of interrelated concepts, emotions, values, beliefs, and so forth. Isolating specific concepts in the study of children's knowledge and conceptual change, as is being done in much science education research, can pose some serious problems. For instance, when researchers think they have identified a concept, such as 'worms have tails', they label it as a misconcept or alternative concept. Such a concept is viewed as needing to be changed to conform with the scientific concept. The problems are (*a*) that there is an incredible amount of meaning attached to the concept, 'worms have tails'; (*b*) that by not paying attention to and appreciating the significance of that meaning, we are missing most of what a child understands; and (*c*) that by not working with the child's contexts of meaning that surround concepts, we will have greater difficulty helping children to meaningfully incorporate scientific versions of concepts. Children's understandings of the natural world are not only fascinating, but are incredibly complex.

As teacher educators, we need to encourage our students (*a*) to incorporate multiple perspectives in instruction and (*b*) to recognize and elucidate the various contextual components that affect meaning-making. Incorporating multiple perspectives can be accomplished by having teachers construct what I call 'context maps'. Such maps place the object or topic of study in the centre of a piece of paper. Then as many perspectives as possible are brainstormed and written down around the topic and connected to the topic by lines. The interrelationships between the perspectives are connected by lines and labelled. For example, the topic of worms could include the following perspectives (aspects to understanding): animal, slimy, bird food, fishing bait, (good for) gardens, movement, chocolate covered, cartoons, reproduction, slinkies, and so forth. Slinkies can be linked to movement as an example of what their movement looks like. Movement can be linked to fishing bait

as a way to help attract fish. In addition, teachers can plan activities that allow children to explore the extent of their contexts of meaning through drawing, story telling, poetry, as well as through explorations of worm ecology, behaviour, anatomy, the social benefits of worms, and so forth. The point is to have children explore and develop their contexts of meaning and, at the same time, recognize the value and nature of each aspect of their personal contexts of meaning.

In addition, if we want children to adopt more scientific concepts, then we should be addressing more than the specific concepts themselves. Returning to the 'worms have tails' concept, we could encourage children to explore the contexts of meaning surrounding that concept, rather than controlling the concept directly. For instance, the children could explore tails, what they do and where they occur. Their aesthetic appreciation, emotions, and so on, can be explored as well. In other words, children can be encouraged to explore and define the extent of their contexts of meaning. Out of the newly defined context of meaning a more specific definition of tails can be formulated with the children. A re-examination of worms could then reveal that they do not have tails, but they are *like* one big tail. Essentially, researchers and teachers should be more concerned with encouraging children to incorporate scientific concepts into their contexts of meaning, rather than trying to replace 'misconceptions' with scientific conceptions. The richness of meaning that accompanies many 'misconceptions' is a significant part of the way we as human beings understand our world. To deny that richness of meaning is dangerous.

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References

BARBOUR, B. 1985, Theories of learning: Pask. In R. Osborne and J. Gilbert (eds), *Some Issues of Theory in Science Education* (University of Waikato, Hamilton, New Zealand), pp. 42–63.

BATESON, G. 1972, *Steps to an Ecology of Mind* (Bantam, New York).

BATESON, G. 1979, *Mind and Nature: A Necessary Unity* (Bantam, New York).

BELL, B. 1981, When is an animal not an animal? *Journal of Biological Education*, Vol. 15, pp. 213–218.

BLOOM, J. W. (in press), Contexts of meaning and conceptual integration: how children understand and learn. In R. A. Duschl and R. Hamilton (eds), *Philosophy of Science, Cognitive Science in Educational Theory and Practice* (State University of New York Press, Albany, NY).

BRUNER, J. 1986, *Actual Minds, Possible Worlds* (Harvard University Press, Cambridge, MA).

CAREY, S. 1986, Cognitive science and science education. *American Psychologist*, Vol. 14, pp. 1123–1130.

CHAMPAGNE, A. B. and KLOPFER, L. E. 1984, The cognitive perspective in science education. In R. W. Bybee, J. Carlson and A. J. McCormack (eds), *Redesigning Science and Technology Education: 1984 Yearbook of the National Science Teachers Association* (NSTA, Washington, DC), pp. 90–103.

DRIVER, R. and BELL, B. 1986, Students' thinking and the learning of science: a constructivist view. *School Science Review*, vol. 67, pp. 443–456.

GILBERT, J. K., OSBORNE, R. J. and FENSHAM, P. J. 1982, Children's science and its consequences for teaching. *Science Education*, vol. 66, pp. 623–633.

HEWSON, M. G. A'B. 1988, The ecological context of knowledge: implications for learning science in developing countries. *Journal of Curriculum Studies*, vol. 20, pp. 317–326.

NOVAK, J. D. 1987, Human constructivism: toward a unity of psychological and epistemological meaning making. *Proceedings of the Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics*, Vol. 1, pp. 348–360.

OSBORNE, R. 1985, Theories of learning: Wittrock. In R. Osborne and J. Gilbert (eds), *Some Issues of Theory in Science Education* (University of Waikato, Hamilton New Zealand), pp. 6–18.

OSBORNE, R. and WITTROCK, M. C. 1983, Learning science: a generative process. *Science Education*, vol. 67, no. 4, pp. 489–508.

PINES, A. L. and WEST, L. H. T. 1986, Conceptual understanding and science learning: an interpretation of research within a sources-of-knowledge framework. *Science Education*, vol. 70, pp. 583–604.

POPE, M. and GILBERT, J. 1985, Theories of learning: Kelly. In R. Osborne and J. Gilbert (eds), *Some Issues of Theory in Science Education* (University of Waikato, Hamilton, New Zealand), pp. 19–41.

POSNER, G. and STRIKE, K. 1989, The conceptual ecology of physics learning. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

RESNICK, L. B. 1983, Mathematics and science learning: a new conception. *Science*, Vol. 220, pp. 477–478.

TOULMIN, S. 1972, *Human Understanding*. Vol. 1. *The Collective Use and Evolution of Concepts* (Princeton University Press, Princeton, NJ).

TROWBRIDGE, J. E. and MINTZES, J. J. 1985, Student's alternative conceptions of animals and animal classification. *School Science and Mathematics*, Vol. 85, pp. 304–316.

TROWBRIDGE, J. E. and MINTZES, J. J. 1988, Alternative conceptions in animal classification: a cross-age study. *Journal of Research in Science Teaching*, Vol. 25, pp. 547–571.