Islands of Expertise:
Describing and Investigating the Impact of Knowledge on Parent Child Talk

by

Sasha Dawn Palmquist

BA, University of Pennsylvania, 2001

Submitted to the Graduate Faculty of

Psychology in partial fulfillment

of the requirements for the degree of

Master of Science

University of Pittsburgh

2005

UNIVERSITY OF PITTSBURGH

FACULTY OF ARTS AND SCIENCES

This masters thesis was presented

by

Sasha Dawn Palmquist

It was defended on

July 1, 2005

and approved by

Jonathan Schooler, Ph.D.

Christian Schunn, Ph.D.

Kevin Crowley, Ph.D.
Thesis Advisor

Islands of Expertise:
Describing and Investigating the Impact of Knowledge on Parent Child Talk

Sasha Dawn Palmquist, MS

University of Pittsburgh, 2005

This research explored how young children's nascent scientific thinking is supported and encouraged in the context of everyday family activity. Using children's knowledge of dinosaurs as the example domain, we investigated: What is included in the knowledge base of children developing dinosaur expertise? How does a child's level of dinosaur expertise impact parent-child conversations as they visit a dinosaur hall in a natural history museum? In study 1, we developed a knowledge assessment that explored children's behavioral and categorical knowledge about dinosaurs. Participants' ability to think scientifically about inferred characteristics like diet, locomotion, and coexistence when directly asked to do so allowed us to refine our definition of the kinds of knowledge and skills that can be supported by an island of expertise. In study 2, we investigated the ways that child knowledge influences family interactions in an informal learning environment. Dinosaur Hall provides a space where parents and children can actively negotiate learning conversation roles. While parents acted as primary information mediators for children with novice understanding of dinosaurs, we found that expert children, empowered by their knowledge, assumed responsibility for initiating more sophisticated topics of conversation within the family group while visiting Dinosaur Hall. These findings reinforce the hypothesis that family conversations in everyday settings can act as a mechanism through which islands of expertise knowledge supports early understanding of scientific thinking at the systems and process levels, as well as categorical and taxonomic levels.

TABLE OF CONTENTS

1. Introduction

Long before encountering their first formal science lessons, children are actively engaged in gathering information about topics, artifacts, and processes that spark their interest and imagination. Often these experiences occur in the company of family and friends in the contexts of everyday activities. Embedded in these experiences are the seeds of scientific thinking and knowledge. Informed by the islands of expertise framework, this research explores how young children's nascent scientific thinking is supported and encouraged in the context of everyday family activity. Using children's knowledge of dinosaurs as the example domain, this research addresses two questions: What is included in the knowledge base of children developing dinosaur expertise? How does a child's level of dinosaur expertise impact parent-child conversations as they visit a dinosaur hall in a natural history museum?

Many young children become intensely interested in and knowledgeable about subjects like trains, horses, ancient cultures, planets, and dinosaurs. When children develop a relatively sophisticated understanding of a topic, like dinosaurs, Crowley and Jacobs (2002), refer to this phenomenon as the development of an island of expertise. An island of expertise emerges through the active pursuit and co-construction of knowledge between parents or caregivers and children. As an island develops, parents establish shared information resources with their children that can be accessed to support conversations in a variety of informal and everyday contexts. By constructing an artifact and information rich environment that incorporates these factors and reflects children's interests and knowledge the cognitive ecology of childhood is enriched. Through reading books, watching videos, collecting toys and games, and visiting museums, an island expands and can support young children as they develop a sense of identity as "experts" for the first time. Developing expertise in a topic like dinosaurs is often driven by children's initial interest. The desire to maintain "expert" status may provide additional external motivation for a child to learn more, integrate new knowledge with prior knowledge and demonstrate their extensive knowledge whenever possible.

As a result of this convergence of self-motivation and parent support, an island of expertise may provide an intellectual space that facilitates the development of domain specific higher level reasoning as well as more generalized learning strategies and social skills. While islands knowledge about a topic like dinosaurs may facilitate learning about some of the big ideas in science (e.g. predation, adaptation, extinction or evolution), connecting and transferring these more sophisticated knowledge structures to other domains is not likely to occur without explicit guidance and mediation. Informal learning environments like museums are uniquely positioned to illustrate these cross-domain connections and provide visitors with opportunities to integrate big ideas into their conversations. Examining family interactions through the islands of expertise framework provides a structure for investigating how families access and apply knowledge in informal learning environments.

2. Childhood Expertise

Many forms of expertise can be achieved through focused study and deliberate practice and researchers have investigated the domain general and the domain specific mechanisms that contribute to expert performance (Ericsson, 1986). Examinations of procedural and problem solving forms of expertise have been conducted in chess (Charness 1996; Chase & Simon, 1973; de Groot 1946/1978;), sports (Starkes & Allard, 1993), music (Sloboda, 1991), medical diagnosis (Patel, 1996), and physics (Chi, Feltovich & Glaser, 1981). In addition, investigations of conceptual or declarative forms of expertise have been conducted in dinosaurs (Chi & Koeske, 1983; Chi et al., 1989; Gobbo & Chi, 1986; Johnson & Eilers, 1998; Alexander et. al, 2002), birds (Tanaka & Taylor, 1991; Johnson 2001), dogs (Tanaka & Taylor, 1991), and fish (Boster & Johnson, 1986; Johnson & Mervis, 1997). While Simon & Chase (1973) suggested that to achieve expertise in any skilled domain an individual must engage in focused study for approximately 10 years, more recent work has qualified this time estimate by emphasizing the importance of engaging in activities designed to improve a critical skill sets in a given domain (Ericsson & Charness, 1994).

Though a 5-year-old child who has established a relatively extensive knowledge base about a topic like dinosaurs cannot satisfy the 10-year definition typically applied to the development of professional expertise, the skills and depth of knowledge achieved by relatively young children can be considered a form of expertise. Beginning with a case study of dinosaur expertise, Chi & Koeske (1983) demonstrated that a relatively young child could possess a sophisticated network representation of the domain of dinosaurs that reflected the available information in his environment (e.g. information included in his collection of dinosaur books). Incorporating and extending this finding, Chi, Hutchinson & Robin (1989) discussed a series of studies illustrating how children structure knowledge in a declarative domain like dinosaurs and how that organization impacts the subsequent application of knowledge. In declarative or conceptual forms of expertise, the ability to correctly identify salient features of objects and use them to categorize instances at basic and subordinate levels is a critical skill for knowledge acquisition. In this set of studies, Chi and colleagues found that childhood dinosaur experts were able to accurately categorize a novel dinosaur based on highly integrated, hierarchical family relations. In contrast, dinosaur novices seemed to rely on surface attributes, greatly limiting the amount of information available to inform categorical placement of a novel dinosaur. Consistent with adult experts in domains like physics, these childhood dinosaur experts were able to look beyond similarities in surface attributes and instead rely on the perception of deep hierarchical relationships to make distinctions among concepts and categories (Chi et. al., 1981).

Discussions of expertise in conceptual/ object-centered domains suggest that the distinctions between novices and experts are dependent on the development of perceptual sensitivity for object attributes, familiarity with subordinate level category names (species), and more generalized verbal and intelligence characteristics (Mervis, Johnson & Mervis, 1994; Johnson & Mervis, 1994). Continuing with this approach to investigating childhood expertise, Johnson & Eilers (1998) conducted a study to determine the impact of domain specific knowledge and level of development on subordinate level category formation and transfer of expert categorization skills to another domain. Through an investigation of both children and adults with high, moderate and low levels of dinosaur knowledge they found that high dinosaur knowledge adults and children were able to accurately differentiate categories at the subordinate level, were less likely to over-extend category assignment, and more likely to under-extend categories. In comparison, child and adult novices performed more poorly on category differentiation, were more likely to over-extend category assignment and less likely to make errors of under extension than more knowledgeable groups. The authors suggest that performance differences between knowledge groups is a result of prior knowledge and perceptual acuity and recognition of salient physical attributes between category examples. While children and adults in knowledge matched groups performed at comparable levels on dinosaur tasks, adults in all groups consistently outperformed child counterparts in their ability to generalize categorization skills to a novel domain (shorebirds). In addition, adults were also more willing to revise incorrect categorization strategies when confronted with contradictory evidence. Johnson and Eilers suggest that unlike the children in this study, adults possess some domain general, metacognitive strategies for attending to perceptual distinctions to inform categorization of biological kinds. This finding suggests that childhood experts in conceptual domains can perceive detailed perceptual differences among examples of biological kinds, however, their ability to correctly associate these feature attributes with categorical distinction is typically not generalized beyond their domain of expertise. Johnson and Eilers conclude that these differences may be attributed to children's lack of experience with the hierarchical organization of other domains.

More recently, Johnson, Scott, & Mervis (2004) have begun to move beyond studies of expert performance on categorization tasks and have conducted two investigations of how adult and child dinosaur experts use their associated conceptual knowledge both within and between biological domains. Johnson and colleagues found that children primarily rely on surface attributes to make selections and justify their reasoning on both familiar and unfamiliar domains regardless of level of knowledge. In a related study, Johnson et. al. (2004) replicated findings from Chi and colleagues (1989) that high knowledge children are able to attend to relatively detailed physical attributes and make inferences based on them. Using an inference task similar Chi and colleagues, Johnson et al found that high knowledge children were able to evaluate whether an image of a novel dinosaur represented a possible or impossible new species more accurately than their less knowledgeable peers. However, unlike high and moderate knowledge adults in the sample, children's reasoning for excluding novel dinosaurs was more often based on the similarity of the proposed dinosaur to other known instances than grounded in possible attribute co-occurances. Johnson and colleagues conclude that for most children, expert levels of knowledge are necessary for more sophisticated reasoning about conceptual relationships, however, knowledge alone is not sufficient to extend and transfer this knowledge to other domains. While higher knowledge adults seem to have this flexibility in knowledge application, children's expertise and associated reasoning skills seem to be restricted to their topic of expertise.

With a few notable exceptions (Gobbo & Chi, 1986; Chi et al 1989; Johnson et al 2004) most existing studies of childhood expertise in conceptual domains suggest that the measure and value added of the knowledge is the ability to know instances of a kind and be capable of more and more detailed categorization. While knowledge of subordinate level categories and their organization is a critical component of expertise, it is not the most exciting potential application for this collection of knowledge. Instead, this knowledge base has the potential to be used to support the development of early scientific thinking and experience with some of the big ideas of science that can be transferred to other biological domains. Islands of expertise can be recognized as instances of early childhood domain specific expertise generated through socially facilitated knowledge acquisition and application to a variety of informal learning opportunities. The process of building an island undoubtedly includes the learning and organization of subordinate level categories and related concepts. However, once children and families have a shared base of knowledge that includes several instances of subordinate level categories, we are interested in investigating how families use this shared information in the context of informal learning environments. As Johnson and colleagues have demonstrated (1998, 2004), knowledge alone is not sufficient to support most children's ability to transfer conceptual knowledge and reasoning between biological domains. However, the islands framework proposes that family conversations in everyday settings can act as the mechanism through which islands knowledge supports early understanding of scientific thinking at the systems and process levels, not just at the categorical and taxonomic levels.

2.1. Parent-child talk: A mechanism for supporting early scientific thinking

Research on children's scientific thinking and reasoning consistently demonstrates their limitations in generating theories, conducting informative tests, and evaluating evidence (Kuhn, 1989; Kuhn, Garcia-Mila, Zohar, & Andersen 1995, Schauble, 1996). However, despite these acknowledged limitations, many children develop mental models of the shape of the earth (Vosniadou & Brewer, 1992) and naïve theories about what fundamentally defines biological entities (Carey, 1985; Keil, 1989) without direct instruction. Klahr (2000) describes this phenomenon as a "developmental paradox", and suggests that while children are unable to consistently use formal scientific methods, they seem capable of discovering and beginning to understand fundamental truths about the world around them. Most of the existing literature reporting on laboratory based research suggests that internal cognitive mechanisms like metacognition, prior knowledge, or theory revision are responsible for the patterns of how children perceive, organize, and interpret new information. It remains unclear if these same mechanisms can account for children's reasoning in everyday settings.

In the context of everyday parent-child activities (e.g. watching T.V., reading books, or driving in the car) research has found that children often ask questions and engage in basic science oriented conversations with their parents (Korpan, Bisanz, Bisanz & Boehme, 1997). When adults provide causal explanations and support basic reasoning, children are more accurate in constructing family relations categories (Krascum & Andrews, 1998). However, without adult modeling and encouragement, children will rarely generate explicit explanations for the construction of categories and their associated reasoning (Goncu & Rogoff, 1998). Research examining parent's assistance of children's scientific reasoning have found that parents are responsive to children's abilities and often provide extra guidance in areas where children need more support and yield control to children in areas where they are more independently capable of task completion (Gleason & Schauble, 2000). This negotiation of roles is consistent with interaction patterns that have been identified as a common context for children's apprenticeship into communities of practice (Gauvain, 2001; Rogoff, 1990). We hypothesize that parents may also use these strategies while interacting with their children in informal learning environments. For example, trips to museums, zoos, and parks often provide specialized opportunities for children to practice reasoning and theory building with the guidance of their parents and in collaboration with peers.

Museum based research has provided insight into the range of ways that families engage with interactive exhibits that support this hypothesis. In these settings, parents often provide labels, pose questions, provide procedural coaching, ask for evidence, highlight causal relationships, and suggest analogies to enrich the museum experience for their children (Ash, 2002; Ash, 2004; Callanan & Jipson, 2001; Callanan & Oakes, 1992; Crowley, Callanan, Tenenbaum, & Allen, 2001). In an extension of these findings, work conducted by Fender & Crowley (in press) suggests that parent explanation changes what children learn from shared science based activities in informal learning environments. Though parents' explanations in these settings were often observed to be incomplete and are unlikely to communicate a deep understanding of the objects or phenomena being observed, research suggests that these explanations are powerful and able to enhance children's learning because they are offered when relevant evidence is the focus of joint parent-child attention. Fender & Crowley (in press) acknowledge that each individual explanation is unlikely to cause large scale conceptual change or theory development, however, the cumulative effect of simple parent explanation over time could be one of the direct mechanisms through which parents and children co-construct scientific thinking in everyday settings. Findings like these suggest that patterns of parent-child talk can be a process as well as an outcome of collaborative family learning (Allen, 2002).

Two studies were conducted to explore the structure and function of one island of expertise—children's knowledge about dinosaurs. In the first study, children were interviewed about the dinosaurs they could identify, behavioral and functional characteristics, and their knowledge of paleontology. Parents also completed a questionnaire about the extent to which children were involved with dinosaurs and the places where that involvement was cultivated. Findings are analyzed to address the question: What is it that an expert, intermediate, or novice child knows about dinosaurs? In the second study, families with expert, intermediate, or novice children were videotaped as they visited dinosaur hall in a natural history museum. Family conversations in the hall are analyzed to reveal how it is that families learn together when they are "on" or "off" an island of expertise.

3. Study 1: Describing the Knowledge of Dinosaur Experts, Intermediates, and Novices

The domain we focus on in these studies is dinosaur knowledge. Dinosaurs are a favorite informal science topic because they offer one of the most compelling and accessible examples of historical science and evolution (Thomson, 2005). Children are fascinated with dinosaurs, perhaps because they are real life monsters—big, scary, exotic, and, of course, extinct. Dinosaurs are not just a topic of formal and informal science, they have crossed over to become a legitimate cultural phenomenon. Children are as likely to see a new dinosaur for the first time on their pajamas or lunchboxes as they are to see it in a museum. Among the many topics that spark children's intense interests, dinosaurs may be one of the best examples of a domain that often supports the development of islands of expertise. Johnson and colleagues (2004) investigated the prevalence of intense interests in pre-school children and the most popular topic of conceptual interest was dinosaurs, maintained by 42% of the sample (p. 333). Recognizing this appeal, dinosaurs have been the topic of several studies of childhood expertise that have revealed the sophistication of child dinosaur experts' knowledge, categorization skills, ability to reason about dinosaurs, and how their knowledge, categorization and reasoning skills compare with those of adults (Chi, Hutchinson, Robin, 1989; Chi & Koeske, 1983; Gobbo & Chi, 1986; Johnson & Eilers, 1998; Johnson, Scott, Mervis, 2004). Only recently have researchers begun to seriously investigate how these bodies of knowledge are developed and sustained by relatively young children (Johnson et. al, 2004).

One of the goals of study one was to develop a knowledge assessment that included features of past assessments (e.g. identification and parent ratings) in order to replicate laboratory-based results from directly recruited subjects from a museum going population. In addition, the inclusion of questions focused on implicit characteristics and inferred behaviors (e.g. diet, interactions, locomotion, categorical relations and co-existence) provided opportunities to observe participants reasoning about types of dinosaur knowledge that less expert children rarely spontaneously produced in prior studies. This insight into children's ability (or inability) to reason about implicit characteristics will allow us to further define the kinds of knowledge indicative of an island of expertise.

3.1. Method

3.2. Participants

Participants were 30 families with children between the ages of 4- and 7-years old recruited while visiting the Children's Museum of Pittsburgh. There were 14 boys and 16 girls who completed the dinosaur knowledge assessment. Eight children were 4-years old, nine children were 5-years old, nine children were 6-years old, and four children were 7-years old.

Age was collapsed into older/ younger categories where older participants (n=14) were 6- and 7-years old and younger participants (n=16) were 4- and 5-years old.

3.3. Procedure

Researchers obtained informed written consent from families prior to conducting the interview. If a child in the target age group approached the table without their parents, they were asked to find their parents in order to complete the written consent document. Parents were asked to complete a questionnaire while their children were interviewed. Parent questionnaires and child knowledge assessment interviews were conducted in a relatively quiet space in the lower level of the museum. The experimenter sat with a table displaying ten model dinosaurs [T-rex, Triceratops, Stegosaurus, Velociraptor, Diplodocus, Allosaurus, Apatosaurus, Iguanodon, Maiasaura, Parasaurolophus, four models of non-dinosaur creatures [giraffe, tiger, Pteranodon, Elasmosaurus] and a rotating platform used to focus attention on a sub-set of figures during individual questions. The average interview lasted 10-minutes and was videotaped.

3.4. Instruments

3.4.1. Dinosaur knowledge assessment interview

The dinosaur knowledge assessment interview included 15-questions designed to elicit four types of knowledge: identification, behavioral characteristics, categorical relationships, and scientific theories related to dinosaurs. With this approach, we directly investigated the kinds of knowledge associated with dinosaur expertise. For the assessment stimuli we selected Carnegie Museum of Natural History Collection resin dinosaur figures. These models represent current scientific knowledge of dinosaur stance and are molded to approximately relative scale. Of the fourteen models on the table, four were non-dinosaurs: two of the non-dinosaurs were mammals (giraffe and tiger) and two were reptiles from the Mesozoic Era (*Pteranodon* and *Elasmosaurus*).

Mammal examples were included because of their familiarity to children as obviously non-dinosaurian, while Mesozoic reptile examples were included to assess whether children could recognize and identify these figures as non-dinosaurs despite their similarity of appearance and popular inclusion in “dinosaur” books. The interview begins with a confidence building activity where participants were asked to identify which creatures on the table were not dinosaurs.

3.4.1.1. Identification

One of the necessary features of childhood dinosaur expertise is the ability to correctly label representations of dinosaurs. Previous studies have consistently demonstrated identification and subordinate level categorization as components of conceptual expertise (Chi & Koeske, 1983; Johnson & Eilers, 1998). In addition, Chi & Koeske (1983) found that dinosaur knowledge was better structured around a set of high frequency dinosaurs (instances that appeared more often in a child’s collection of dinosaur books) and was less well structured around low frequency dinosaurs (instances that appeared less often). Over time, the subject was found to remember and retain high frequency dinosaurs better than low frequency examples. In consideration of this finding, we constructed our identification set of ten dinosaur figures to include five “high frequency” figures (T-rex, Triceratops, Stegosaurus, Velociraptor, Diplodocus) and five “low frequency dinosaurs” (Brachiosaurus, Allosaurus, Apatosaurus, Iguanodon, Maisaura). High frequency figures are representations of those dinosaurs that are prominently featured in many children’s dinosaur books, movies, and TV programs as well as in the local natural history museum’s dinosaur hall. Low frequency figures are representations of those dinosaurs that are familiar, but often less prominently featured in books and videos. The interviewer always indicated the T-rex figure first and asked participants if they knew the name of this dinosaur. Beginning with T-rex was consistent across subjects because T-rex is the single most recognizable and familiar dinosaur species. If participants were familiar with dinosaurs, then beginning with this dinosaur was a confidence builder. However, if participants were completely unfamiliar with dinosaurs, their inability to correctly identify T-rex provided an almost immediate cue for the interviewer to move onto the next section of the assessment. All participants named as many dinosaurs as they could and when they could name no more, the interviewer removed the remaining figures and proceeded to the next section of the assessment.

3.4.1.2. Domain knowledge questions

Based on prior research with childhood dinosaur experts (Chi& Koeske, 1983; Gobbo & Chi, 1986), we anticipated that some of children's knowledge associated with dinosaurs would include behavioral characteristics and categorical relationships. In this section, participants were asked questions about dinosaur diet, locomotion, family relationships, and co-existence. The experimenter used a rotating platform to focus participants' attention on three to four dinosaur figures at a time. Children were asked a question about the featured dinosaurs and were asked to indicate their answer by pointing to the figure or saying the name of the appropriate dinosaur. Following each answer, they were asked to explain their selection. For example:

Some dinosaurs were plant-eaters. Their favorite foods were trees and bushes like these. (fern) Take a look at these dinosaurs. Which of these dinosaurs would think that this (point to plant) was a good meal? [Figures on platform: Allosaurus, Brachiosaurus, Raptor] How come?

3.4.1.3. Theory Generation

In addition to measuring domain-related facts, we were also interested in children's awareness of theories related to dinosaurs and the science of paleontology. This was of particular interest because many informal learning programs integrate elements of paleontology into their dinosaur programs and exhibitions. Most previous expertise work in this area has often restricted questions to dinosaur identification and describing what they know about individual species and their characteristics as opposed to investigating children's knowledge of the process of paleontology. In our assessment, questions were included that focused on how we know about dinosaurs, extinction theories, and generating the name of the scientists who study dinosaurs.

3.4.2. Parent Questionnaire

The parent questionnaire consisted of 12-questions divided into three parts: 7-point Likert scales rating children's interest and knowledge about dinosaurs; 7-point Likert scales rating parent interest and knowledge about dinosaurs; and open-ended questions about their children's interests and favorite activities. Open-ended questions focused on the origins of children's dinosaur knowledge, the kinds of material support for dinosaur interests (toys, figures, books, games) available at home, as well as questions about children's other interests, favorite toys, games, and topics. On average, parents completed the questionnaire in 10 minutes.

3.5. Coding

Participant's responses were analyzed according to the number of correctly identified dinosaur figures, number of correctly identified non-dinosaur figures, number of correctly answered domain and inferential knowledge questions, quality of explanation of forced choice selections, and quality of theories generated and explanations associated with how we know about dinosaurs. Forced choice selection explanations were also coded for the presence or absence of additional inference based dinosaur knowledge included in the explanations. Participants received one point for every correctly identified dinosaur and non-dinosaur figure and one point for every correctly answered forced choice question. The remaining responses for quality of explanations and theories generated were coded on a 0-3 scale for use of causal reasoning and use of domain relevant vocabulary. For example, answers that did not include an explanation (e.g. “don’t know”) received no points, answers that use observable features of the figures that are non-salient for the question (e.g. color, open or closed mouth, or affective traits like nice or mean) received one point, observable features and characteristics that could be salient to the question (e.g. size, stance or informal category references like “longneck”) received two points, and answers that referenced formal categorical relationships (e.g. they’re both sauropods) or causal reasons with respect to features and functions (e.g. it has sharp teeth to tear meat) received three points. Two researchers coded 100% of the data independently and then compared answers for consistency. Agreements were divided by the total number of possible answers generating an inter-rater reliability score of 93% for this coding. All disagreements were subsequently discussed and resolved.

3.6. Results

We first present findings about the number of dinosaurs children could identify, then analyze relationships between the number of identified dinosaurs and children’s domain related and inferred knowledge, and then explore relations between these findings and parent questionnaire data.

3.6.1. Identifying dinosaur species

One of the first indicators of dinosaur knowledge is the ability to identify dinosaurs by name. Participants were more likely to correctly identify T-rex, Stegosaurus, Triceratops, Raptor and Brachiosaurus than they were to identify Iguanodon, Allosaurus, Diplodocus, Maisaura or Apatosaurus. This identification pattern was mostly consistent with our expectations that participants would correctly name all of the figures in the high frequency set more often than those in the low frequency set with the exception that Brachiosaurus (a lower frequency dinosaur) was more often correctly identified than Diplodocus. One explanation for this switch could be that Brachiosaurus' upright stance and head shape may make its identification easier than the Diplodocus that shares many attributes with Apatosaurus (two of the long necked, long tailed plant eaters). In our sample, approximately 30% of participants were unable to correctly identify any dinosaur figures. This was somewhat surprising considering the popularity of dinosaurs among children in this age group. More consistent with expectations, we found that approximately 66% were able to correctly identify T-rex (n=20), 30% were able to correctly identify Triceratops (n=10) and 17% were able to name Stegosaurus (n=5). This distribution of correct identification for three of the most high frequency dinosaurs suggests that most of the sample had minimal dinosaur knowledge.

Consistent with participant knowledge of dinosaur names beyond the two most popular dinosaurs (*T-rex & Triceratops*), performance on the identification section of the assessment revealed that 76% of participants (n=23) could name 2 or fewer dinosaurs, 20% of participants (n=6) could name 3-4 dinosaurs, and only 4% of participants (n=1) could name over 5 dinosaurs, naming 8 during our assessment. A similar pattern was revealed with respect to identifying which figures were non-dinosaur reptiles from the Mesozoic (Pteranodon and Elasmosaurus). In this sample, 73% of participants (n=22) were unable to identify either of the Mesozoic reptiles as non-dinosaurs, 17% of participants (n=5) were able to correctly identify one of the non-dinosaurs, and only 10% of participants (n=3) were able to identify both of the Mesozoic reptiles as non-dinosaurs.

3.6.2. Knowledge Categories & Associated Performance

As noted in previous studies of dinosaur expertise (Gobbo & Chi, 1986; Jonhson & Eilers 1998), one indicator of dinosaur knowledge level is the ability to identify dinosaurs by their subordinate level category or species name. Consistent with previous research strategies, we chose to define expertise categories based on performance on the identification portion of the knowledge assessment. Using a distributional sort, three knowledge categories were formed: novice, intermediate and expert. Novice- Members of the novice group were able to correctly identify two or fewer dinosaurs from the presented set. Intermediate-Members of the intermediate group were able to correctly identify three or four dinosaurs from the presented set. Expert-Members of the expert group were able to correctly identify five or more dinosaurs from the presented set. Analysis revealed that 76% met the criteria for inclusion in the novice category (m=.87), 20% met the criteria for inclusion in the transitional category (m=3.5), and only one participant met the criteria for inclusion in the expert category, correctly identifying 8 dinosaurs.

Based on the distribution of dinosaur knowledge in our sample, we collapsed the three target categories into two groups representing participants with less and more dinosaur knowledge. The novice group became the "less" dinosaur knowledge group (n=23, with 10 boys and 13 girls). In this group, many were unable to name any dinosaurs (n=8), some were only able to identify a single dinosaur (n=10, usually T-rex) and the rest were able to identify 2 dinosaurs (n=5, usually T-rex and Triceratops). The intermediate and expert groups were collapsed and became the "more" dinosaur knowledge group (n=7, with 4 boys and 3 girls). A one-way ANOVA was conducted to determine if age was predictive of expertise category, using dinosaur identification scores as a dependant measure. Analysis of dinosaur identification scores found no significant differences for age category, $F(1, 28)=2.32$, with younger participants (m=1.2) on average correctly naming one fewer dinosaur than older participants (m=2.1).

Though we were primarily interested in how children's level of dinosaur knowledge impacted performance on the assessment interview, we were also curious to determine whether age was a factor that significantly influenced performance. A series of two-way ANOVAs were conducted to explore the impact of age and knowledge on performance on each section of the knowledge assessment.

3.6.2.1. Identification

Analysis of Mesozoic reptile identification scores found a non-significant main effect for knowledge group, $F(1,26)=.21$, where participants in both less ($m=.39$) and more ($m=.25$) knowledge groups typically identified fewer than one of the Mesozoic reptiles; a non-significant main effect for age, $F(1, 26)=1.5$, where participants in both younger ($m=.5$) and older ($m=.13$) age groups typically identified fewer than one of the Mesozoic reptiles; and a non-significant interaction between age and knowledge, $F(1, 26)=.21$.

3.6.2.2. Domain Knowledge

Analysis of domain knowledge scores found a non-significant main effect for knowledge group, $F(1,26)=.00$, where participants in less ($m=7$) and more ($m=7$) knowledge groups answered forced choice questions with equal success; a significant main effect for age, $F(1, 26)=14.5$, $p=.001$, where younger participants ($m=5.5$) correctly answering significantly fewer forced choice questions than older participants ($m=8.8$); and a non-significant interaction between age and knowledge. Analysis of explanation scores for domain knowledge questions found a significant main effect for knowledge group, $F(1, 26)= 4.8$, $p=.037$, where participants in the less knowledge group ($m=21.7$) on average provided less sophisticated explanations for their answers to forced choice questions than participants in the more knowledge group ($m=28$); a significant main effect for age, $F(1, 26)=9.1$, $p=.006$, with younger participants ($m=20.5$) on average providing less sophisticated explanations for their answers to forced choice questions than older participants (m=29.2); and a non-significant interaction between age and knowledge, $F(1, 26)=.002$.

3.6.2.3. Theory Generation & Paleontology Knowledge

Analysis of participants' ability to generate theories of dinosaur extinction found no significant main effect for expertise category, $F(1, 26)=3.4$, $p=.08$, however there is a trend suggesting that participants in the less knowledge group (m=1.3) on average generate fewer theories of extinction than participants in the more knowledge group (m=2); found no significant differences for age category, F(1,26)=,03, with both younger (m=1.6) and older (m=1.7) participants generally able to generate one theory to explain dinosaur extinction; and a non-significant interaction between age and knowledge, $F(1,26)=3.1$. A final analysis of participants' ability to identify paleontologists as the scientists who study dinosaurs found a significant main effect for expertise category, $F(1, 26)=8.2$, $p=.008$, where participants in the less knowledge group never correctly identified paleontologists while members in the more knowledge group (m=.3) correctly identified paleontologists significantly more often; no significant differences for age category, $F(1,26)=.17$, with both younger (m=.13) and older (m=.17) participants generally unable to correctly identify paleontologists; and a non-significant interaction between age and knowledge.

These results suggest that higher levels of dinosaur knowledge impact children's ability to explain their answers to forced choice, domain knowledge questions and improves their awareness of extinction theories and the scientists who study dinosaurs. In addition, these analyses suggest that while older children were not significantly different from younger children in their ability to identify dinosaurs, generate theories of dinosaur extinction and know that paleontologists study dinosaurs, on average older children made significantly better selections on forced choice domain related questions and were better able to articulate the reasons for their selections than younger children. Both participants with more dinosaur knowledge and older participants were able to provide more sophisticated explanations for their responses to domain knowledge questions, often including references to inferred dinosaur knowledge (like behavioral characteristics). Consistent with prior expertise research, this may suggest that knowledge can support more developmentally advanced kinds of scientific thinking. However, in contrast to prior studies, findings from study 1 suggest that even non-dinosaur expert children may know and be able to retrieve inferred dinosaur information when directly asked to do so.

3.6.3. Parent Questionnaires

In previous studies of early childhood intense interests, parent reports have been used to identify childhood experts for inclusion in research (Johnson & Eilers, 1998). More recently, parental ratings have been paired with knowledge assessments as components of expertise measures and used to provide insight into knowledge and interest factors associated with expertise (Johnson et. al., 2004) In this study, through a combination of parent ratings of children, parent self-report, and a small set of follow-up questions focused on material support for children's interests (books, toys, games), this instrument explored the extent to which not only a child but their family participates in the development of an island of expertise through shared activities and the co-construction of dinosaur knowledge. As a result of incomplete information, eight parent questionnaires were excluded from subsequent analysis. Six of these were associated with less knowledgeable participants and two were associated with participants in the more knowledge group.

Analyses of parent questionnaires indicate parent ratings of their children's level of interest in and knowledge about dinosaurs was consistent with knowledge category assignment.

Parents rated their children's knowledge about dinosaurs on a 7-point scale. Children in the more knowledge group received significantly higher parent ratings for knowledge (m=5.8) than children in the less knowledge group (m=2.8), $F(1,20)=18.8$, $p<.000$. Parents also rated their children's interest in dinosaurs on a 7-point scale. Children in the more knowledge group received higher parent ratings for interest (m=4.8) than children in the less knowledge group (m=3.2), $F(1,20)=6.5$, $p<.02$. This agreement between knowledge level category assignment and parent ratings provides a measure of external validity for the assessment.

Comparisons of parents ratings of their own knowledge about dinosaurs revealed that almost 90% of parents with children in the "less" knowledge group rated their children's dinosaur knowledge as equal to or lower than their own knowledge, while 100% of parents with children in the "more" knowledge group rated their children's dinosaur knowledge as equal to or greater than their own knowledge. Comparisons of parents ratings of their own interest in dinosaurs with ratings of their children revealed that 70% of parents with children in the less knowledge group rated their children's interest in dinosaurs as equal to or greater than their own interest, while 100% of parents with children in the more knowledge group rated their children's interests as equal to or greater than their own. This comparison suggests that as children become more knowledgeable in a domain, parents are willing to acknowledge that children can become the family experts in particular domains and that they are willing to support that kind of empowerment.

Parent questionnaires also revealed that 100% of the sample owned dinosaur books and more than half also owned dinosaur figures and movies. There was no relationship between parent report of the presence of dinosaur related toys and objects in the home and children's knowledge category. While we might expect to see differences in the presence of dinosaur materials between the homes of low knowledge and high knowledge children, the current sample did not support that expectation. One explanation for this finding is that in our sample, the range of dinosaur knowledge was relatively narrow, and all of the children were rated as having moderate to high levels of dinosaur interest. As a result, they all may have a similar distribution of basic dinosaur materials. Finally, when parents were asked about their children's other interests, on average parents reported children had three additional interests. For all knowledge level groups, animals were the most popular additional interest reported by parents (65%), followed by arts & crafts (60%) and princesses (43%). These findings suggest that most of the children in our sample had a broad range of interests and with the exception of one child, may not have had a focused enough interest in dinosaurs to have fully developed an island of expertise.

3.7. Discussion

Previous studies of dinosaur expertise have used various forms of knowledge assessments, parent report, and a combination of assessment and parent support to determine knowledge categories for subsequent analysis. Knowledge assessment protocols have featured a range of activities including: card sorts; identification tasks; open-ended elaboration of knowledge related to instances of dinosaurs; statement completion tasks; triad categorization tasks and feature interpretation tasks. Most of these measures require participants to use context free instances of dinosaurs (e.g. pictures of T-rex, Triceratops, or some other dinosaur) to generate related feature based (sharp teeth, duckbilled) and inferential (predatory or herding behavior) knowledge. While children in all knowledge categories are capable of responding to questions about observable dinosaur features, assessments of expertise often consider the percentage of inferential knowledge that children spontaneously produce in relation to dinosaur stimuli as an indicator of expertise. Interestingly, many assessment protocols fail to directly ask about inferential knowledge and instead rely on indirect approaches to elicit this kind of information from participants. In response to this missing component, elements of the assessment protocol in study 1 were designed to directly ask participants about inferential dinosaur knowledge. Findings from study 1 suggest that children with low and intermediate levels of dinosaur knowledge can successfully reason about implicit dinosaur information when directly asked to do so. Previous measures may have underestimated the abilities of lower knowledge participants by placing them in experimental protocol contexts that did not support this kind of reasoning. In addition, because children often learn about dinosaurs in social contexts where parents and children are actively (and directly) asking questions, modeling reasoning and providing explanations, laboratory-based assessments and activities that feature children independently responding to primarily open ended questions may be too far removed from the ways that they typically encounter and learn about this domain for all but the most expert children to succeed.

4. Study 2: Family Learning Conversations On and Off an Island of Expertise

Study 1 provided insight into the level of sophistication with which children who know more or less about dinosaurs were able to identify species, reason about inferred dinosaur knowledge, and explain their answers to dinosaur related questions and their understanding of paleontology. By asking questions that challenged participants to directly focus on inferential knowledge about dinosaurs in ways that were similar to the kinds of conversations that parents and children might have in an informal learning environment, we found that even less knowledgeable participants could be successful. Most studies of expertise have limited their assessments to the structure and application of knowledge in laboratory-based tasks. Recently, Johnson and colleagues have begun to explore other causes and consequences of childhood expertise. Through an examination of the home factors associated with short-term maintenance of focused interests, Johnson and colleagues (2004) found that the emphasis on consistency/ order in the home was correlated with the development of conceptual interests. In addition, opportunities for free play, an educational emphasis in activities, and prioritization of child's interests, were found to be correlated with the maintenance of conceptual interests only when the value of communication was also highly emphasized. While the literature has documented how expert children perform in laboratory-based assessments, research has yet to investigate how expert knowledge is used in real world situations. Johnson and colleagues (2004) have initiated a set of studies considering the implications of conceptual expertise in the transition to formal education, however, these investigations are primarily focused on the relationship between individual factors (IQ and vocabulary) and expert strategy use. Existing research continues to overlook the role of collaborative conversation in supporting children's acquisition and use of expert knowledge. This study represents the first investigation of the way that children's level of knowledge and interest in a conceptual domain like dinosaurs shapes parent-child interactions in a typical informal learning environment.

4.1. Methods

4.2. Participants

Participants were 42 families with at least one child between the ages of 5- and 7- years old recruited while visiting the Carnegie Museum of Natural History. All families were weekend visitors. There were 25 boys and 17 girls. Using a median split at approximately 6-years old, age was collapsed into older (n=20) and younger (n=22) categories.

4.3. Procedure

Interviewers obtained informed written consent from parents and verbal consent from children prior to participation in the study. If a child in the target age group approached the table without their parents, they were asked to find their parents in order to complete the written consent document. Families were asked to allow a research assistant to accompany them during their visit to video record their conversations and interactions. Target children were fitted with a small wireless microphone and asked to say their name to provide a sound check. Families were encouraged to visit Dinosaur Hall as they normally would and return to the table at the entrance after approximately 10 minutes to complete a short knowledge assessment and questionnaire. After completing their visit, the target child completed a knowledge assessment interview that used the same question approach and procedure as study one. While children were interviewed, a parent completed a questionnaire. The experimenter conducted parent questionnaires and child knowledge assessment interviews by the entrance to Dinosaur Hall. Dinosaur stimuli included twelve model dinosaurs: six were high frequency dinosaurs (*T-rex, Triceratops, Stegosaurus, Velociraptor, Brachiosaurus,* and *Diplodocus*) and six were low frequency dinosaurs (*Spinosaurus, Iguanodon, Allosaurus, Maiasaura, Apatosaurus* and *Parasaurolophus*). In addition, the table held four models of non-dinosaurs [giraffe, tiger, *Pteranodon, Elasmosaurus*] and a rotating platform used to focus attention on a sub-set of figures during individual questions. The complete interview was videotaped.

4.4. Instruments

Both the child knowledge assessment interview and the parent questionnaire are closely adapted from study 1. Overall structure and content were similar except where noted below.

4.4.1. Knowledge Assessment

The protocol was streamlined to reduce repetition of topics while preserving the emphasis on inferred behavioral and categorical relationships of dinosaurs. As in study one, the assessment interview measured children's ability to identify dinosaur and non-dinosaur species, correctly associate behavioral characteristics and categorical relationships of dinosaurs, generate scientific theories related to dinosaur reproduction, extinction, paleontological processes and ways of knowing. The revised assessment interview included 14-questions; 10 of which are identical to study 1 and four new questions focused on paleontological ways of knowing designed to further measure the relationship between dinosaur knowledge and the scientific processes that produce that knowledge.

4.4.2. Parent Questionnaire

As in study 1, parents were asked to rate their child's interest and knowledge about dinosaurs and their own interest and knowledge about dinosaurs on a seven point scale. In addition, parents were asked to describe their children's other interests and dinosaur related artifacts in the home. New in study 2, parents were also asked to report the annual frequency of family visits to the Carnegie Museum of Natural History and which exhibits were family favorites.

4.5. Coding

Participant's responses to the knowledge assessment were analyzed according to the same criteria as study one. Two researchers coded 100% of the data independently and then compared answers for consistency. Agreements were divided by the total number of possible answers generating an inter-rater reliability score above 90% for this coding. All disagreements were resolved through discussion.

4.6. Results

In the results we first present findings about the number of dinosaurs children could identify, then analyze relationships between the number of identified dinosaurs and children's conceptual and domain specific knowledge, and explore relationships between these findings and the parent questionnaire data. We then examine parent-child conversations in Dinosaur Hall and investigate the impact of child knowledge level on what families talk about and who is doing the talking.

4.6.1. Identifying Dinosaur Species

As discussed in study 1, ability to identify dinosaur species is a critical component of dinosaur expertise. Of the twelve dinosaur figures used in this assessment, six were high frequency dinosaurs (*T-rex, Triceratops, Stegosaurus, Velociraptor, Brachiosaurus*, and *Diplodocus*) and six were low frequency dinosaurs (*Spinosaurus, Iguanodon, Allosaurus, Maiasaura, Apatosaurus* and *Parasaurolophus*). Consistent with expectations, most participants recognized high frequency dinosaurs, however, the drop off rate for correct identifications was steep. While 92% of the participants correctly named *T-rex* only 66% correctly named *Triceratops.* And while 62% correctly named Stegosaurus only 38% correctly identified *Velociraptor.* Less than 20% of participants were able to correctly name any of the dinosaurs in the low frequency group.

4.6.2. Knowledge Categories & Associated Performance

Participants were assigned to expertise categories based on their ability to identify dinosaur figures from the Carnegie Collection. Novices (42%) could correctly name two or fewer dinosaurs, intermediates (29%) could correctly name three or four dinosaurs and experts (29%) could correctly name five or more dinosaurs. A one-way ANOVA was conducted to determine if age was predictive of expertise category based on dinosaur identification. Analysis of dinosaur identification scores found no significant differences for age category, $F(1,40)=.018$, with younger (m=3.8) and older (m=3.7) participants on average correctly naming the same number of dinosaur species. While age was not found to be predictive of expertise category assignment, we hypothesized that participant scores on associated knowledge questions might be affected by age and expertise consistent with the findings from Study 1. A series of two-way ANOVAs were conducted to explore the impact of age and expertise on performance on each section of the knowledge assessment.

4.6.2.1. Identification

Analysis of participants' scores on identification of non-dinosaurs produced a significant main effect for expertise, $F(2, 36)=6.39$, $p=.004$, but no significant main effect for age, $F(1, 36)= .05$, $p=.82$, nor a significant interaction, $F(2, 36)=.048$, $p=.953$. A Tukey post hoc analysis revealed that successful identification of non dinosaurs by novices ($m<.00$) and intermediates ($m=.22$) were not significantly different from one another. However, both means were significantly lower than the successful identifications by experts ($m=.92$). These findings suggested that on average experts are more successful when identifying prehistoric reptiles as non-dinosaurs than intermediates and novices. In addition, the lack of interaction indicated that age and expertise do not affect participants' ability to identify non-dinosaurs differently.

4.6.2.2. Domain Knowledge

Results of a 2x3 ANOVA on participants' scores on forced choice questions produced a significant main effect for expertise $F(2,36) =12.85$, $p=.000$, and for age $F(1,36)= 5.17$, $p=.03$, but no significant interaction, $F(2,36)= .25$, $p=.78$. A Tukey post hoc analysis indicated that mean scores on the forced choice questions for novices (m=6.1) and intermediates (m=6.8) were not significantly different from one another. However, both means were significantly lower than the mean scores on the forced choice questions for experts (m=9.2). In addition, forced choice scores for younger participants (m=6.8) were significantly lower than scores for older participants (m=7.9). These findings indicated that experts are more successful at choosing the correct answers to forced choice questions about inferred dinosaur knowledge (e.g. diet, interaction behaviors, locomotion, coexistence) than novices and intermediates. In addition, as in study 1, older participants outperformed younger participants when selecting correct answers to domain knowledge questions, which suggested that general knowledge about biological relationships may support successful responses. Following each forced choice response, participants were asked to provide an explanation for their answers. Results of a 2x3 ANOVA on participants' scores on explanations of forced choice responses produced a significant main effect for expertise, $F(2,36) = 4.88$, $p=.013$, and for age $F(1,36)= 15.56$, $p<.000$, but no significant interaction between age and expertise, $F(2, 36)= .27$, $p=.77$. A Tukey post hoc analysis indicated that mean scores on the explanations of forced choice responses for novices (m=19.2) were significantly lower than experts (m=24.5). However, means scores on the explanations of forced choice responses for intermediates (m=22.6) were not significantly different from novices or experts. In addition, mean scores for explanations of forced choice responses for younger participants (m=19.2) were significantly lower than scores for older participants (m=25.3). These findings indicated that experts provided more explanations that were rich in causal reasoning and domain relevant vocabulary than novices. The finding that older participants outperformed younger participants with the quality of their explanations reinforces the idea that expert dinosaur knowledge may support the development of scientific thinking skills that are typically associated with older children.

4.6.2.3. Theory Generation & Paleontology Knowledge

Results of a 2x3 ANOVA on participants responses to open ended questions related to paleontology produced a main effect for age, $F(1, 36)=6.95$, $p=.012$, but no main effect for expertise $F(2, 36)= 2.15$, nor a significant interaction for age and expertise, $F(2, 36)=.427$. Consistent with previous patterns in the assessment data, average scores for older children ($m=8.37$) were higher than for younger children ($m=5.79$). These findings suggest that older children may be more capable of articulating their theories about dinosaur reproduction, extinction and evolution than younger children. A final analysis of participants' ability to identify paleontologists as the scientists who study dinosaurs found a significant main effect for expertise category, $F(2, 36)=9.2$, $p=.001$, where experts ($m=.67$) correctly identified paleontologists significantly more often than intermediates ($m=.25$) and novices ($m=.06$).

These results suggest that higher levels of dinosaur knowledge impact children's ability to make correct selections and explain their answers to forced choice, domain knowledge questions and improves their awareness of the scientists who study dinosaurs. In addition, these analyses suggest that while older children were not significantly different from younger children in their ability to identify dinosaurs and know that paleontologists study dinosaurs, on average older children were better able to articulate theories associated with paleontology than younger children during the assessment. Both participants with more dinosaur knowledge and older participants were able to provide more sophisticated explanations for their responses to domain knowledge questions, often including references to inferred dinosaur knowledge (like behavioral characteristics). Consistent with prior expertise research, this may suggest that knowledge can support more developmentally advanced kinds of scientific thinking.

4.6.3. Parent Questionnaire

As in study 1, the parent questionnaire explored the parents' beliefs about their children's dinosaur interests and knowledge, their beliefs about their own dinosaur interest and knowledge, and some of the material and experiential ways that families support and actively participate development of an island of expertise through shared activities and the co-construction of dinosaur knowledge.

Analyses of parent questionnaires indicate parents' ratings of their children's level of interest in and knowledge about dinosaurs was consistent with knowledge category assignment. Parents rated their children's knowledge about dinosaurs on a 7-point scale. A one way AVOVA found significant differences in parent ratings for children's dinosaur knowledge, $F(2, 39)=28.25$, $p<.000$. Children in the expert category received the highest parents ratings for knowledge ($m=6.7$), while intermediates ($m=5.6$) and novices ($m=3.2$) were rated as less knowledgeable. A Tukey post hoc analysis revealed that while expert and intermediate children's scores were not significantly different from each other, both were rated significantly higher than novices. A second one way AVOVA found significant differences in parent ratings for children's dinosaur interest, $F(2, 39)=13.9$, $p<.000$. Children in the expert category received the highest parents ratings for interest ($m=5.8$), while intermediates ($m=5.1$) and novices ($m=3.6$) were rated as less interested resepectively. A Tukey post hoc analysis revealed that while expert and intermediate children's scores were not significantly different from each other, both were rated significantly higher than novices. This agreement between knowledge level category assignment and parent ratings provides a measure of external validity for the knowledge assessment.

Comparisons of parents' ratings of their own knowledge about dinosaurs revealed that almost 85% of parents with children in the novice category rated their children's dinosaur knowledge as equal to or lower than their own knowledge. In contrast, 75% of parents with intermediate's and 92% of parent with experts rated their children's dinosaur knowledge as equal to or greater than their own knowledge. Comparisons of parents ratings of their own interest in dinosaurs with ratings of their children revealed that 77% of parents with children in the novice category rated their children's interest in dinosaurs as equal to or greater than their own interest, while 92% of parents with intermediates and 75% of parents with experts with children rated their children's interests as equal to greater than their own.

A set of one-way ANOVAs was conducted on parents' responses to questions about the ways they enrich their children's cognitive ecology revealed several significant differences between groups. Parent questionnaires revealed that 95% of participants owned dinosaur books, figures, or movies. Analysis revealed that there was a significant difference between expertise categories and number of different kinds of dinosaur materials that were available at home, $F(2, 29)=5.9$, $p=.006$, with experts ($m=3.6$) having significantly more of a range than novices ($m=2.4$). Intermediates ($m=3.3$) range of dinosaur materials was not significantly different from either group. Unlike study 1, this analysis suggests that presence of a range of dinosaur materials seems to be related to a child's knowledge level. When parents were asked about their children's other interests, analysis revealed no significant differences between expertise categories and average number of other reported interests, $F(2,39)=2.3$, with parents reporting that dinosaur novices ($m=4.2$) have more additional interests than experts ($m=3.6$) and intermediates ($m=3.3$). Finally, an analysis of annual visitation to CMNH revealed a significant interaction between expertise and annual museum attendance, $F(2,39)=5$, $p=.012$, with expert families ($m=2.3$)

reporting that they visit the museum significantly more often than either novices (m=1.7) or intermediates (1.5). Parents of novices and intermediates reported annual visitation was not significantly different. These findings suggest that parents enrichment of the cognitive ecology of childhood around a topic like dinosaurs supports the development of an island of expertise by providing a variety of informal learning opportunities during which parents and children can co-construct a shared body of related dinosaur knowledge.

5. Parent-Child Conversations in Dinosaur Hall

Each family visit to dinosaur hall was video recorded and fully transcribed. Following transcription, all of the visit-talk was segmented by object focus (typically a dinosaur mount/display). Agreements were divided by the total number of possible answers generating an inter-rater reliability score of 88% on this coding.

After segments were identified, a line-by-line coding was conducted to extract the units of topic-focused talk generated by adults and children. We refer to these topic-focused units of talk as mediation pathways. In this analysis, mediation pathways are defined as the ways that parents and children talk about the objects in the hall and information associated with them, in personally meaningful ways. Through these pathways, parents and children negotiate who initiates conversations, introduces new information into discussions, and recognizes connections between observable features of exhibit specimens and domain specific facts and inferences about dinosaurs.

Once mediation pathways were extracted from the visit talk, they were coded for location (e.g. if they were associated with mounts of *T-rex, Diplodocus,* etc.), content and themes addressed (e.g. size, diet, age, locomotion), learning environment support (e.g. reading/ re-voicing signs), who initiated the pathway (adults, target children), and who (if anyone) completed the idea or picked-up on the topic once it was introduced. This process produced nearly 3,000 pathways that were then characterized by 28 content codes (appendix A). Each pathway was coded for specific content and verified for consistency. Agreements were divided by the total number of possible answers generating an inter-rater reliability score of 87% on this coding.

Based on expected themes and patterns that emerged from the data, these 28 content specific m-path codes were coalesced into five over-arching categories of talk that generally characterize the range of conversational content present in family interactions in Dinosaur Hall. These talk categories include: form & function; domain related; analogical/ personal experiences; affective and visit navigation. See the coding summary table below for descriptions and examples of each category of talk.

Categories of Talk	**Descriptions**	**Examples**
Form & Function	Identifying individual parts and connecting them with their uses	"The spiked tail was used to defend itself", "sharp teeth were good for cutting meat"
Domain Related	Description of paleontology processes, detailed categorization	"This is a stone with a fossil in it. Remember the little animal is not there anymore. Just the stone is left"
Analogy/ Personal Experience	Comparing specimens to everyday objects, animals, experiences	"The teeth are sharp, sharp like a steak knife", "I think that's as big as a school bus"
Affective Comments	Identifying favorite dinosaurs/ descriptions of value judgments	"That flying one is so cool" "My very favorite is duckbill. They were plant eaters and were very neat"
Visit Navigation	Way finding/ visit agenda talk	"What do you want to see next?" "*T-rex!*"

Parent-child conversation results reflect these five categories and how they relate to independent variables like expertise category, age category, and gender. In the first set of analyses, family conversations were investigated as a single unit with the distribution of total talk in each of the five summary categories as the dependant measure. The second set of analyses examines the conversational roles that adults and children assume in relation to these 5-overarching categories and the impact of expertise categories on the negotiation of conversational roles.

5.1. What do families talk about?

We anticipated that families with expert children might engage in higher proportions of more sophisticated categories of talk (e.g. form & function, domain related and analogy/personal experience) than families with intermediates and novices. However, results from a 2 way ANOVA for total form-and-function talk (T-rex has sharp teeth that allow it to rip flesh, Stegosaurus used its plates to keep warm) produced no significant main effect for expertise category, $F(2,36)=1.58$, no significant main effect for age, $F(1,36)=.76$, nor a significant interaction for age and expertise, $F(2,36)=1.21$. Results from a 2 way ANOVA for total domain related talk (fossilization process, how and where paleontologists find fossils) were similar to those for form & function talk: no significant main effect for expertise category, $F(2,36)=.57$, no significant main effect for age, $F(1,36)=.83$, nor a significant interaction for age and expertise, $F(2,36)=.52$. Consistent with this pattern, results from a 2 way ANOVA for total analogical/ personal experience talk (Does that look like a bridge? That leg bone is bigger than me!") produced no significant main effect for expertise category, $F(2, 36)=2.59$, no significant main effect for age, $F(1,36)=.35$,nor a significant interaction for age and expertise, $F(2, 36)=1.18$. In contrast to expectations, we found that neither age nor expertise category predicted a significantly different amount of form & function, domain related, nor analogy/ personal experience related m-paths during family visits.

Interestingly, where we began to find group differences was with affective commentary. Results from a 2 way ANOVA for total affective talk (wow, cool, that's my favorite dinosaur) produced no significant main effects for age, $F(1,36)=1.54$, and no main effect for expertise, $F(2,36)= 1.23$, however, there was a significant interaction between age and expertise $F(2, 36)=6.03$, $p=.006$. These findings suggest that while family visit groups with older novices generate significantly more affective m-paths ($m=20.4$) than visit groups with younger novices (m=4.4), this pattern flips for visit groups with older intermediates (m=5.8) and experts (m=7.6) groups, generating fewer affective m-paths than their younger intermediates (m=9.3) and younger experts (m=9.9). One possible reason for this flip might involve the kinds of conversations that are available to groups with older novices. In the absence of fact or inference based commentary, these groups shared more opinions and affective responses during their visits. In contrast, it is possible that groups with older intermediates and experts engaged in conversations that were more evenly distributed across categories of talk producing less affective comments than groups with their younger counterparts. Finally, groups with younger intermediates and experts may share a conversational pattern that often includes discussions of favorite dinosaurs. These conversational components may account for the observed differences.

Finally, results from a 2 way ANOVA of visit navigation talk (desires to see different parts of the hall, questions of what to see/do next) produced a significant main effect for expertise category, $F(2,36)=5.01$, $p=.012$, but no significant main effect for age, $F(1,36)=1.3$, nor a significant interaction for age and expertise, $F(2,36)=2.21$. A Tukey post hoc analysis revealed that while the mean scores for visit navigation talk for families with experts (m=3.3) and novices (m=3.9) were not significantly different from each other, the mean scores families with intermediates (m=6.5) were significantly higher than those for both experts and novices. These findings suggest that families with intermediates may be engaged in more active negotiations of the larger visit agenda while they are in dinosaur hall. While in contrast, it is possible that families with experts and novices (though qualitatively different) have a more clearly defined visit agenda that required less verbal negotiation.

In summary, the lack of significant differences between total family talk in several of these categories, suggests that when parents and children visit Dinosaur Hall they engage in conversations that cover a wide range of topics regardless of their age and level of expertise. From the perspective of the museum this is an encouraging finding. This suggests that when the museum provides impressive reconstructed specimens with associated signage including basic facts all of the groups demonstrated good coverage of those topics. However, we were skeptical of this result that expertise did not seem to be an influential factor in the way that a family talked and interacted in dinosaur hall. We concluded that analysis of family talk as a whole was too broad to capture the influence of expertise on family conversations.

5.2. Parent–Child Contributions to Family Conversations

Our second research question focused on who with in the family group (adults or target children) were responsible for initiating topics of talk during the visit. At this finer grain size we began to observe the impact of expertise on the way that families use informal learning environments like museums to support family learning conversations.

Results of a 2-way ANOVA for form and function talk generated a significant interaction between expertise category and who initiates conversations on this topic, $F(2,39)=4.95$, $p=.01$. There were no main effects for expertise category $F(2, 39)=2.07$, or who initiates form & function talk $F(1,39)=1.55$. Expert children ($m=3.4$) were significantly more likely to initiate conversations about form & function topics that the adults who accompanied them during their visit ($m=.91$). The opposite was true in visit groups with novice children, where we found that adults ($m=1.5$) were more likely to initiate conversations about form & function than children ($m=.44$). In visit groups with intermediate children, adults ($m=.58$) and children ($m=.92$) seem to initiate form & function conversations more equally, with children somewhat more likely to take the lead in these groups.

Analyses of domain-related talk revealed a similar pattern of behavior. Results from a 2-way ANOVA for domain related talk produced a significant interaction between expertise category and who initiates conversations about this topic, $F(2, 39)=5.69$, $p=.007$. There were no significant main effects for expertise category, $F(2, 39)=.65$, or who initiates conversations on this topic, $F(1, 39)=.31$. Consistent with the findings from form-and-function talk, expert children (m=7.7) were significantly more likely to initiate conversations about domain related topics that the adults who accompanied them during their visit (m=2.8). The opposite was true in visit groups with novice children, where we found that adults (m=4.8) were significantly more likely to initiate conversations about form & function than children (m=2.6). In visit groups with intermediate children, adults (m=4.3) and children (m=3.3) shared the responsibility to initiate domain related conversations, with adults somewhat more likely to take the lead.

Results of a 2-way ANOVA for analogy/personal experience talk produced a marginally significant interaction between expertise category and who initiates conversations about this topic, $F(2,39)=2.67$, $p=.08$. In addition, there was a marginal main effects for expertise category, $F(2, 39)=2.6$, $p=.09$. There was no main effect for who initiates conversations on this topic, $F(1, 39)=.23$, $p=.63$. The trend in the means suggests that while expert children (m=10.7) initiate slightly more analogical conversations than the adults with them (m=6.1) and intermediate children (m=10.7) have a similar pattern of behavior with the adults in the their visit groups (m=7.8), the pattern flips for visit groups with novices. In these groups, adults (m=16.1) are more likely to initiate more analogical conversations, while children (m=11.4) initiate relatively fewer.

Results of a 2-way ANOVA for affective talk generated a non-significant interaction between expertise category and who initiates conversations about this topic, $F(2,39)=.43$, $p=.66$.

There was no significant main effect for expertise category, $F(2, 39)=.95$, however, there was a main effect for who initiates conversations on this topic, $F(1.39)=6.42$, $p=.02$. Children in expert (m=6.1), intermediate (m=4.6), and novice (m=7) were found to initiate conversations about affective topics more often than the adults in their visit groups, expert (m=2.8), intermediate (m=3), and novice (m=5.4).

Results of a 2-way ANOVA for visit negotiation talk generated a non-significant interaction between expertise category and who initiates conversations about this topic, $F(2,39)=1.16$. However there was a significant main effect for expertise category $F(2,39)=4.57$, $p=.017$ where intermediate children (m=3) initiate more of these topic conversations than, novices (m=1.6) and experts (m=.67). As well as a significant main effect for who initiates conversations on this topic, $F(1.39)=7.69$, $p=.009$, with adults in visit groups with intermediates (m=3.5), experts (m=2.6), and novices (m=2.3) initiating conversations about visit negotiation than children.

These findings suggest that in an informal learning environment like a museum, childhood expertise in a domain like dinosaurs shifts some of the responsibility for mediating available information from the parent to the child. This pattern is most clearly demonstrated in the analysis of form and function and domain specific topic m-paths, where expert children have the opportunity to demonstrate their knowledge through the initiation of m-paths that shape family learning conversations throughout the visit. While m-path topic totals indicate that all visit groups are exploring the same general range of information when they visit the hall, the critical difference between experts and novices emerges through the analysis of who takes responsibility for initiating more sophisticated topics of conversation. In visit groups with novices, adults assume the primary information mediation role, while for groups with expert children this role is more often occupied by the child.

5.3. Example Interactions

In order to illustrate these patterns more clearly, we include two transcript excerpts—one from a novice family and one from an expert. Like most novice families, this father and son moved through Dinosaur Hall relatively quickly. This pacing, often set by the parent, allows minimal time for exploration and discussion of the available artifacts. Illustrating a typical novice pattern, this father and son engage with a range of content, but they each initiate conversations around different aspects of the hall.

5.3.1. Father and 5-year-old son

> Dad: See the footprint? See how the feet fit in? (Dad leans over and points into the print)
>
> Son: Yeah
>
> Dad: You can see how the claws fit there.
>
> Son: Yeah, I bet their claws were about this wide, (son gestures about a 6-inch space between his hands) but this turned out to be that way (rotates his hands to line up with the imprint)
>
> Dad: Right. Let's look at this one here. (Dad guides them over the *Allosaurus* and points up to the mount) See the ribs? These are the ribs. Feel here on you… do you know what you can feel? (Dad puts son's hands on his torso so that he can feel where his own ribs are located)
>
> Son: I think this part of the bones is like this wide. (Son indicates width with hands) I bet it's about this wide at the end.
>
> Dad: Oh yeah, it does look like that. (Together they walk slowly along the mount) Look it goes all the way to the end of its tail. Look at how long that is. (Dad traces the shape of the tail)
>
> Son: (son turns away and they continue walking into the center of the hall) Wow, he has a long tail. (Points up to the *Apatosaurus*)

Or is that his head. Is that his head? (Points towards the neck and head)

Dad: Yes, that's the head (Points and traces the neck and head)

Son: Wow, that's a umm, big dinosaur. (Both look up at the *Quetzalcoatlus*) I didn't recognize they were that big.

Dad: Yeah, that's a *Pterodactyl*, a flying one. (Son leads and they cross the hall to look at the *Diplodocus*) This one is long. His head is over there, and his tail is way over there. (Dad points and traces the whole length of the dinosaur) Does he look like a bridge? (Son doesn't answer, crosses the hall again and looks into the case with the *Apatosaurus* tail)

Son: And did you know this one that has his tail about that (looks closely at the *Apatosaurus* tail) I think larger.

Dad: What have you got?

Son: See? Even larger

Dad: (Dad leans closer) Oh, a large tail.

Son: (Son crosses the hall again to the *Diplodocus* tail and dad follows behind) I bet that's larger.

Dad: Is it? How would we know? Could you measure?

Son: Because (pause) I just think (pause) a little tiny part about this one is. (Son seems to think *Diplodocus* is larger now) So good thing he has a long tail.

Dad: Uh huh. (Both move to the center of the hall to stand under *T-rex* and look directly up) Look at this one. Do you know what that is called?

Son: What?

Dad: (leans close to see the sign) It's a *T-rex*.

Son: (long pause) I have dinosaur toys.

Dad: Mmm hmm. Are they bones like these?

Son: I have one that's just a bone; I think it's a type of that one (looks up at the *T-rex*)

Dad: There's the umm, head of the other type, umm (points to the *Triceratops'* head)

Son: (walks over to the case at the foot of the *T-rex*, looks at *Polyglyphanodon* lizard) Is that how big the lizards were?

Dad: Mmm hmm. Now what's this? Is that a fossil?

Son: I think so.

Dad: Is it? You can see it in the stone. So it's a stone. This is a stone with a fossil in it.

Son: Is it in it?

Dad: Remember the little animal is not there anymore. Just the stone is left. (pause while son looks up at the *T-rex* again)

Son: Dinosaurs were very huge.

Dad: Yeah, they are pretty big.

This visit seemed to skim the surface of Dinosaur Hall without deeply engaging with much of the available information. Consistent with many novices, this child is impressed with the size and the scale of the dinosaurs on display and the majority of his comments throughout the transcript focus on these attributes. While the father encourages his son to compare features between dinosaurs (length of tail), to identify body parts that he shares with the dinosaurs (ribs), and consider the process of fossilization, the son continually returns to issues of size. This visit record presents a learning conversation in the context of a rich experience that has the potential to support subsequent learning about dinosaurs. However, in its current form this interaction reinforces the idea that novices often see the hall in terms of the surface attributes of the dinosaurs and other prehistoric creatures on display.

Consider now an example of an expert visit. Like most expert families, this mother and son moved more slowly and systemically through the hall. This pacing is often due to the depth of conversational engagement between parents and children as they examine the artifacts on display. As they moved through the space, the son in this family sets the pace while his mother and he bounced the leadership role back and forth when introducing new information into the conversation. While the son was interested in rehearsing his knowledge about dinosaurs, his mother frequently asked questions, challenged his statements, and encouraged him to explain how he knows the facts he recites. Each one of these exchanges gave him an opportunity to make references to his prior knowledge. After stopping and discussing a few plant eating dinosaurs along the wall, the pair make their way to the foot of the T-rex and the son begins to rehearse what he knows.

5.3.2. Mother and 5-year-old son

> Son: *T-rex* was the biggest most fearsome meat eater in the world and it could catch up with a *Triceratops* with its running and its sight was good and its hearing, it could hear a dinosaur very far away. And it was carnivorous.
>
> Mom: Ok, and what does that mean, carnivorous?
>
> Son: Umm, that means that it's a meat eater
>
> Mom: That's right. That means he's a meat eater. [mother smiles and kneels down next to her son to examine the sign in front of *T-rex* more carefully. They both lean over the cushions and read through the information together]
>
> Son: [Son glances back up at the mount and continues his thought] And it would break down and bones and broken flesh
>
> Mom: Right. Now look what it says here [points to top of the sign and son leans over for a closer look] Here it says Triassic, Jurassic, Cretaceous and it says that it lived at the very end of the Cretaceous. That means that it must have been around when the dinosaurs went extinct.

Son: Yes, it was.

Mom: And it was found in the Unites States, it was found in Montana.

Son: And it was the toughest meat eater to rule the planet. Its fingers were ideal to claw onto stuff and its jaws could rip off huge chunks of meat.

Mom: Hmm, did you hear that when they did the show? [Reference to light show and story presentation in dinosaur hall]

Son: Yeah. And its skull…

Mom: Yes, do you know how long it (*T-rex*) was?

Son: [Examines the sign] Yeah, up to 50 feet!

Mom: That's right, you got it! [points to the place on the sign that talks about measurement]

Son: And 15.2 meters. And it would weigh a lot.

Mom: And that's who collected it. Barnum Brown.

Son: In 1902 to 1903.

Mom: [gestures to the sign again and then looks at her son] Well, what year is it now?

Son: 2003.

Mom: So that means that that was 100 years ago. It was discovered 100 years ago.

Son: So that isn't a very long time.

Mom: No, but it's been extinct for a very long time, right?

Son: Yup. [both mother and son look away from the sign and up at *T-rex* in a shared moment of silence. Then the son moves away and heads towards another dinosaur of interest. He stops next to one of the large sauropods and points as he asks his mother] Is that Dippy?

Mom: Yes, that is Dippy.

Son: Dippy is my favorite buddy dinosaur and he has a sculpture outside. He was even the first dinosaur to be discovered.

Mom: Was it?

Son: Yeah. Of the plant eaters. He's been my favorite for a long time.

Mom: Yeah, I like Dippy, too. He was a nice dinosaur. Do you want me to read any of this to you? [Kneels down with son to look at the sign. Son glances at the sign and then back to his mom]

Son: He lived in the Jurassic [points to the sign]

Mom: Exactly, so you can figure out how this works [indicates the time scale on the sign]

Son: She was my favorite that lived at the end of the Jurassic period

Mom: Uh huh.

Son: And that was my favorite time on land when dinosaurs were around

Mom: You know what? It says that *Diplodocus* was a close relative of *Apatosaurus* and that makes sense right?

Son: Yes [mother and son take one final look together at the *Diplodocus* and then son glances at *Apatosaurus*. He waits for mom to stand up and leads the way to the *Allosaurus* mount] Now *Allosaurus*, he's a lot like *T-rex*, a good hunting and stalking dinosaur. He could run fast, and he was strong.

Mom: Yes, it says his jaws were very strong and held teeth that were sharp, sharp like a steak knife [She points to the sign]

Son: Yes, and that means they were good for cutting meat

The Mother and Son engaged deeply with the information presented in Dinosaur Hall. Though the son seemed content to rehearse the things he knew about the dinosaurs as he visited them, his mother took each opportunity to direct his attention to additional sources of information and to challenge him to think more deeply about dinosaurs and how they were related to each other. Consistent with many experts, the boy demonstrates his knowledge through the range of content information he references at each mount. While he and mom talk about size and scale (*Diplodocus*), he also initiates conversation about more sophisticated content like dinosaur diet (*T-rex, Diplodocus, Allosaurus*), interaction with other dinosaurs (*T-rex* and *Triceratops*), and form and function relationships (*Allosaurus'* teeth). Perhaps due to their comfort with the domain content, this mother and son seemed to be in synch when engaging and disengaging in a discussion about a particular mount, regardless of who had expressed the initial interest. In contrast to the novice visit, this expert visit illustrates active and dynamic co-construction of knowledge. Both the novice and expert children were five years old. Although there may be other factors that affected their interactions in the hall, we think the big finding here is that even five year olds—when they are on an island of expertise—are capable of fairly advanced talk and learning through informal activity.

6. General Discussion

Informed by the islands of expertise framework, and the existing literatures on childhood expertise and family learning in museums, this research explored how young children's nascent scientific thinking is supported and encouraged in the context of everyday family activity. Using children's knowledge of dinosaurs as the example domain, this research investigated two central questions: What is included in the knowledge base of children developing dinosaur expertise? How does a child's level of dinosaur expertise impact parent-child conversations as they visit a dinosaur hall in a natural history museum?

In study 1, we developed a knowledge assessment interview that would allow us to investigate the characteristics of children's behavioral and categorical knowledge about dinosaurs. Unlike prior investigations of expertise that use more indirect methods to elicit participant knowledge, by directly asking children questions about inferred characteristics in a way that a parent might when reading The Magic School Bus book series or visiting a museum, we found that lower knowledge participants performed above expectations. Participants in study 1 were recruited from the Children's Museum of Pittsburgh, and as group, we discovered they possessed much less sophisticated dinosaur knowledge than their age-matched peers in study 2. However, despite their inexperience with dinosaurs, they were capable of thinking and reasoning beyond what the existing expertise literature predicted. The finding that children with low to moderate levels of dinosaur knowledge were able to think scientifically about inferred characteristics like diet, locomotion, and coexistence when directly asked to do so allowed us to refine our definition of the kinds of knowledge and skills that can supported by an island of expertise.

For study 2, we investigated the ways that child knowledge impacts family interactions in an informal learning environment. Dinosaur Hall supported similar content features in family conversations, regardless of children's knowledge level category, however, the effect of expertise was demonstrated in who took responsibility for initiating more sophisticated topics. On the continuum of expertise, as children become more knowledgeable, museum visits can provide an opportunity to perform their knowledge with minimal guidance from parents. For more novice visitors, parents provide critical support for their children as mediators of more sophisticated information. For intermediate knowledge children, the roles of parents and children in the conversation tend to shift frequently in response to information and affective responses to the experience. Unlike more formal learning contexts, Dinosaur Hall seemed to provide a space where parents and children actively negotiate learning conversation roles in response to who is empowered as more expert with in the visit group from moment to moment. Findings from these two studies, reinforce the islands of expertise hypothesis that family conversations in everyday settings can act as the mechanism through which islands knowledge supports early understanding of scientific thinking at the systems and process levels, not just at the categorical and taxonomic levels.

7. Future Directions

As we continue to gather data in Dinosaur Hall we are able to generate a more detailed image of who the visitors are and how they interact with a broad range of exhibit elements. The next challenge is to provide parents and caregivers with tools that can extend children's interests and connect them to discipline-specific learning when teachable moments arise. Through participating in our research collaboration, we have found that the museum staff are beginning to change their ideas of who their visitors are and what they are capable of learning about natural history in a dinosaur exhibit. For example, when we began working with the museum we soon found out that one of the common ways to consider visitors was that they were either "streakers, strollers, or students". This resonated with the informal on-floor observations that the staff is able to do as they walk through the spaces they've designed. They can easily see only the time, speed, and path of visitors. But what are those visitors really talking about and learning?

Our research has given the staff a means by which to have conversations that can move beyond their existing models and being to struggle with some answers to these questions. Our partnership reflects a new wave of design experiments that are beginning to be mounted in between the museum and university worlds. Our notion of museums as places that are well suited to seed, nurture, and exploit islands of expertise has begun to find its way into the museum staffs' models of visitor learning. We are now working with the museum in a four-year project to integrate our research into their design of a new Dinosaur Hall that will include a special emphasis on supporting powerful family learning conversations for novices, intermediates, and experts. We look forward to using the new dinosaur hall as a learning laboratory where we can ask questions about the role of informal family activity in the development of children's scientific thinking.

APPENDIX

Detailed Content Coding

A. Visit Navigation talk

-24.Mueum navigation / visit planning (microphone refs., let's go here, I want to see…)

B. Affective talk

-15. Affective comments/ descriptions (scary, ferocious, nice, favorite, neat, cool, wow)

-25. Request for information (tell me what you know, name all of them)

C. Analogy/ personal experience talk

-1. Size (big, biggest without comparison object, long, huge, small, little)

-2. Scale (as big as, as long as, as tall as, number of whole objects, lots of them, all of them)

-3. Museum History/Culture (references to Carnegie, founding of museum, namesake dinosaurs)

-5. Contextual/ prior shared experience comparisons including animals or objects (at the zoo, at the beach, have one like this, reminds me of)

-6. Non-contextual animal (parts/whole) comparisons (looks like, comparative anatomy, feature matching)

-7. Dinosaur comparisons [non-size driven comparison] (diet like a t-rex, looks like raptor, this dinosaur smarter than that one, this dinosaur faster than that one)

-8. Reference to everyday objects, non-size driven (it looks like pool, it looks like a bridge)

-14. Feature descriptions (sharp, pointy, colors, lots of them, # of them w/parts, strong, powerful)

-17. Body parts (unresolved/ no functions attached, placement on creature like spikes on tail, horns on head, plates on back, has a particular part, does not have a particular part)

-18. Family roles reference/ reproduction related (baby, daddy, mommy dino, eggs hatching)

-19. Dinosaurs in culture/ cognitive ecology dinosaur focus (Big Al, Sue, buddy dinosaurs, ducky, Dippy, Jurassic Park, Dinosaur toys, books, movies, pictures, TV shows)

-28. Dinosaurs as school topic (did you learn about this in school, what do I know from school)

D. Form and function Talk (implicit and explicit references)

-9. Body part for protection (tail, spikes, horns) or reference to defense/ protection without explicit mention of body part

-10. Body part for locomotion (legs, counter balance, speed) or reference to speed/ locomotion

-11. Body part for temp regulation (plates)

-12. Body part to make sounds (air passages)

-13. Body parts for sensing/intelligence (nose/ nostrils- scent, eyes-sight, brain size-intelligence) or reference to senses/ intelligence with out associated body part

-26. Body part for eating (teeth for chewing, claws for tearing flesh)

E. Domain related talk

-4. Diet/Taxonomy related to diet (it ate plants/ meat, it’s one of the meat eaters/ plant eaters, carnivore, herbivore, omnivore)

-16. Paleontology (fossil process, how they find them, reconstruction, skeletons, name meanings)

-20. Time/ Age related (how old, time periods, when discovered, coexistence

-21. Geography/ Environment (where found, habitat, continental drift, landscape changes)

-22. Dinosaur/ artifact being classified/ taxonomy (ancestors, descendants, evolution)

-23. Dinosaur Interaction without part references

-27. Diet associated behavior (predator, scavenger, prey, hunt for other dinosaurs)

BIBLIOGRAPHY

Alexander, J. M., Johnson, K. E., & Schreiber, J. B. (2002). Knowledge isn't everything: Analysis of children's performance on a haptic comparison task. *Journal of Experimental Psychology*, *82*, 341–366.

Allen, S. (2002). Looking for learning in visitor talk. In G. Leinhardt, K. Crowley & K. Knutson. *Learning Conversations in Museums*. Mahwah, NJ: Erlbaum.

Ash, D. (2003). Dialogic Inquiry in Life Science Conversations of Family Groups in a Museum. *Journal of Research in Science Teaching,* 40(2), 138-162.

---.(2004).How families use questions at dioramas: Ideas for exhibit design.*Curator*, 47(1),84 100.

---. (2002). Negotiation of thematic conversations about biology. In G. Leinhardt, K. Crowley & K. Knutson (Eds.), *Learning Conversations in Museums*. Mahwah, NJ: Erlbaum.

Boster, J. S.,& Johnson, J. C. (1986). Form or function: A comparison of expert and novice judgments of similarity among fish. *American Anthropologist*, *91*, 866–889.

Callanan, M. A., & Jipson, J. (2001). Explanatory conversations and young children's developing scientific literacy. In K.Crowley, C.D. Schunn, & T.Okada (Eds.), *Designing for science: Implications from everyday, classroom, and professional science*. Mahwah, NJ: Lawrence Erlbaum Associates.

Callanan, M. A., & Oakes, L. A. (1992). Preschoolers' questions and parent's explanations: Causal thinking in everyday activity. *Cognitive Development, 7*, 231-233.

Carey, S. (1985). *Conceptual change in childhood.* Cambridge, MA: MIT Press.

Charness, N., Krampe, R., & Mayr, U. (1986) The role of practice and coaching in entrepreneurial skill domains: An international comparison of life-span chess skill acquisition. In K In K. A. Ericsson (Ed.) *The Road to Excellence: The Acquisition of Expert Performance in the Arts and Sciences, Sports and Games.* (pp.51-80). Mahwah, NJ: Lawrence Erlbaum Associates.

Chase, W.G. & Simon, H. (1973). The mind's eye in chess. In W.G. Chase (Ed.) *Visual information processing* (pp.215-281). New York: Academic Press.

Chi, M. T. H., Feltovich, P., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science*, 5, 121-152.

Chi, M.T.H., Hutchinson, J. & Robin, A.F. (1989) How inferences about novel domain-related concepts can be constrained by structural knowledge. *Merrill-Palmer Quarterly* 35(1) 27-62.

Chi, M.T.H. & Koeske, R. (1983)"Network representation of a child's dinosaur knowledge." *Developmental Psychology* 19, 29-39.

Crowley, K., and Callanan, M.A. (1998) "Identifying and supporting collaborative scientific thinking in parent-child interactions." *Journal of Museum Education* 23.1 (1998): 12-17.

Crowley, K. Callanan, M. A., Tenenbaum, H. R. & Allen E. (2001). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science,12*, 258-261.

Crowley, K., Callanan, M., Jipson, J., Galco, J., Topping, K., & Shrager, J. (2001). *Shared scientific thinking in everyday parent-child activity.* Science Education, 85*, 712-732.*

Crowley, K. & Jacobs, M. (2002). Islands of expertise and the development of family scientific literacy. In G. Leinhardt, K. Crowley, & K. Knutson (Eds.) *Learning conversations in museums* (pp. 333-356). Mahwah, NJ: Lawrence Erlbaum Associates.

Crowley, K., & Knutson, K. (2005). Museum as learning laboratory: Bringing research and practice together. *Hand to Hand* 19(1), 3-6.

Crowley, K., Schunn, C. D., Okada, T. (Eds.). (2001) *Designing for science: Implications from everyday, classroom, and professional settings.* Mahwah, NJ: Erlbaum.

De Groot, A. (1978). *Thought and choice and chess.* The Hague: Mouton (Original work published 1946).

Dierking, L.D., and Falk, J.H. (1994). Family behavior and learning in informal science settings: A review of the research. *Science Education* 78(1), 57-72.

Ericsson, K.A. (Ed.) (1996). *The Road to Excellence: The Acquisition of Expert Performance in the Arts and Sciences, Sports and Games.* Mahwah, NJ: Lawrence Erlbaum Associates.

Ericsson, K.A. & Charness, N. (1994). Expert performance: Its structure and acquisition. *American Psychologist*, 49(8), 725-747.

Falk, J.H., and Dierking, L.D. (2000). *Learning from Museums: Visitor Experience and the Making of Meaning*. Walnut Creek, CA: AltaMira Press.

Fender, J. G., and Crowley, K. (in press) "How parent explanation changes what children learn from everyday scientific thinking." *Journal of Applied Developmental Psychology*.

Gauvain, M. (2001). *The social context of cognitive development*. New York: The Guilford Press.

Gelman, S. A., Coley, J. D., Rosengren, K. S., Hartman, E., & Pappas, A. (1998). Beyond labeling: The role of maternal input in the acquisition of richly structured categories. *Monographs of the Society for Research in Child Development, 63*, (1).

Gleason, M. E., & Schauble, L. (2000). Parents' assistance of their children's scientific reasoning. *Cognition and Instruction, 17*, 343-378.

Gobbo, C., & Chi, M. T. H. (1986). How knowledge is structured and used by expert and novice children. *Cognitive Development*, 1, 221-237

Goncu, A., & Rogoff B. (1998). Children's categorization with varying adult support. *American Educational Research Journal, 35*, 333-349.

Johnson, K. E. (2001). Determinants of typicality throughout the continuum of expertise. *Memory* & *Cognition*, *29*, 1036–1050.

Johnson, K. E., Alexander, J.M., Spencer, S., Leibham, M. and Neitzel, C. (2004) Factors associated with the early emergence of intense interests within conceptual domains. *Cognitive Development* 19, 325-343.

Johnson, K. E., & Eilers, A. T. (1998). Effects of knowledge and development on the extension and evolution of subordinate categories. *Cognitive Development*, *13*, 515–545.

Johnson, K. E., & Mervis, C. B. (1994). Microgenetic analysis of first steps in the acquisition of expertise on shorebirds. *Developmental Psychology*, *30*, 418–435.

Johnson, K. E., & Mervis, C. B. (1997). Effects of varying levels of expertise on the basic level of categorization. *Journal of Experimental Psychology: General*, *126*, 248–277.

Johnson, K. E. & Mervis, C. B. (1998). Impact of intuitive theories on feature recruitment throughout the continuum of expertise. *Memory* & *Cognition*, *26*, 382–401.

Johnson, K. E., Scott, P. & Mervis, C. B. (2004). What are theories for? Concept use throughout the continuum of dinosaur expertise. *Journal of Experimental Child Psychology*,*87*,171–200.

Keil, F. C. (1989). *Concepts, kinds, and cognitive development*. Cambridge, MA: MIT Press.

Keil, F.C. (1998). "Words, moms, and things: Language as a road map to reality." *Beyond labeling: The role of maternal input in the acquisition of richly structured categories.* Ed. S. Gelman, J. Coley, K. Rosengren, E. Hartman, and A. Pappas. *Monographs of the Society for Research and Child Development* 253, 63.1, 152-158.

Klahr, D. (2000). *Exploring science: The cognition and development of discovery processes.* Cambridge, MA: MIT Press.

Korpan, C.A., Bisanz, G.L., Bisanz,J., & Boehme,C. (1997). What Did You Learn Outside of School Today? Using Structured Interviews to Document Home and Community Activities Related to Science and Technology. *Science Education, 81 (6),* 651-662.

Krascum, R. M., & Andrews, S. (1998). The effects of theories on children's acquisition of family-resemblance categories. *Child Development, 69*, 333-346.

Kuhn, D. (1989). Children and adults as intuitive scientists. *Psychological Review, 96*, 674-689.

Leinhardt, G., Crowley, K. & Knutson, K. (2002). *Learning Conversations in Museums*. Mahwah, NJ: Erlbaum.

Leinhardt, G., and Knutson, K. (2004). *Listening in on Museum Conversations*. Walnut Creek, CA: AltaMira Press.

Lehrer, R. & Schauble,L. (in press) Scientific thinking and scientific literacy: Supporting development in learning contexts. *Handbook of Child Development*. Hoboken, NJ: Wiley.

Mervis, C. B., Johnson, K. E., & Mervis, C. A. (1994). Acquisition of subordinate categories by 3-year-olds: The roles of attribute salience, linguistic input, and child characteristics. *Cognitive Development*, *9*, 211–234.

Metz, K.E. (2000). Young children's inquiry in biology: Building the knowledge bases to empower independent inquiry. *Inquiring into inquiry learning and teaching in science.* Ed. J. Minstrell and E. H. van Zee. Washington DC: American Association for the Advancement of Science

Metz, K. (1991). Development of explanation: Incremental and fundamental change in children's physics knowledge. *Journal of Research in Science Teaching, 28*, 785-797.

Patel, V.L., Kaufman, D.R. & Magder, S.A. (1996) The acquisition of medical expertise in complex, dynamic environments. In K. A. Ericsson (Ed.) *The Road to Excellence: The Acquisition of Expert Performance in the Arts and Sciences, Sports and Games.* (pp.127-163). Mahwah, NJ: Lawrence Erlbaum Associates.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press.

Schauble, L. (1996). The development of scientific reasoning in knowledge-rich contexts. *Developmental Psychology, 32,* 102-119.

Siegler, R. S. (1981). Developmental sequences within and between concepts. *Monographs of the Society for Research in Child Development*, 46, 1-84.

Siegler, R. S. (1996). *Emerging minds: The process of change in children's thinking.* New York: Oxford University Press.

Simon, H. & Chase, R. (1973). Skill in Chess. *American Scientist,* 61, 394-403.

Sloboda, J.A. (1991). Musical Expertise. In K. A. Ericsson & J. Smith (Eds.) *Towards a general theory of expertise: Prospects and limits.* (pp.153-171). New York: Cambridge University Press.

Starkes, J.L. & Allard, F. (Eds.) (1993). Cognitive issues in motor expertise. Amsterdam: Elsevier.

Tanaka, J. M., & Taylor, M. (1991). Object categories and expertise: Is the basic level in the eye of the beholder? *Cognitive Psychology*, *23*, 457–482.

Thomson, K.S. (2005). Dinosaurs as a Cultural Phenomenon. *American Scientist*, 93, (3), 212.

Vosniadou, S. & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood*. Cognitive Psychology, 24,* 535-585.

Wellman, H. & Gelman, S. (1998). Knowledge acquisition in foundational domains. In D. Kuhn & R. S. Siegler (Eds.) *Handbook of child psychology: Cognition, perception and language.* New York: Wiley.