The Development of Scientific Knowledge in Elementary School Children: A Context of Meaning Perspective

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The way in which young children think and construct knowledge is much more complex than we may have previously thought. What is meaningful to children is not always within the realm of semantic or formal knowledge. Their personal experiences, emotions, metaphors, interpretive frameworks, and so forth serve to create a complex system of processes that affect the nature of their personal knowledge and how it is constructed. The present article examines how such interrelated processes affect knowledge construction in young children.

An abundance of literature exists which describes learning processes and the acquisition of knowledge from a constructivist perspective. From the early work of Ausubel (1963) to the more recent work of Gilbert, Osborne, and Fensham (1982); Osborne and Wittrock (1983); Carey (1985); and Driver and Bell (1986) among many others, the emphasis has been on the construction of meaningful knowledge. This view, however, has focused almost exclusively upon semantic knowledge. For instance, Driver and Bell suggest that "learning involves constructing meanings. People construct meanings of what they hear or see by generating links between their existing knowledge and new phenomena attended to" (p. 447). The process of linking knowledge implies a propositional or semantic basis for personal knowledge. In several earlier reports, the notion of contexts of meaning has been elaborated upon as a dynamic view of cognition that includes not only semantic (or formal textbook-type) knowledge, but also personal experiences (episodic knowledge), interpretive frameworks, emotions–values–aesthetics (EVAs), and the products of various mental processes (e.g., metaphors, etc.) (Bloom, 1992; 1990a–c). Although the notion of "context" is usually associated with the physical, social, or cultural setting in which individuals function, the notion of context in the present article is primarily cognitive. Certainly the physical, social, and cultural contexts impact on an individual's personal contexts on meaning, but for the purpose of this article only the cognition of individuals is examined.

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In the original study (Bloom, 1990a), the typology of contexts of meaning was established to describe patterns evident in the data. The definitions of some of the typological components are relatively standard, such as semantic and episodic knowledge. However, the other components warrant brief explanations.

> Mental processes are obvious at one level, especially considering the amount of research devoted to the description of such processes (e.g., inferring, elaborating, recalling, perceiving, etc.). However, the important notion is that such processes are constantly changing the nature of what children understand by changing knowledge and by adding new information. New information added to an individual's context of meaning may be the product of a specific process, such as metaphors . . . . Interpretive frameworks describe how certain points of view, belief systems, or knowledge sets influence the operations of various mental processes. For example, anthropomorphism may influence the way an inference is made. The subcomponents of anthropomorphism and zoomorphism both refer to the process of transferring the characteristics of humans and other animals (respectively) to the object or organism at hand. Anthropocentricism, on the other hand, concerns the view that focuses upon human needs, desires, concerns, and so forth. The category of emotions–values–aesthetics was formulated to describe what appeared to be the basis of various statements. Each aspect has been combined because of the difficulty in separating them as they manifest in children's speech. A child may be disgusted by earthworms, think they are ugly, and not like them. All three aspects of emotions, values, and aesthetics are strongly associated. (Bloom, 1992)

A contexts of meaning point of view questions the static, semantic, or propositional nature of knowledge and understanding. From this perspective, meaningful knowledge includes more than semantic propositions of formal knowledge. Meaning is founded in highly personal and very powerful influences of emotion–values–aesthetics, metaphors, interpretive frameworks, and personal experiences. The power and significance of contexts of meaning lies in the integrated whole that can result.

Contexts of meaning can involve traditional cognitive processes, such as categorizing, inferring, and elaborating. Moreover, for the purposes of this article, these three aspects of cognition will be separated and examined in terms of how they are influenced by the other aspects of contexts of meaning (episodic knowledge, metaphors, interpretive frameworks or patterns, and emotions–values–aesthetics). Categorizing (Rosch and Lloyd, 1978, Lakoff, 1987), inferring, and elaborating appear to be accepted as fundamental processes involved in learning. Although such processes form the foundation for the development of knowledge, very little research has looked at what affects these processes. We know that children develop highly personalized knowledge "structures." Yet we know very little about what aspects of cognition contribute to the personalization process. In the previous studies, a few instances of knowledge and meaning development process have been highlighted and discussed (Bloom, 1990a–c, 1992). The present article, however, will examine more thoroughly how episodic knowledge, metaphors, interpretive frameworks, and emotions–values–aesthetics influence the processes affecting the development of new knowledge and meaning.

METHOD

The students who participated in the study attended a school in a middle to upper middle class neighborhood in a small city in eastern Ontario. Nine grade 5 and eight grade 1 students were informally interviewed in one activity-based setting, which involved observing earthworms. Such informal interviews provided opportunities for a more naturalistic view of students interacting with and trying to make sense of their observations. The interviews were conducted individually either at the end of the school day (grade 5) or during class time (grade 1). All interviews were tape recorded and transcribed. In addition, occasional field notes were taken during or immediately after the interviews. The pseudonyms have been assigned to match the letter of the alphabet with the grade level (A = 1; E = 5).

The interviews were informally structured in order to accommodate the children's natural exploration and conversation. The interviews usually started off with general questions or suggestions to stimulate conversation. As the conversations progressed, a common set of questions were introduced as opportunities arose. The questions were more or less as follows: (a) how do they move? (b) what do they eat? (c) what is on the inside? (d) what other things are they related to? (e) can they communicate with each other? (f) are they good for anything?

Each interview was tape recorded and transcribed. Analysis of the transcripts began with a process of pattern analysis which combined categorizing and sorting segments of statements. This process was one of mutual negotiation between myself and my research assistants. Although the original intent of the initial study (Bloom, 1990a) was to identify types of questions children asked and the concepts associated with these questions, what arose from the data was quite different. The types of thinking that were evident in the data led to the development of the typology of what was termed "contexts of meaning" (described previously). [The procedures fall within the scope of grounded theory as described by Charmaz (1983).] A similar study with older children (grade 5) confirmed the same patterns of thinking (excerpts appear in Bloom, 1992). Other studies using different data collection approaches have also demonstrated the prevalence of such categories of thinking as described within a context of meaning framework (Bloom, 1990b, 1990c). The studies using different data collection techniques and the study using the same technique with different children all serve to act as "data triangulation" for the context of meaning framework. In addition, the thick descriptions provided in the following pages will help the reader verify the claims made in the present paper.

RESULTS

The students in the present study actively engaged in trying to make sense out of their observations of earthworms. Only four (two grade 1 and two grade 5 students) of the 17 students tended to be less actively engaged in the activities or in verbalizing their thoughts. The two aspects of cognition under scrutiny are (a) the components of contexts of meaning [episodic knowledge or personal experiences (EK); metaphors (MET); interpretive frameworks (IF); and emotions, values, and aesthetics (EVAs)]; and (b) three general processes involved in knowledge

TABLE 1
Students' Cognitive Involvement During the Worm Activity Interview

	Episodic Knowledge			Metaphors			Interpretive Frameworks			Emotions–Values Aesthetics		
	CAT	A/I	E/ST	CAT	A/I	E/ST	CAT	A/I	E/ST	CAT	A/I	E/ST
Evan		1		3	4	3		5	4		5	6
Amy		3	5		6	4		2	1			2
Adam		1		1	2	3		5	2		1	1
April		2	2		2			3			1	
Emily					5	2		1	1		3	1
Ann						2		1	5	1		2
Ella					1	1	1	3	1	1	1	1
Andy					2				2	1	2	
Elliot						1		1	2		1	2
Earl				1	3	1	1	3	1			
Elaine					2	1	3					
Elise								6				
Arnold								3				
Eddie		1										1
Alex					1							
Angie								1				
Eileen		1										

Note: Number of instances in which the aspects of meaning interacted with processes involved in knowledge development. A/I, associating and inferring; CAT, categorizing; E/ST, elaborating and story-telling.

development [categorizing (CAT), associating and inferring (A/I), and elaborating and story-telling (E/ST)]. Although the children showed evidence of using various components of contexts of meaning independent of the knowledge development processes and vice versa, the focus of this analysis (and Table 1) is on how such aspects of contexts of meaning involved these processes of knowledge development. Since children's thinking is complex, different aspects of contexts of meaning may appear in the same segment of a transcript. For example, a child may generate an anthropomorphic metaphor laden with emotions, values, and aesthetics. In such cases, each aspect was coded to the segment, so that the number of coded instances can exceed the actual number of segments.

The overall patterns of interaction, as depicted in Table 1, show a similar range of activity between first and fifth graders. Approximately 24% of the children showed relatively high levels of interaction between all four contextual components and one or more of the learning processes. Over 29% of the children showed similar levels of interaction between three of the contextual components (all except for episodic knowledge) and one or more of the learning processes. Almost 12%

of the children demonstrated high levels of interaction between (a) two contextual and one or more process components; and (b) one contextual component and one process component. The rest of the children showed low levels of interaction. When interacting with context of meaning components, categorization processes were evident among only seven children, while elaborating and story-telling were evident among 12 children and associating and inferring among 17 children. Such patterns suggest that the components of contexts of meaning, particularly metaphors, interpretive frameworks, and EVAs, substantially influence knowledge development processes. However, I must qualify this claim. Obviously, not all cognition is verbalized, and, in fact, some aspects (such as categorization) may operate automatically and even the individual may not be aware of such processes. The following discussion will explore the more explicit interactions in detail.

The Role of Episodic Knowledge

Episodic knowledge or personal experiences may have played a larger role in the students' thinking than is evident in the transcripts, since only explicitly verbalized instances are used in the analysis of the results. If a child mentioned a specific setting or time in a particular verbalized sequence, the instance was considered to be an example of episodic knowledge. In this particular study, the children showed no explicit reliance upon personal experiences when attempting to categorize earthworms or other animals discussed during the interviews. On the other hand, the interaction of episodic knowledge with associative and inferential processes and with elaborations and story-telling was more common. Among the six students who did exhibit episodic knowledge, it appears to act as a way of (a) establishing a contextual foundation; (b) establishing a comparative association; (c) establishing a comparative basis for an inference; and (d) providing material for elaborating and story-telling.

Establishing a contextual foundation involves the recall of personal experiences that provide a basis for further elaboration or interpretation. For instance, when Adam talks about how worms move, he sets his discussion in the context of experiences he has had fishing.

> Well he moves by the front part. The back part goes forward and the front part goes back. 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 in the front. That's where they put the hook in and that's where the thing eats.

In this instance, Adam's experiences of fishing have provided the context in which to elaborate on the information he is discussing. He is already talking about which is the front and which is the back. He appears to know that already. Furthermore, his personal experiences provide a context for further interpretations, particularly the anthropocentric (interpretive framework) rationale for hook placement.

Establishing a comparative association involves the linking of information from personal experiences with new observations or with other prior knowledge. For example, when asked what's inside earthworms, Evan says,

> That black stuff looks like they've got dirt inside them . . . . Oh! that's just about the weirdest part! Have you ever seen something that you can see through? It's sort of like those things at the science museum. You can see them, you can see little blobs and bones and stuff.

Here, Evan has associated what he has seen in the past at a museum with his current observation of the earthworm.

Establishing a comparative basis for an inference is similar to the previous discussion of associations, except that here the personal experience triggers an inference about a new situation. In this instance, April was asked how the earthworms move. After turning one over she said, "There's little wrinkles in him like snake skin." This comment seems to have very little to do with the question of how worms move. However, several minutes later, she commented that she had not seen many earthworms, but "I know them because of snakes. I know they have wrinkles on the bottom that help them move and I caught a snake before . . . ." After describing her connection with the "wrinkles" she had seen on snakes, we begin to see how her personal experience has provided the comparative basis for the inference of how the wrinkles help worms move.

Episodic knowledge also provides material for elaboration and story-telling. We have seen before how Adam's experiences with fishing allowed him to elaborate on how he knew front from back. Personal experiences can provide a powerful basis for elaboration and story-telling as ways of establishing coherent and meaningful knowledge (Bateson, 1979; Bruner, 1986; Egan, 1988; Hulland, 1990). For example, Amy did not know what earthworms eat, but proceeded to weave the following story about what eats earthworms. (**Boldface** in parentheses designates interviewer's speech.)

> 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, because they got a great big lawn. Ours is very small and we don't usually get birds, just once in a while. **(Do you think they find lots of worms?)** Not really, but yesterday I saw a bird with a worm, or a twig. **(How do they get the worms?)** 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. Sometimes when they squirm they kind of go in like animal slinkies and go. They're moving and they go in and then they move.

Such stories provide a richness of meaning beyond simple concepts, such as, birds eat earthworms. As described by White (1988), "a person whose knowledge of a concept is almost wholly propositional has a different form of understanding than someone with many images or episodes" (p. 51). In the above story, Amy links numbers of worms with numbers of birds and size of lawn with numbers of birds. We even get a glimpse of how her knowledge (and stories) of birds eating worms provided the basis for her inference that the bird she observed on the sidewalk was eating a worm.

The Role of Metaphors

Metaphors act as comparative mechanisms that link different types of information. Such comparisons are evident in the categorizing, associating or inferring,

and elaborating sequences of the students' conversations. The metaphors used by the children are of nine basic types: (a) action links; (b) attribute comparisons; (c) structure–function links; (d) attribute–function links; (e) structure–action links; (f) structure–attribute comparisons; (g) situational transpositions; (h) self as creature (or object) transpositions; and (i) function comparisons. This categorization of metaphors is based upon the characteristics of the metaphors as they appear in the data. Each of these metaphorical types will be discussed in terms of how they affect the three knowledge development processes. Although, in this article, metaphors are being discussed separately from other aspects of contexts of meanings, they are often embedded within or associated with episodic knowledge, interpretive frameworks, or emotions–values–aesthetics.

The two most common types of metaphors were those that linked actions and those that compared attributes. Action link metaphors connect an observed phenomenon to another phenomenon or object. When discussing how earthworms move, the metaphor "slinky" was used by two children. Amy described that, "when they squirm they kind of go in like *animal slinkies* . . . . They're moving and they go in and then they move." An older child, Emily, describes worm movement in more detail:

> [They] kind of slide. It looks like one part of the head moves, stretches, the other part kind of flings back and comes, kind of like one of those *slinkies.* You stretch it and the other part comes flying back. Then the front moves again.

In both cases, the metaphor "slinky" links the observed movement of earthworms with the familiar phenomenon of how slinkies move. The conceptual development of how earthworms move is enhanced by the meaning contained within the metaphorical comparison. Such an associative–inferential process is facilitated by the metaphor.

Attribute comparison metaphors connect an attribute of one phenomenon or object with that of another. For example, Emily's initial reaction to looking at the earthworms was that they looked "gross" and that she did not "like the color." She continued,

> The color, it's a purple that looks like, you know, *when you hold your finger like this for too long, cut off the circulation.* That's what it looks like. Or when you find a *dead body* that's been lying there for a long time. It's usually about purple or blue or something . . . . The head's usually pink and the tail's usually pink. **(Why is that?)** Maybe it had to do with the amount of blood that's in the [head] and tail, too.

Part of the earthworm is not just purple, but is purple like a finger with its circulation cut off or like a dead body. Such a comparison of attributes not only creates a much more robust and meaningful concept of earthworm color, but also provides a contextual background for the inference that the color is due to the amount of blood in a particular area.

Evan's use of a structure–function metaphor contributes to his thinking about how to categorize earthworms. While he was holding an earthworm, which ended up dangling from his fingers, Evan remarked that this "guy is sticky . . . . I don't

know. He hasn't got any *plungers* on him, like a caterpillar." Adam's use of an attribute comparison metaphor leads him to a categorization of earthworms. As he observes several worms, he remarks,

> some of them really go fast. Some even look like an "*S*" . . . . Look, some worms look just like a snake. **(What's the difference between a snake and a worm?)** The worm's smaller than a snake, but worms are just small snakes.

In both cases, metaphors help guide the categorization process. With Evan the metaphor did not confirm a possible categorical association, but with Adam, the "S" shape appeared to trigger an association with snakes.

Metaphors also appear within elaborative and story-telling sequences. In some cases, the stories themselves are metaphorical. For instance, after Amy was asked what it would be like for earthworms living in the ground, she said:

> 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!" **(Worms wear clothes do they?)** I wonder if their skin is really clothes, clothes for them?

Although rooted in an anthropocentric and anthropomorphic framework (which may be grounded in her own personal experiences), the story creates the basis for the skin-as-clothes structure–function metaphor.

Table 2 lists examples of the metaphor types evident among the children in this study. Each example demonstrates how metaphors enrich conceptual understanding. For each child who generates his or her own metaphor, a connection or understanding is established that is not only personally meaningful but also extends

TABLE 2
Examples of Metaphor Types

Child	Metaphor Type	Metaphor
Alex	Action link	"like *springs* and they stretch"
Ann	Action link	"*play dirt games* [underground]"
Adam	Attribute comparison	"they feel like *stickers*"
Amy	Attribute comparison	"it feels like *your sheets are all cool*"
Amy	Structure–function link	"I wonder if their *skin is really clothes*"
Emily	Structure–function link	"a sensor . . . like *cat's whiskers*"
Earl	Attribute–function link	"goes in like . . . *jelly* and then spreads this end out" (describing earthworm movement)
Adam	Structure–action link	"sticked their noses into the dirt and tried to *drill it around*"
Elaine	Structure–action link	"legs [move] like a *barber's [pole]*" (millipede)
Andy	Structure–attribute comparison	"looks like a *dragon's mouth*"
Elliot	Situational transposition	"*I wouldn't ride on him*" . . . too slimy"
Evan	Self-creature transposition	"*it would be dark*" (life as a worm)
Evan	Self–creature transposition	"*it would be lonely*" (life as a worm)
Evan	Function comparison	"antennas are sort of like *eyes and ears*"

that understanding beyond the basic concept. For example, the tip (or "nose") of the earthworm does not just sense the environment, but, for Emily, it functions like "cat's whiskers." All of her personal experiences and knowledge of how cat's use their whiskers are linked to her new observations of how the earthworm appears to be using its "nose." As children explore new phenomena and create new understandings, personally generated metaphors are powerful tools for facilitating, establishing, and extending those understandings.

The Role of Interpretive Frameworks

The interpretive frameworks discussed previously (Bloom, 1990a–c, 1992), include anthropocentrism, anthropomorphism, and zoomorphism. In the present analysis, the following interpretive aspects have been identified. These include: (a) size–sex relations; (b) size–capability relations; (c) effect on humans–category relations; (d) attribute–category relations; (e) attribute–structure relations; and (f) environment–attribute relations (see Table 3 for examples). Four of these aspects (a, b, d, and e, above) appear to be associated with zoomorphic and/or anthropomorphic frameworks. Knowledge and experiences of other animals or human beings may have helped to establish such relations. Aspect c, effect on humans–category relations, appears to be associated more closely with an anthropocentric framework. The last aspect, environment–attribute relations, is more distinct from the centric and morphic frameworks, and, interestingly, has a Lamarckian quality, as well.

TABLE 3
Examples of the Newly Identified Aspects of Interpretive Frameworks

Child	Example
size–sex relations	
Andy	that's a boy, boys are fatter
size–capability relations	
Arnold	I don't think they could [get away from birds], they're pretty small
effect on humans–category relations	
Elaine	[worms] don't bother you [but leeches do] (so they're not the same)
attribute–category relations	
Earl	probably [related to] snakes [because of the] shape
Elaine	leeches have the same like touch, slimy [as worms]
attribute–structure relations	
Angie	skinny part's the back and the fat part's the front
April	the fat end is the head
April	they can see . . . [the eyes] are in the fat part somewhere
Ella	[head's] this side 'cause it's fatter than that side and it's lighter
environment–attribute relations	
April	they live in the [mud] . . . and that makes them slimy
Arnold	slimy . . . because the ground's wet and they live in the ground

Interpretive frameworks, as the name suggests, act as guides to the processes involved in interpreting and making sense of the world. In terms of categorization, Earl's and Elaine's statements in Table 3 are examples of how interpretive frameworks guide the categorization process. In each example, the guiding framework (attribute or effect on humans) influences the selection of attributes or other criteria upon which similarities or dissimilarities are based.

Interpretive frameworks can act as selective guides for associative and inferential processes. The examples in Table 3 demonstrate how particular frameworks affect children's thinking. In fact, the name of each framework suggests the relational pattern that guides the thinking about specific topics. For example, the environment–attribute relation suggests that the environment affects the attributes of animals. April's and Arnold's inferences about why worms are slimy have been guided by such an environment–attribute relational framework.

In a similar way, the more general anthropomorphic, zoomorphic, and anthropocentric frameworks guide inferences, as well. Anthropomorphism, in the form of earthworms' "liking," influences Emily's thinking about why earthworms live in the soil: "they like soil . . . . they just don't like being out in the open. They just like dark places the way we like light places, like Florida. Maybe they just prefer wet places like England." Zoomorphic patterns, that attribute the qualities or structures of one group of animals to another, are strong influences on children's inferences. Arnold's contention that earthworms have eyes in one such example: "I think he has eyes. **(Where would they be?)** Well, they'd be at one end or the other, because if they don't have eyes, I don't think they could see where they're going." Adam's discussion of how to determine the front part of an earthworm is guided by an anthropocentric perspective:

> 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 in the front. That's where they put the hook in and that's where the thing eats.

In each of these examples, children's inferences have been influenced by particular interpretive patterns.

As we have seen in the previous discussion of results, interpretive frameworks also affect and are affected by the recall of personal experiences and metaphors. The same interrelations are apparent with emotions, values, and aesthetics, as well. The richness of such interrelations are most obvious within story-telling episodes. The following is an example from Ann:

> **(What is it that he is doing?)** Slithering along on his tummy. He goes like this (she copies the worm by slithering on the floor). How does he move? I bet he looks . . . I bet the moms tell them when they are babies and then they learn to know. **(How do the moms teach them?)** They show them how over and over again and the babies finally try it and they can do it. This guy's learning, he's going to try it. **(Do you think worms can talk to each other?)** Well, no. **(Do you think they can hear each other?)** No, I don't think so. **(Do you think they can see each other?)** Yeah, I think they can see each other.

The dominant influence on Ann's thinking in this sequence is anthropomorphic or zoomorphic in nature. EVAs and, possibly, personal experiences are involved more

subtly. In another instance, Ann's story about how snakes and worms share the same enemies is a metaphoric and anthropomorphic one:

> Well, the enemies could hurt them in different ways. If a worm was up at the surface and a lion came along and stepped on his head, a lion could be an enemy. And, to a snake, a lion could be an enemy, because the lion could eat it. On the other hand, if it was a poisonous snake, then the snake would be the enemy.

Although the notion of enemy is a human one, Ann uses the idea to explore different relationships between a snake (or worm) and a lion.

In two story sequences from Evan's discussion on earthworms, the inclusion of personal experiences, metaphors, and EVAs are more explicitly apparent. The two sequences are related, but several minutes transpired between them.

> Have you ever ever tried thinking about what it would like to be a bug? **(To be a bug? No. What do you think it would be like?)** I don't know . . . . It would just be dark, I think. It would be a bit boring. I think it would be lonely. **(Lonely?)** I don't know. It just feels weird to be a human being. **(It feels weird to be a human being?)** I don't know. It depends. There are some times when I just get really, really confused. But how come everything, every subject in my life has to do with a Led Zeppelin song I just realized but that has absolutely nothing to do with it. **(So what's so confusing?)** What's so confusing? I don't know. I just feel different. Have you ever noticed on days when it's like really, really sunny. It's a picture that I have. It's like on days when it's really, really sunny . . . . when I go outside, I have a totally new feeling and that must happen to lots of people. But on days when it's really, really sunny, when I go outside or inside, I can hardly tell whether I'm inside or outside. But, I can remember my trip to Florida. It was really sunny and it was really nice. Something like that. Even school days . . . when it's sunny, it's still nice . . . . [Several minutes of discussion elapse.] Worms will not die of being bitten, so you can probably use a worm after being fished. I don't know, a couple of times. I was just wondering. I think worms can drown. I don't know, but usually if the fish bites the worm in half while it's on the hook and it's still on the hook, the worm probably'll live because the worm can't be killed by being bitten. Though if it's digested, the stomach acid would just dissolve it. Or it would drown in the water. But life as a worm, that would be really weird, life as a worm. Have you ever thought about life after death? What happens to you after you die? **(What do you think?)** You may go to a different rank of life? Like the first time you live, from the last time you lived as a human being, you're really, really poor. Or every time you're a different animal. You start off as a worm, and then you come to a horse, and then you come to a human. Or maybe you just go to a different planet, a different dimension. No one knows. Maybe you go to heaven. Maybe you just become a flying mind and just zoom around, eyes and ears. Except nobody knows.

Evan's attempts to understand what life as a worm would be like involve anthropomorphic patterns, as well as the recall of personal experiences, the use of metaphors, and the inclusion of emotions–values–aesthetics. His story becomes a personal one that explores his own questions and ideas about life. It is a reflective, metaphysical story.

The Role of Emotions, Values, and Aesthetics

In the previous sections, EVAs have been associated with other aspects of contexts of meaning. In some instances, EVAs have been subsumed by anthropomorphism as qualities held by other animals. Emily's comments that earthworms ". . . don't like being out in the open" and "like dark places . . . the way we like . . . Florida" attribute the EVA quality of liking to earthworms. In other instances, the child's own reaction to earthworms involved strong EVA responses. Emily's initial reaction was that they were "ugly, tiny, I don't like the color." As you may recall, she then compared the color to that of a finger with its circulation cut off and to that of a dead body. The outcome was one of inferring that blood was helping to create the color. EVA responses make a strong connection with the child. If the color had not evoked such a response, Emily may not have made the connection with blood. Andy's reaction facilitated a similar connection between skin and wetness: "Ooh, yuck, It's disgusting when you feel them. It feels yucky squirmy stuff. [It's skin is like] squirmy yuckies . . . . It's a little wet."

Story-telling, as we have seen, often includes or is stimulated by EVA responses. Ella's story about millipedes is particularly interesting in that it is a fable: "This one's got feet (millipede). My friend told me, here in Canada, if you find one of these, if it bites you, you have to count all its feet or you die." Such a story is particularly tied into her own emotions and personal experiences of living in other countries, in which some of the cultures were heavily influenced by fables and myths. Her family's flight from her country of origin has been characterized by continued apprehension and fear. The legs of the millipede and the possibility of being bitten (she is probably thinking of centipedes) are associated with a larger and EVA-laden story.

DISCUSSION

In the discussion of the results, four components of contexts of meaning (episodic knowledge, metaphors, interpretive frameworks, and emotions–values–aesthetics) have been examined in terms of their influence on knowledge development. The important message is that contexts of meaning do influence learning. However, not all knowlege development evident in the data was explicitly influenced by any of these components of contexts of meaning. In some instances, the influence of contexts of meaning was apparent, but the children worked around the influence. For example, Elise was asked what earthworms ate. She responded,

> Probably dirt. Probably insects or something. No, microscopic thingies. I don't know. Probably mud, earth. **(Why would they eat that?)** Because they feel like getting around in it and well, I guess . . . they don't have any teeth, I don't think. Eew! You can see his veins, or whatever he eats. There's stuff inside him coming down him. Yeah, it's dirt. It looks like it. See?

Although she started off with the same answer she ended up with, she was initially distracted by a zoomorphic influence. The ideas of eating dirt was pushed aside for a more reasonable food of insects, then for "microscopic thingies." What is interesting is her logic that followed. Worms live in the dirt and they do not have teeth.

Then, once she saw what appeared to be dirt inside, she verified her idea that worms eat dirt. Some of the children also came up with the notion that earthworms eat dirt, but others followed a similar zoomorphic path to alternative foods, could not decide between several alternatives, or changed the topic.

The children's development of knowledge and meaning has shown itself to be a complex and dynamic process. The notion of a knowledge structure that is static has not been evident. Knowledge and meaning undergo constant change as new information, connections, and perceptions are taken in and influenced by the various contextual factors. The context of meaning components not only affect the processes of knowledge development, but also affect one another. Interpretive frameworks affect metaphors and EVAs. EVAs affect metaphors and interpretive frameworks and so forth. For example, Ann's metaphor (Table 2), "play dirt games," demonstrates the influence of anthropomorphism. The intermingling of EVAs, personal experiences, and anthropocentric patterns are evident from Andy's reaction to earthworms:

> That is disgusting. **(Why?)** I only like the one at the end of my fishing rod. **(Oh, you go fishing?)** It's sort of bad. **(Why?)** Because he's sort of killable. **(Oh, what happens when you go fishing?)** He gets eaten by a fish.

In addition to the intermingling of influences between several context of meaning components, Andy's example displays the dynamic quality of knowledge and meaning. Looking at the earthworm was disgusting, but he liked the idea of earthworms and fishing. However, as he thought about it further, the use of earthworms for fishing was bad as well, because they get eaten by fish. In similar ways and over longer periods of time, knowledge and meaning undergo constant change.

The teaching of science needs to incorporate how contexts of meaning affect learning. The problem is twofold. On the one hand, the power of contexts of meaning cannot be ignored. Thus, we do a serious disservice to our children in not developing their broader potential of thinking and understanding. On the other hand, the components of contexts of meaning can be perceived as antithetical to the learning of science. As a result, we risk turning children off to science and developing misconceptions about the nature of science and the nature of knowing.

As we have seen, categorizing, inferring, and elaborating are affected by various components of contexts of meaning. The processes and dynamics of meaning and knowledge development are robust and highly personal. Learning from this perspective is personal in the sense that children feel connected to and have ownership of the ideas they have generated. Such processes, as we have seen, are not particularly different between the children in grade 1 and those in grade 5. From the data, it is apparent that children in both age groups are quite similar in their complexity of thinking and level of abstraction. Such results run contrary to popular belief. However, Paley's (1986) examination of preschool children's fantasy play suggests that learning is strongly embedded in their imaginative stories. Such stories provide a context to make sense of their world and provide a means to generate more complex thinking.

Most research and practice have not recognized the impact of contexts of meaning of learning and meaning-making (Bloom, 1992). However, one emerging avenue

of research into learning as a multisource phenomenon suggests that learning goes beyond the simplified notions of specific processes acting on semantic knowledge. The contention is that learning is multisensory and draws on" . . . qualitatively diverse sources of information in the outside world . . . [and] remembering, far from being a single-source retrieval process, also involves integration of information from qualitatively diverse internal and external sources" (Iran-Nejad, McKeachie, & Berliner, 1990, p. 511). The aspect of remembering from this point of view is subsumed by contexts of meaning.

Contexts of meaning describe the natural processes involved in meaningful learning. From a traditional point of view, contexts of meaning hinder academic learning. Such a view holds that anthropomorphism should be avoided in the descriptions of animals or the behavior of other objects and that emotions are not relevant in the study of scientific phenomena. Such claims do not recognize the power and utility or morphic and emotional aspects of knowing. Tamir and Zohar (1991), however, have pointed to the utility of anthropomorphic reasoning for making sense of concepts among high school students and for communicating among scientists. As human beings we are capable of understanding our world and various phenomena from multiple perspectives. We are also capable of understanding how we develop such understandings (i.e., we can recognize that we are being anthropomorphic, etc.). Understanding from different perspectives and understanding how we come to understand are the key aspects of what is meant by saying that contexts of meaning are powerful.

As science educators in western societies, it is difficult to divorce ourselves from the right (scientific) answer syndrome, which tends to see learning science as positivistic and/or empirical in nature. The alternative to such a view involves seeing learning as a holistic, organic, and natural process. To take advantage of such a process in the classroom necessitates (a) recognizing, by teachers and students, the different contexts of meaning and their various components and how they affect the various knowledge development processes (e.g., categorizing, inferring, elaborating, and story-telling); (b) facilitating the use of these components and processes of contexts of meaning; (c) valuing children's idiosyncratic products; and (d) analyzing (with or by students) these products in terms of their contextual and multiple perspective understandings. From this point of view, the process of inquiry not only looks at the object of study, but also at how ideas are formulated and used.

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