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ABSTRACT

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Abstract

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Children's Understandings of Dinosaurs

Dinosaurs, ancient life, and geologic time are among the most frequently studied topics in elementary school science (Bernard, 1991). Many elementary classrooms are decorated with colorful dinosaur posters, plastic dinosaur models, and an assortment of paraphernalia associated with Mesozoic life forms. Museum shops and toy stores enjoy a steady profit from sales of objects imprinted with dinosaur images. Dinosaurs are used to market children's breakfast cereals, wearing apparel, dishes, calendars, and candies. Science fiction writers and the general public have remained fascinated with the term "dinosaur" since it was coined by Richard Owen in 1841 (Kritsky, 1987, p. 28). Modern children's television programs depict cartoon images of Fred Flintstone® sitting astride an Apatosaurus earth mover and Barney® the pinkish-purple dinosaur dancing and leading a group of children in singing "I love you, you love me, we're a happy family". Recently produced Hollywood movies; such as, Baby, Dinosaur!, and Jurassic Park, feature dinosaurs as leading characters. In light of the amount of mass media attention and instructional time devoted to Mesozoic life forms, one might ask, what are children's notions and perceptions of dinosaurs?

Few empirical studies have been conducted to assess children's understandings of ancient life. A search of literature (from electronic databases including ERIC, Current Contents, Mags, Psychlit, Dissertation Abstracts, and CARL), undertaken as part of the current study, reveals that more than 300 articles have been published during the past two decades dealing with the topic of dinosaurs. The vast majority of these articles discuss dinosaurs as a motivational topic in children's reading and language arts programs. Science education articles investigating the topic of dinosaurs may be typically classified as position papers or curriculum development reports (Bernard, 1991; Lockley, 1984; Kritsky, 1987; Rauber, 1992; Stokes, 1989).

Through the use of a contrast group technique, Chi investigated children's understandings of classification using dinosaurs as a topic. Chi (1983) asked students to classify dinosaur pictures into groups in an unstructured classification activity. Findings from this study suggest that children categorize or classify dinosaurs based on concrete properties such as the number and type of appendages dinosaurs possess. This author concluded that children classify objects in a linear, nonhierarchial manner.

In a related study, Gobbo and Chi (1986) inquired into expert and novice children's abilities to produce the names of dinosaurs from pictorial stimuli and their abilities to classify dinosaurs by common characteristics. Findings from this second study indicated that "novices" classify dinosaurs based on superficial features, while "experts" classify dinosaurs based on "deep level" concepts. Additionally, the authors of this study indicated that experts' knowledge of dinosaurs is more integrated and cohesive than novices' knowledge structures. Finally, Gobbo and Chi's study indicated that "experts" are able to access information more readily than "novices".

Theoretical Perspectives on Tacit and Explicit Knowledge

Many children enter elementary school with well defined conceptual knowledge of scientific phenomena which they are able to easily verbalize. Other children seem to hold unconscious conceptual understandings, which they appear to act on, yet are unable to verbalize. Michael Polyani (1966) described this difference between a person's possession of knowledge and an ability to verbalize that knowledge in terms of tacit and explicit knowledge. Polyani states that "we can know more than we can tell" (1966, p. 4). He goes on to point out that there are two types of knowledge, tacit and explicit. What is usually described as conscious knowledge, as set out in written words or maps, or mathematical formulae is only one kind of knowledge - explicit knowledge; while unconscious or unformulated knowledge, such as we have of something we are in the act of doing is another form of knowledge - tacit knowledge (Polyani, 1963, p.12). Polyani points out that tacit knowing has four attributes (a) the functional where we know an object or term only by relying on our awareness of it by attending to a second object or term (Polyani, 1966, p.10); (b) the phenomenal where we are aware of that which we are attending to another thing, in the appearance of that thing (Polyani, 1966, p. 11), (c) the semantic where we are aware of the impact of transposing meaningless feelings into meaningful ones (Polyani, 1966, pp.12-13), and (d) the ontological where we define the meaning of the knowledge (Polyani, 1966, p. 13)). In Polyani's view, there is a movement from a tacit knowledge to something that may be outside of the learner.

Other authors (Alexander, Schallert, & Hare, 1991; Prawat, 1989) have defined tacit knowledge more simply, stating that it is knowledge of which we are normally or currently not aware, having the property of being unanalyzed knowledge. In describing the formation of tacit knowledge, Reber (1989) states that (a) implicit learning produces a tacit knowledge base that is abstract and representative of the structure of the environment; (b) such knowledge is optimally acquired independently of conscious efforts to learn; and (c) can be used implicitly to solve problems and make accurate decisions about novel stimulus conditions (p. 219). Explicit knowledge on the other hand, is knowledge that is directly guiding on-going interaction with the world; it is analyzed knowledge or knowledge that is currently or usually the object of thought (Alexander, Schallert, & Hare, 1991; Prawat, 1989). In explaining the difference between the two types of knowledge, Polyani reflected that the difference between the two kinds of knowledge lies in the fact that we can critically reflect on something explicitly stated, in a way in which we cannot reflect on our tacit awareness of an experience (1963, p. 14).

The current cross-age study was designed to provide "observational windows" into children's thinking and understanding. Arnaudin and Mintzes (1985) point out that cross-age studies provide opportunities to examine changes in students' understandings of scientific phenomena which result from maturation and instruction. It is to be noted cross-age studies provide normative data, rather than evidence of conceptual change within a particular child. The current study was part of a larger study which sought to use Piagetian-type tasks to assess children's conceptual knowledge of dinosaurs and ancient life.

Specifically, this study sought to investigate the following questions:

1. Is there evidence that children hold tacit notions and perceptions of dinosaurs?
2. If there is evidence that children hold tacit notions and perceptions of dinosaurs, how do these notions and perceptions change as a result of instruction and/or maturation?

Method

Subjects

The subjects in this study attended a large southern California school district located near the border of the United States and Mexico. A total of 120 students in grades K-5 were selected as participants. Children were selected from a stratified sample (stratified by grade level) so that equal numbers of subjects at each grade level were sampled. By gender the participants were 54.16% males and 45.84% females. By ethnicity participating subjects could be described as being 49.16% Chicano, 31.83% Anglo, 10.83% African American, and 8.18% Asian American. Linguistically, the children were identified by their parents and teachers as being 20.00% monolingual Spanish speakers, 54.17% monolingual English speakers, and 25.83% bilingual (Spanish/ English) speakers.

Piagetian-type Tasks

As a preliminary step in the task development process, a survey of the five most commonly used (in this geographic area) elementary science textbooks was undertaken. A list of concepts associated with dinosaurs and geologic time was generated from the textual passages, and their frequency among the textbook series was recorded with a tally count. Seven concepts were identified as being common to these textbooks: (a) fossils as evidence of past life, (b) the principle of superposition, (c) fossil formation and/or fossilization by mineralization, (d) geologic time and/or radioactive dating, (e) faunal and/or biotic succession, (f) simultaneity or paleoenvironments, and (g) physical attributes of dinosaurs.

Piagetian-type tasks suitable for individual administration to elementary-aged children were developed by the author to address these concepts. A panel of seven judges (a geologist, a biologist, a science educator, two elementary teachers, and two reading specialists) rated each of the tasks in terms of face validity. Each task was translated into Spanish (since a large portion of the subjects were Spanish speakers) and three elementary bilingual teachers reviewed the Spanish language version to determine the accuracy of the translation.

Design and Data Collection

Interviews were held during the Spring of 1993. With parental consent, the children were individually interviewed in their dominant or preferred language (Spanish or English) by the researcher and graduate assistants. Each interview, approximately 30 minutes in duration, was audiotaped, transcribed for later analysis, and edited for readability. Monolingual Spanish transcripts and some bilingual students' transcripts containing Spanish words and phrases were translated into English prior to analyses. Following transcription and/or translation of the interviews, transcripts were checked for accuracy against the audiotaped interviews by the first author in order to ensure the fidelity of the transcription.

Data Analysis

The first task, the Dinosaur Definition Task, assessed children's abilities to define the concept "dinosaur". Children were presented with plastic models of an Iguanodon, a Stegosaurus, and a Tyrannosaurus; and were asked "What are these?". Probing questions were asked to encourage children to clarify their working definitions of the term "dinosaur". Student responses were scored from the transcripted (and in some cases translated) interviews using a modified form of the concept evaluation scheme developed by Westbrook and Marek (1991; 1992). A coefficient of agreement of $r = 0.85$ was obtained across five raters for this task using the scoring categories shown below:

> *Complete understanding* (scored as 4 points)- The student's response closely approximates the explanation found in an age appropriate science textbook.
> *Partial understanding* (scored as 3 points)- The student's response contains part, but not all, of the information necessary to convey a complete understanding. No incorrect information is included in the explanation.
> *Partial understanding with some inaccuracies* (scored as 2 points) - The student's response contains correct information but also some inaccuracies.
> *Inaccurate information* (scored as 1 point)- The student's response indicates a complete lack of understanding of the concept.
> *No response* (scored as 0 points)- The student's response consists of "I don't know."

The textbook-based criteria for a complete understanding of the concept of dinosaur used to rate middle elementary students' conceptual knowledge was:

> A dinosaur is a member of a group of ancient reptiles. They lived during the Mesozoic era. Some dinosaurs were herbivores and some were carnivores. The name dinosaur means "terrible lizard". Dinosaurs are extinct. we know of them from the fossil record. [1]

The second task, the Mesozoic Diorama Task, assessed children's' abilities to apply their conceptual understandings of dinosaurs or Mesozoic fauna. During the administration of this task, children were presented with a collection of 20 plastic models of ancient and modern animals (Dimetrodon, chicken, Woolly mammoth, Stegosaurus, goat, Hadrosaurus, human, horse, Pteranodon, Tyrannosaurus, Mosasaur, Saber-tooth tiger, Apatosaurus, Ankylosaurus, sheep, cow, Camptosaurus, pig, Triceratops, and Diplodocus). Each child was asked to place those animals that lived during the "Age of Dinosaurs" into a Mesozoic backdrop. As the children manipulated the materials, two separate observations, one on children's classification of the animal models as Mesozoic or non-Mesozoic fauna and a second on their knowledge of specific species' names were recorded. Item difficulties[2] (range 0.65 to 0.98), item discriminations[3] (range 0.05 to 0.58), and item-total correlations[4] (range $\underline{r}$ = 0.02 to 0.62) were computed for each of the 20 models on the classification task. Additionally, a split-half reliability (KR-21) of $\underline{r}$ = 0.90 was computed for the classification subtask. Simple univariate statistics were used to report the percentage of Mesozoic fauna models correctly named by the children on the identification subtask.

The third task, the Dinosaur Coloring Task, assessed student's perceptions of dinosaur skin coloration and pattern; as a measure of students' knowledge of the physical attributes of dinosaurs. Students were given a black-and-white line drawing of a Dimetrodon and were asked to: "Color the dinosaur realistically; that is, the way you think dinosaurs really looked." In interpreting students' responses, a 4-category scoring rubric was devised to holistically rate children's' drawings. The categories were:

Reptilian skin pattern (scored as 3 points) Drawing shows a typical modern reptilian skin pattern (a) darkened dorsal surface and lighter ventral surface, (b) Pine lizard-type stripes, (c) Gila monster-type beading patterns, or (d) Coral snake-like bands of color (vibrant but plausible coloration).
Monochromatic reptilian coloration (scored as 2 points) Drawing shows a monochromatic reptilian coloration - typically green or brown.
Cartoon or fantasy image (scored as 1 point) Drawing shows a fantasy image of dinosaur coloration, including (a) unreal colors (pinkish-purple image) or (b) implausible colors and markings.
No response (scored as 0 points) Drawing is uncolored, no response from the student.

A coefficient of agreement of $\underline{r}$ = 0.95 was computed across the five raters, using this scoring rubric.

Segments of the transcripts pertaining to the Dinosaur Definition Task were analyzed using the Westbrook and Marek scoring rubric, while portions of the transcripts relating to the Dinosaur Coloring Task were evaluated using the aforementioned holistic rating scale. Because an analysis of variance revealed that there were no statistically significant differences between the mean scores of students on any of the three tasks by ethnicity, students' preferred instructional language, or gender; data were analyzed in an aggregate manner. Finally, transcripts and interviewers checklists were analyzed in order to identify common categories of responses among the participants.

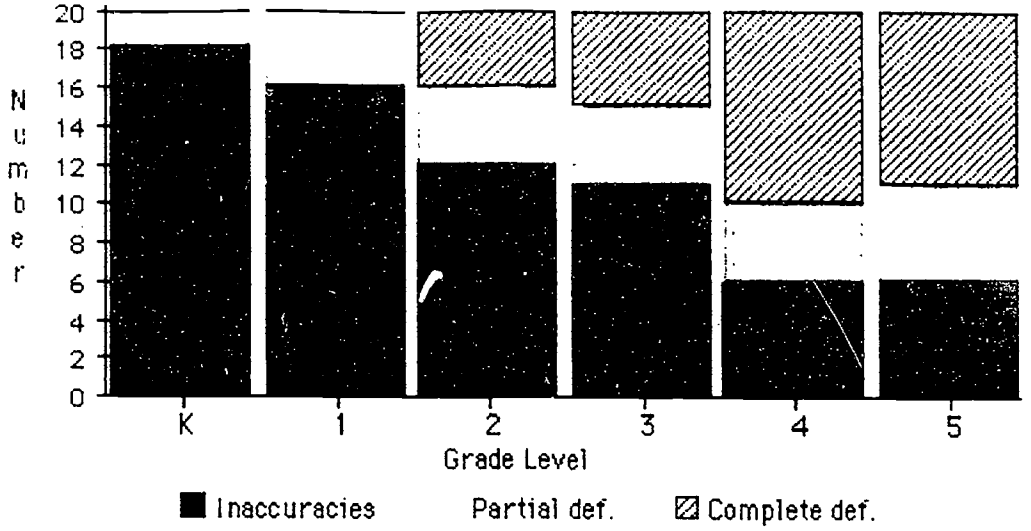
Results

Categories of data addressed in this section emerged from the interviewers' transcripts, from interviewers' notes and comments made on the interviewers' checklists as students worked through the tasks.

Category 1. Childrens' perceptions or notions of dinosaurs.

This category came out of the transcripts of children's audiotaped responses to the Dinosaur Definition Task (Task #1). Since all of the students had previous knowledge of dinosaurs (as evidenced by their correctly identifying the Iguanodon, Stegosaurus, and Tyrannosaurus models as dinosaurs) and verbalized some understandings of dinosaurs, the categories of "no response" and "inaccurate information" were eliminated in the reporting. A distribution of the level of conceptual complexity of students' explicitly stated definitions for the concept "dinosaur" is shown in Figure 1 below:

Figure 1. Distribution of "Dinosaur" Definitions by Conceptual Complexity and Grade Level



Some young children were able to verbalize sophisticated conceptual understandings of dinosaurs. An excerpt from the translated (from Spanish to English) transcript of the interview between Alfredo (a six-year old) and one of the researchers illustrates this type of response:

Interviewer:	I have some models here (pouring dinosaur models from the tray onto the table). Do you know what they are?
Alfredo:	Oh, yes! They're dinosaurs. I like dinosaurs, I got some at home.
Interviewer:	Alfredo, what's a dinosaur?
Alfredo:	It's these (pointing to the model). Animals that lived a long time ago. They ate plants and sometimes animals. Most were big. Tyrannosaurus was the meanest of all. He was fierce, really mean. He ate other dinosaurs.
Interviewer:	Anything else?
Alfredo:	No, that's all I know.

Other primary students had great difficulty verbalizing their conceptual understandings of dinosaurs. An interview with Natasha, a five-year old, illustrates this type of response:

Interviewer:	I have some models (putting dinosaur models on the table). Do you know what they are?
Natasha:	Dinosaurs
Interviewer:	Natasha, what's a dinosaur?
Natasha:	Them
Interviewer:	If I had never heard of dinosaurs before, what would you tell me about them?
Natasha:	It's these.
Interviewer:	Can you tell me more about dinosaurs?
Natasha:	No

Upper elementary students often verbalized a more complex knowledge base regarding dinosaurs. A portion of a transcript between an interviewer and Leticia (a 5th grader) reflects this type of knowledge base:

Interviewer:	What are these? (Putting models of dinosaurs on table)
Leticia:	Dinosaurs, well models of 'em.
Interviewer:	What's a dinosaur?
Leticia:	You know, don't you? This is dumb.
Interviewer:	Okay, let's suppose I had never heard the word dinosaur before, that I came from another planet or something. What would you tell me about dinosaurs?
Leticia:	They're ancient animals that lived on earth a long time ago. And some were really large, like the Apatosaurus and some ... the bird-footed dinosaurs were really small. Some of them lived on the land, some of them in the air, like the Pteranodon and some of them, like Plesiosaur, lived in the water. They've been extinct for a really long time.
Interviewer:	What else?
Leticia:	Well, some of them had armor for protection. And some of them were meat eaters, like the Tyrannosaurus. And some of them ate plants, like Stegosaurus.
Interviewer:	You said dinosaurs were extinct, what's that mean?
Leticia:	Well, it means that none of them are alive today. Dinosaurs lived a long time ago, during the Mesozoic or the Jurassic, I think.
Interviewer:	How long ago was that?
Leticia:	About 100 million years, I think.
Interviewer:	How do you know so much about dinosaurs?
Leticia:	Reading and movies and TV, I guess.

Finally, many children held rich knowledge bases regarding Mesozoic fauna, yet probing questions revealed that they actually lacked a scientist's understanding of the concept. The interview with James (a 1st grade student) illustrates this type of conceptualization:

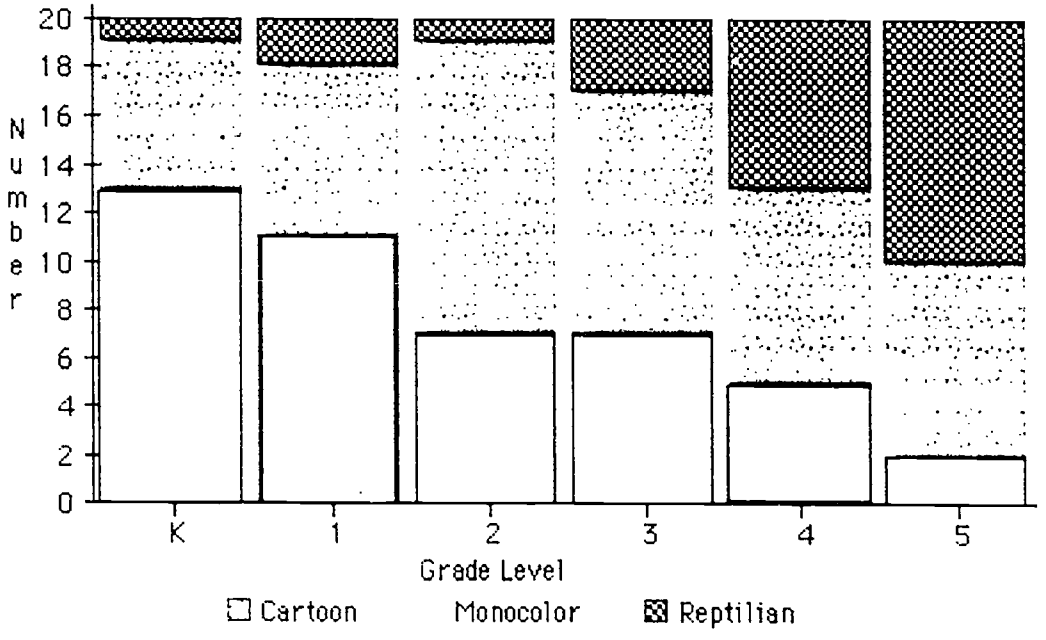
Interviewer:	James, what are these? (showing student the dinosaur models)
James:	Dinosaurs. There's a Tyrannosaurus, this one's Stegosaurus, and that one's .... it's Iguanodon. (accurately identifying dinosaur models)
Interviewer:	Good, you seem to know a lot about them. What's a dinosaur anyway?
James:	They're animals that lived a long time ago. Some were big. They ate plants and some ate other dinosaurs, they're meat eaters. Dinosaur means terrible lizard. Some of them had nests. Some could fly. Some ran on two legs. Tyrannosaurus was mean. He ate other dinosaurs. Stegosaurus had armor for protection. Brontosaurus was supposed the dumbest. It lived in water. They were bigger than a house. My mom took me to see them. At the museum. I saw a Pteranodon, and Stegosaurus, and Tyrannosaurus rex, and oh, yeah, Triceratops, and Diplodocus. I saw a lot of them. They're reptiles, like snakes and lizards. They're extinct.
Interviewer:	You said they're extinct. What's that mean?
James:	They're dead.
Interviewer:	Oh, I see. Extinct means they're dead.
James:	Yeah, extinct, that means they lived a long time ago.
Interviewer:	Could I get one today? If I wanted a Tyrannosaurus for a pet could I have one?
James:	Maybe. You could go to the pet shop. I think, they sell them.
Interviewer:	Oh?
James:	Yeah, some of them are dead, but you could get one to take home.

Interviewer:	Wow! You mean, I could have my very own Tyrannosaurus? Living in my backyard. Gee .... I bet my neighbors would be impressed.
James:	Un ... yeah, you can still get 'em.

Category 2. Children's perceptions of dinosaurs' physical appearance and the source of those perceptions.

Children's representations of dinosaur skin patterns and interviews about those drawings served as evidence in this category of responses. In this task, children were asked to color a black-and-white line drawing of a Dimetrodon. Drawings were rated using the four-category scoring rubric mentioned earlier in the article. A distribution of skin pattern configurations shaded by the children is shown in Figure 3 below:

Figure 3. Distribution of Skin Color Patterns Use by Children



Children in primary grades tended to portray dinosaurs in stereotypical cartoon images. When interviewed about their drawings, these children frequently referred to television shows, movies, and mass media as authority sources influencing their perceptions of dinosaur skin patterns. Young children appear to base their conceptual understandings of dinosaurs on visual images found in their environment. An interview with Jordan, a first grade student, seems to support this assertion:

Interviewer:	I notice that you colored your dinosaur yellow with green spots. (Interviewer is discussing Jordan's colored Dimetrodon drawing.) Why did you pick those colors?
Jordan:	'Cause I wanted it to be like my bed.
Interviewer:	Your bed?
Jordan:	Yeah, I gots yellow dinosaurs on my bed and curtains.
Interviewer:	Oh?
Jordan:	My grandmom made 'em for me.
Interviewer:	You've got a nice grandmother. Do you think dinosaurs were yellow with green spots?
Jordan:	Sure

The distribution of skin patterns for dinosaurs varies as a function of age; older children select reptilian skin patterns more often than younger children. Although cartoon images of dinosaurs persist throughout elementary school years, upper elementary children readily identified these images as being based on cartoon representations rather than on a scientific understanding of dinosaurs. A portion of a transcript between Isabel (a 5th grade student) and an interviewer illustrates this:

Interviewer:	I noticed that you colored your Dimetrodon's body pink, with a green belly and you colored the sail bright yellow. (Referring to Isabel's drawing.)
Isabel:	Yeah, I wanted it to look like Barney®.
Interviewer:	Barney® ?
Isabel:	You know, on TV.
Interviewer:	Were dinosaurs pink?
Isabel:	Probably not, they probably looked like crocodiles or alligators or something. You know, green or brown or something with tan bellies. But I like Barney® a lot. His songs are real cute.

Unlike Jordan (the previously mentioned first grade student), Isabel recognized that dinosaurs probably resembled modern day reptiles, but she elected to color her Dimetrodon in vibrant colors as a matter of preference. By the end of elementary school, 90% of the students were depicting dinosaurs in terms of modern reptilian skin colors and/or skin patterns.

Category 3. Children's applications of their conceptual understandings of dinosaur classification.

This category emerged from transcripts of the Mesozoic Diorama Task (Task #2). Examples were found in the audiotaped interviews and from interviewer's checklists recorded as children worked through the task. The first subtask, of this two-part question, required students to classify 20 animal models as Mesozoic or non-Mesozic fauna. Mean scores and standard deviations for the classification subtask are reported by grade level in Table 1 below:

Table 1
Mesozoic Diorama Task Means and Standard Deviations for Classification Subtask by Grade Level

Grade level	Mean	Standard Deviation
K	16.45	4.36
1	18.80	1.01
2	19.40	0.82
3	18.80	1.19
4	17.75	1.62
5	19.80	0.41

It is interesting to note that while no Kindergarten or first grade student was able to verbalize a textbook definition for dinosaurs, most were able to readily classify models as dinosaurs or non-dinosaur species. Superficially, this finding would seem to conflict with earlier data. Young children were unable to verbalize an accurate working definition for the term dinosaur, yet they were very capable of making visual discriminations between the plastic models. Children's verbalizations of their knowledge of dinosaurs would indicate that they should be unable to complete the classification task, yet even young children performed the task with relative ease.

Category 4. Evidence that children's tacit knowledge of dinosaurs differs from their explicit knowledge.

This category was identified in the transcripts where children worked through the Mesozoic Diorama Task and from the interviewers' checklists of students' responses. This identification subtask served to establish a relative measure of children's knowledge of Mesozoic fauna. A chart showing the percentage of dinosaurs correctly named by children at each grade level is shown in Table 2 below:

Table 2

Mesozoic Diorama Task Scores, Identification Subtask Percentage of Correct Responses by Grade Level

	Grade Level					
Dinosaur model (Dinosaur name and accepted substitute)	K (n= 20)	1 (n= 20)	2 (n= 20)	3 (n= 20)	4 (n= 20)	5 (n= 20)
Dimetrodon (Sail-backed)	10.0 0%	10.0 0%	5.00 %	25.0 0%	35.0 0%	45.0 0%
Stegosaurus	35.0 0%	35.0 0%	35.0 0%	45.0 0%	55.0 0%	65.0 0%
Hadrosaurus (Duck billed)	10.0 0%	10.0 0%	15.0 0%	15.0 0%	25.0 0%	20.0 0%
Pterodactyl (Pteranodon)	10.0 0%	15.0 0%	15.0 0%	20.0 0%	35.0 0%	35.0 0%
Tyrannosaurus (T Rex)	80.0 0%	90.0 0%	100. 00%	100. 00%	100. 00%	100. 00%
Mosasaur (Plesiosaur)	10.0 0%	5.00 %	5.00 %	10.0 0%	10.0 0%	15.0 0%
Apatosaurus (Brontosaurus)	15.0 0%	25.0 0%	25.0 0%	40.0 0%	65.0 0%	75.0 0%
Ankylosaurus	10.0 0%	10.0 0%	15.0 0%	20.0 0%	20.0 0%	25.0 0%
Camptosaurus	10.0 0%	5.00 %	0.00 %	5.00 %	10.0 0%	10.0 0%
Triceratops	10.0 0%	10.0 0%	15.0 0%	25.0 0%	35.0 0%	45.0 0%
Diplodocus	10.0 0%	10.0 0%	0.00 %	10.0 0%	10.0 0%	10.0 0%

Tyrannosaurus was recognized by nearly all of the children. Apatosaurus (Brontosaurus) and Stegosaurus were also widely known among the ranks of elementary-aged children. As was expected, children's knowledge base regarding dinosaur names increased as a function of age. Older children typically named more dinosaur models correctly than did younger children. However, several Kindergarten children in this study possessed a well developed knowledge base regarding dinosaur names. During their performance of the Mesozoic Diorama Task, Kindergarten and first grade students correctly identified 80 and 90% respectively of the plastic models as being dinosaurs. Students ability to name dinosaur species was not correlated ($r = 0.12$) with their ability to verbalize a working definition for the concept of dinosaurs.

Category #5 Children's understandings of geologic time periods.

Young children, those in Kindergarten and first grade, typically identified the Saber-tooth Tiger and the Woolly Mammoth as being modern animals, and thus not living during the "Age of Dinosaurs" (see

Tables 1 and 2). Kindergarten and first grade students relied on physical attributes of models as a means for distinguishing between ancient and modern species. Children of this age classified unfamiliar objects as dinosaurs, while those that were familiar in appearnace were grouped as being modern animals. The Woolly Mammoth was commonly mistaken for an elephant and the Saber-tooth Tiger was mistaken for a modern day tiger. Children in primary grades typically got the "right" answer for the "wrong" reason. Evidence of this type of understanding is found in a portion of a transcript of an interview between Carla (a 1st grader) and one of the investigators:

Interviewer:	Good, you've finished putting the animals into the scene. Why didn't you put this one with the dinosaurs? (Pointing to the Woolly Mammoth)
Carla:	'Cause that's an elephant.
Interviewer:	What about this one? (Pointing to the Saber-tooth tiger)
Carla:	Oh, it's a cat or a tiger or something.

Carla did not recognize the subtle physical attributes that separate "Ice Age" or Pleistocene species from modern species. She correctly identified the Mammoth and Saber tooth as not living during the "Age of Dinosaurs" because she believed them to be modern fauna. Therefore her score on the Mesozoic Diorama Task does not reflect what she actually knows. Students in the third and fourth grades typically showed a more accurate understanding of ancient fauna, but they failed to correctly identify the Mammoth and Saber tooth as Pleistocene species. At this age, students tended to get the "wrong" answer, but for the "right" reason. Julio, a fourth grader, typifies this level of understanding:

Interviewer:	Is that a dinosaur? (Pointing to the Woolly Mammoth)
Julio:	No, it's some kind of ... like an elephant, but it was hairy, but it's not an elephant, it lived a long time ago.
Interviewer:	So, you're putting it in the scene on the "Age of Dinosaurs"?
Julio:	Un ... yeah.
--------- (Later in the same interview)----------	
Interviewer:	Is that a dinosaur? (Referring to the Saber-tooth tiger)
Julio:	No, it's a Saber tooth. They lived a long time ago.
Interviewer:	So, you're putting it in the scene?
Julio:	Yeah, it's extinct, they don't live any more.

Unlike Carla (the 1st grader previously mentioned), Julio recognized that the Woolly Mammoth and the Saber-tooth Tiger were not modern animal species. Julio was able to distinguish between ancient and modern species, but his responses to the Woolly Mammoth and Saber-tooth Tiger items were scored as incorrect, since he placed these models in the Mesozoic diorama. By the end of 5th grade children were able to verbalize the difference between Mesozoic and Cenozoic fauna. These students typically recognized the Woolly Mammoth and Saber-tooth Tiger as being "Ice Age" animals rather than dinosaurs, as seen in Chelsea's (5th grade student) interview:

Interviewer:	You placed that one (referring to the Woolly Mammoth) aside. Isn't it a dinosaur?
Chelsea:	No, that's a Woolly Mammoth. They lived in the Ice Age, after the dinosaurs had died off.
--------- (Later in the same interview) ----------	
Interviewer:	What's that one? (Pointing to the Saber-tooth Tiger model)
Chelsea:	It's a Saber tooth. They lived when the Woolly Mammoths lived. They're not dinosaurs.

From a cross-age perspective, it became apparent that children's ability to verbalize notions of geologic time begins to develop towards the end of elementary school years. Carla (the 1st grader) appears to view animal species in terms of those with which she is familiar and those that are not familiar. Julio (the 4th grader) recognized that some extinct species bear a remarkable resemblance to modern animal species, yet

he is unable to verbally differentiate between periods of geologic time, referring to an amorphous "long ago". Chelsea's (the 5th graders) response illustrates the beginnings of an ability to verbalize a scientific conceptualization of geologic time, in that she is able to state the notion that may be divided into periods characterized by different fauna.

In spite of cartoon images to the contrary, most children held the idea that humans did not live during the "Age of Dinosaurs." Less than 6% of the children in this study identified humans as living during the "Age of Dinosaurs". When asked why they excluded humans from the Mesozoic diorama, children typically stated that "everyone knows that humans didn't live then." They exhibited a tacit understanding of the relative position of humans in geological time.

Discussion

The conceptual knowledge that children bring with them to science learning is largely based on their informal learning and real world experiences in the home and in the community. Some young children interviewed in this study readily identified television shows and movies as being sources of information about dinosaurs, others refereed to experiences in museums as sources of knowledge about Mesozic fauna. Children seem to have unconsciously constructed a tacit knowledge of ancient life through their exposure to dinosaur toys, models, pictures, and visual representations.

Evidence of children's tacit knowledge of Mesozoic fauna was seen in children's ability to accurately classify models as dinosaurs or modern fauna. Although many young children were unable to provide an accurate working definition for the term dinosaur during the dinosaur definition task, they were able to accurately classify faunal representations during the Mesozoic diorama task. Apparently children in this study were able to use their proximal tacit knowledge of the "particulars" of dinosaurs to solve the classification problem because they were provided with a concrete object to which they could relate their knowledge. Children in this study "knew more than they could tell"; they attend from their tacit knowledge, which they are unable to verbalize, to the concrete representation using mental structures which they were unable to verbally define.

The lack of integration between children's conscious and unconscious knowledge bases may be explained in terms of tacit knowledge, both the proximal and the distal as conceptualized by Polyani. Conceptual knowledge appears, from the data in this study, to include formal and informal knowledge of the physical world. Young children in this study had unconsciously acquired an informal knowledge of dinosaurs, a knowledge that they were unable to articulate. This knowledge could be "tapped into" when children were given an opportunity to relate their tacit knowledge to concrete objects.

Hume (1978) and Ault (1982) point out that one of the few major differences between a geologic explanation and non-scientific one is the geologic sciences' dependence on time. As children construct a knowledge of dinosaurs and ancient life through maturation and instruction they seem to append a knowledge of geologic time to their mental constructions. Children in primary grades tend to hold a broad content knowledge of dinosaurs, a knowledge derived from their real-world experiences with dinosaur representations in their environment. As formal instruction into the topic of dinosaurs and ancient life becomes part of their lives, children move to a domain knowledge (beginning scientific understandings) of dinosaurs, as is evidenced by their awareness of geologic time. Eventually, some children will undertake a formal study of paleontology in a university setting. At that time their mental constructions will move from a domain knowledge level to a discipline knowledge level (formal scientific knowledge) of Mesozoic fauna.

Conclusions

A well defined knowledge of fossils and ancient life is a cornerstone of the geological sciences. Dinosaurs and ancient life should continue to be studied in the elementary grades so that children can develop a content knowledge base. Over time children will use these understandings to construct a knowledge of the relationships, the connections, and the more abstract content of geological sciences. Instruction at the elementary level must be based on concrete and visual representations so that children will be able to make the connections from their tacitly held knowledge to the knowledge of the schools, because it is these connections which constitute the construction of the beginnings of scientific knowledge.

If children come to school with extensive prior knowledge bases (tacit knowledge that they are unable to represent verbally) then teachers must assess this knowledge only through a means that gives

students concrete and visual representations to which they can then relate their knowledge. Asking children to verbally express what they know using verbal methods (What do I know?, What do I want to know?, and What have I learned?), a common practice in elementary classrooms, could result in teachers developing a false sense of students' prior knowledge. Semantic maps, word webs, or concept maps are verbal techniques that may fail to tap the rich tacit knowledge that students bring with them to science learning.

Findings from this study suggest that verbally assessing prior knowledge at the beginning of lessons may mislead teachers as to the actual state of students' prior learning. If a teacher uses an assessment strategy that actively engages students with concrete physical tasks, teachers may acquire a more realistic view of students' prior learning. When students are given oportunities to act on their experiences, they are able to utilize knowledge which they are unable to explicate. More investigations are needed in the area of student's formation of mental structures. The relationship between tacit and explicit knowledge should be investigated further. Additionally, assessment devices which utilize students' tacitly held knowledge base or prior learning should be utilized in order to gain deeper insights into students learning.

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