From Teachers to Testers: How Parents Talk to Novice and Expert Children in a Natural History Museum

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ABSTRACT: Informed by literature on childhood expertise in high-interest topics and parent–child conversation in museum settings, this study explored how children's level of dinosaur expertise influences family learning opportunities in a natural history museum. Interviews identified children with high and low dinosaur knowledge and assigned them to expert and novice groups. Parent surveys revealed that expert children were more likely to have home environments where family members shared interests in dinosaurs and provided a variety of dinosaur learning resources. Analysis of family conversations demonstrated that parents with novice children *more* actively engaged them in learning conversations than parents with expert children. The implications of this shift in parental engagement are considered in terms of interest and knowledge development in informal settings, highlighting how *islands of expertise* might facilitate and in some cases hinder learning through shared family activity. © 2007 Wiley Periodicals, Inc. *Sci Ed* **91:**783–804, 2007

INTRODUCTION

This research investigated how parents talk and interact with children who have developed expert and novice levels of dinosaur knowledge in authentic informal learning environments. We conducted our research in a museum in order to focus on naturally

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occurring conversations between parents and children in a rich learning setting designed to support inquiry and discovery. Our research explored conversations focused on the content of a dinosaur exhibition. We believe this form of talk offers great potential to support the kinds of learning that can contribute to the development and maintenance of an *island of expertise*.

Children often develop individual interests and choose to pursue these topics more than others when they play, read books with their parents, watch television, etc. (Renninger, 2000). One developmental account of how these interests might transition into deeper knowledge and expertise is the islands of expertise framework (Crowley & Jacobs, 2002). We suggest that in collaboration with parents, caregivers, family, and friends, children can develop an island of expertise—a collection of knowledge, interest, and activity around a specific topic. For children who are actively building an island of expertise around a topic like dinosaurs, family support is critical to the development of information-processing skills that can help them to maintain and foster their interest. Research on children's early intense interests revealed that children's most frequent focused interests were around dinosaurs (Johnson, Alexander, Spencer, Leibham, & Neitzel, 2004). In addition, classic expertise research by Chi and Koeske (1983) suggested that relatively young children are capable of developing detailed and organized knowledge about dinosaurs. Supported by this work, we selected dinosaurs as our example domain to investigate how islands of expertise influence family learning in museum settings.

When developing an island of expertise around dinosaurs, young children, in cooperation with parents and caregivers, actively collect information and experiences that expand their knowledge about dinosaurs through reading dinosaur-themed books, suggesting dinosaur DVDs or TV programs, using the Internet to track recent discoveries and visiting museums and active excavation sites. Learning sciences research has been interested in exploring how collections of experiences support the development of interest, knowledge, and identity (Barron, 2004). Building from the islands of expertise theory, Shaffer (2004, 2006) suggested that through coordinated activities that are consistent with a particular community of practice, students could develop *epistemic frames* that may support connections between "islands" knowledge and novel domains.

The islands of expertise theory suggests that family conversations provide a mechanism for children and parents to collect and integrate pieces of knowledge into more sophisticated conceptual understanding. This hypothesis is reinforced by a set of findings indicating that placing an emphasis on communication and supporting curiosity in the home are significant factors in the maintenance of preschool children's intense interests (Johnson et al., 2004; Leibham, Alexander, Johnson, Neitzel, & Reis-Henrie, 2005). This implies that conversation is likely a critical mechanism in the development and maintenance of the kinds of intense interests that support the development of islands of expertise. Through a variety of activities, children working on a dinosaur island of expertise begin to master the pronunciation of complicated names and refine the ability to recognize and describe dinosaur species. This naming knowledge becomes the foundation on which to build an understanding of the categorical and behavioral implications of specific dinosaur features. As children and their families collect dinosaur knowledge, we would expect that opportunities for the development of deeper scientific inquiry would occur both in terms of conceptual development and information-gathering strategies.

When we discuss "deeper" or more "sophisticated" inquiry, we refer to the notion that, as individuals become experts, their patterns of interaction with the objects of study in their field shift from focusing on surface characteristics to investigating and comparing nonapparent functional and categorical characteristics. Research on expertise in object-centered domains such as dinosaurs suggests that the distinctions between novices and experts are dependent on the development of perceptual sensitivity for object attributes and familiarity with subordinate level category names (e.g., at the species level) (Johnson & Eilers, 1998; Johnson & Mervis, 1994; Johnson, Scott, & Mervis, 2004; Mervis, Johnson, & Mervis, 1994). In addition to categorization skills, with the development of expertise, children's mental representations of dinosaur species may also become more flexible and detailed. For example, individual species (like the *T. rex)* may begin to be understood within a larger system of interaction (the Cretaceous food chain) instead of being described and understood exclusively as an individual object of study. This movement from a centralized to a decentralized understanding of knowledge systems is consistent with expertise in complex domains (Hmelo-Silver & Pfeffer, 2004).

Investigating the capabilities and limitations of childhood expert knowledge has been modeled primarily after classic adult expertise studies (Chi, Feltovich, & Glaser, 1981; Ericsson, 1996). Consistent with this tradition, many childhood expertise studies have been conducted in laboratory settings using decontextualized tasks to elicit children's knowledge and understanding of topics (Chi, Hutchinson, & Robin, 1989; Chi & Koeske, 1983; Gobbo & Chi, 1986; Johnson et al., 2004). While these studies have provided insight into the content of child-expert's knowledge, they have not identified how we might consider the coordination between the knowledge and skills children have, their ability to use them in an authentic learning environment, and what role parents might play in this activity. The islands of expertise theory operates from a sociocultural perspective that suggests that the development of expert knowledge is co-constructed with parents, caregivers, and peers across learning opportunities in everyday contexts. Consistent with this approach, we would expect that the habits of information collection and processing established in collaboration with parents might influence the kinds of information that can be connected to an island of expertise. Prior expertise literature has found that the specific ways that experts regularly use knowledge influences the organization and later availability of that information (Hmelo-Silver & Pfeffer, 2004; Tanaka & Taylor, 1991).

Museum settings offer researchers an opportunity to observe and investigate patterns of naturalistic family learning behaviors. Research focused on the family as a learning system has observed that families use remarkably dynamic and often subtle nonverbal and verbal learning strategies in the context of a museum visit (Borun, Cleghorn, & Garfield, 1995; Dierking & Falk, 1994). Regardless of whether the exhibit provides interactive or static displays, families are capable of attending to and engaging with a range of content (Hilke, 1989). Researchers have used a variety of measurement strategies to capture the levels of nuanced interactions that exist between family members as they engage with an informal learning environment. Some of the most popular methods include observations, timing and tracking, pre-post test measures, audio recording, video recording and most recently, tracking log files from computer interactive experiences and usage patterns through sensors embedded in the exhibit environments (Borun, 2002; Crowley & Callanan, 1998; Falk, 1991; Hsi & Fait, 2005; Serrell, 1997). Researchers have also explored the impact of exhibit design and use of signage to facilitate or hinder collaborative family learning (Allen, 2004; Borun, 2002; Borun, Chambers, Dristas, & Johnson, 1997). This work has revealed that the placement of signs, the height of displays, the availability of seating, and the accessibility of interactive elements to multiple family members can greatly impact learning behaviors such as identifying, describing, and interpreting information as well as broader engagement measures such as exhibit hold time, depth of exploration, and overall enjoyment of the exhibit experience (Borun, 2002; Leinhardt, Crowley, & Knutson, 2002).

In an effort to account for the factors that contribute to learning in museum settings, the Museum Learning Collaborative developed a model of learning as "conversational elaboration" that explored the influence of identity, learning environment, and explanatory engagement observed through visitors' talk (Leinhardt & Knutson, 2004). Researchers using this framework as well as those focused more directly on personal meaning making and the use of personal narratives have found evidence for learning and gained important insights into the use of learning strategies by conducting research on visitor conversation (Doering & Pekarik, 1996; Falk & Dierking, 2000). Researchers have examined the influence of prior knowledge, experience, personal-narrative, visit agenda, and other individual differences on the museum experience and potential for learning. Studies have found that individual characteristics of visitors and how these characteristics are distributed in a visitor group can greatly influence the ways that visitors talk and interact in museum environments (Ellenbogen, 2002; Falk & Dierking, 2002; Falk, Moussouri, & Coulson, 1988; Falk & Storksdiek, 2001; Leinhardt & Knutson, 2004).

Family conversations in informal learning environments such as museums and aquariums have been identified as critical tools that allow families to challenge each other to engage more actively with the information embedded in exhibits (Allen, 2002; Ash, 2002, 2003a, 2003b, 2004). As families engage with and exchange information that they have collected from the environment, there seems to be a preference for cross-generational delivery of information. Hilke (1989) found that parents in museums preferred to share information with children and that children also demonstrated a preference for sharing information with their parents. This research suggested that some of the observed intergenerational behaviors might be reflective of well-rehearsed habits of information exchange and collaboration that families use across a range of learning settings.

In addition to providing spaces to learn about information collection and communication, museums can provide opportunities for parents to support children's early experiences with scientific reasoning (Crowley, Callanan, Jipson, Galco, Topping, & Shrager, 2001). The role of parents in museums to interpret information and shape early experiences with science could have powerful implication for children's early science literacy. Researchers have suggested repeatedly that informal learning environments are often the first places that children engage with science content and scientific reasoning, long before attending school (Callanan & Oakes, 1992; Crowley et al., 2001; Keil, 1998; Korpan, Bisanz, Bisanz, & Boehme, 1997). Parents' willingness and ability to provide information mediation and interpretation often depends on their familiarity with the content and processes being exhibited, their beliefs about what their role should be in museum settings, and their larger visit agendas (Falk et al., 1998; Gelman, Masssey, & McManus, 1991; Swartz & Crowley, 2004).

Opportunities for learning through conversation in informal learning environments are often linked to the presentation of facts that place them in personally relevant contexts, as well as the use of just in time explanations that make sense of observed concepts and phenomena. Researchers found that even partial or fragmentary "explanatoids" can provide the necessary support to foster children's early understanding of complex scientific concepts (Crowley et al., 2001). Family interactions and conversations in a museum environment provide a dynamic record of the ways that parents and children use questions, facts, theories, and categorical relationships (Ash & Wells, 2006). Visitor groups often actively negotiate who will provide information interpretation during a visit to the museum depending on who is the most knowledgeable about a presented topic. However, Ash (2004) has found evidence that family members of all ages will seek information as well as confirmation of their understanding of an idea from museum mediation resources when they are available.

Prior museum research focused specifically on children's conversations about dinosaur exhibits has not considered the impact of individual characteristics such as knowledge or interest on the content of children's talk. These general measures of children's conversations among family groups and school groups at dinosaur exhibits suggest that children prefer to discuss anatomical features of static dinosaur displays. However, not surprisingly, when a museum displayed an animatronic dinosaur exhibit, children frequently commented about the movements they observed and offered interpretations of those behaviors (Tunnicliffe, 2000). Previous research has also used the topic of dinosaurs to determine whether children's understanding of death and extinction in relation to dinosaurs was more factual or conceptual and whether this understanding transferred to other domains (Poling & Evans, 2004). While research on children's talk in museums suggests that dinosaurs are discussed in similar ways as other animals, in terms of conceptual development of ideas about speciation, evolution, and extinction, dinosaurs seem to be treated as a special case that children do not intuitively extend or apply to other biological domains.

While prior research related to conversations about dinosaurs in museums and children's expertise in dinosaurs has been conducted, there is no existing literature that coordinates children's interest and knowledge about dinosaurs and considers its impact on patterns of parent–child conversations and interactions in an informal learning environment. How might child expertise influence patterns of family talk and activity during a museum visit? Consistent with prior expertise findings, we expected that the content of parent and child talk would be different between families with expert and novice children. Families with experts would primarily focus on detailed features of dinosaurs like tooth shape and self-defense mechanisms while families with novices would focus on general features like size and scale of dinosaur specimens. We also expected that the interaction pattern between parents with novice and expert children would be different. Families with experts would equally share turns at talk and responsibility for interpreting specimens on display while families with novices would unequally share turns at talk, with parents primarily interpreting information about specimens for their children. Finally, powerful learning conversations would be more likely occur in families with expert children, who have a shared knowledge base to build on in this learning environment, while families with novices would be focused on establishing ways to interpret the experience and information provided by Dinosaur Hall.

METHOD

Participants

Forty-two families with children between the ages of 5 and 7 years were recruited while visiting the Carnegie Museum of Natural History (CMNH), Pittsburgh, PA. Children's mean age was 6 years. There were 25 boys and 17 girls who participated in this study. All participants were weekend visitors to the museum.

Procedure

Families were recruited as they approached Dinosaur Hall. Researchers explained that families would be videotaped while they visited the hall and then children would be asked to complete a short interview while a parent completed a written questionnaire. Families completed written consent forms prior to participating in interviews and observations. To record the family visit to Dinosaur Hall, wireless microphones were attached to a child between the ages of 5 and 7 years who had been designated as the target child. Preliminary data collection revealed that attaching the microphone to the target child adequately captured the child's comments as well as adults' comments that were directed to the target child. This data collection choice allowed us to recruit and include families who visited the museum in larger groups than parent–child dyads. However, when family groups larger than dyads were recruited, researchers ensured that there was only one child within the target age range.

A researcher with a video camera followed at least 10 feet from the family as they toured the hall. Visits lasted for an average of 8 minutes 52 seconds and ranged from 2 minutes 30 seconds to 21 minutes 10 seconds. Parent questionnaires and child knowledge assessment interviews were conducted in a designated area on the museum floor. The average interview lasted 10 minutes and was videotaped.

At the time of this study, Dinosaur Hall was in the configuration it had held from 1978 to 2004 with only minor changes. The largest dinosaur specimens were *Allosaurus**, *Apatosaurus**, *Camarasaurus, Camptosaurus, Corythosaurus, Diplodocus**, *Dryosaurus, Edmontosaurus, Protoceratops, Stegosaurus**, *Triceratops**, and *Tyrannosaurus rex**. The specimen names marked with an asterisk were those that were featured in model form in the child knowledge assessment. As visitors entered Dinosaur Hall, there was a clear sight line of the *Tyrannosaurus rex* at the far end of the hall. If they walked through the center of the exhibit hall toward *T. rex,* visitors would first pass between *Stegosaurus* on the right and *Allosaurus* on the left. Continuing forward, visitors would walk between two enormous sauropods, the *Apatosaurus* on the right and *Diplodocus* on the left. At the end of the center corridor, visitors arrived at the foot of *T. rex* in an impressive upright pose, standing 18 feet high and measuring 47 feet long from snout to tail. The information labels in the original Dinosaur Hall were designed to didactically provide identification, descriptions of characteristics such as height, length, and weight of the specimen, an approximate indication of when this species existed on the Mesozoic timeline, and a small anecdote related to the displayed specimen. Although largely unchanged for over a quarter of a century, Dinosaur Hall was one of the highlights of the CMNH collection and was extremely popular with visitors.

On some of the days when we collected data, there were pairs of teen docents who staffed a touchable specimen cart in the middle of Dinosaur Hall. These were the only museum employees available to families during their visit. While most of the families did not interact with these docents, three families did explore the objects on the cart with the teen docents guiding the interaction. We have excluded those pieces of interactions from the data set because the conversations with docents were qualitatively different from parent–child conversations in the rest of the exhibition. In no case did a docent help a family understand or interpret a mounted specimen. Thus, the data we analyze are conversations among families interpreting the fossils and signage in the hall without staff assistance.

Family Conversation During Visits to Dinosaur Hall. In science centers and children's museums, family talk has been described as a mixture of visit negotiation talk (for instance, children asking which exhibit the family would visit after Dinosaur Hall), process-oriented comments (for instance, parents and children working together to operate an interactive and giving each other instructions), as well as opportunities to connect with previous experiences and knowledge (Falk & Dierking, 2000). Our research will focus on this third type of talk because we believe it offers great potential to support the kinds of learning that can contribute to the development of an island of expertise. Family conversations in museums have been identified as potential mechanisms as well as outcome measures of domain knowledge and understanding (Callanan & Jipson, 2001; Leinhardt et al., 2002).

Our analysis of parent–child conversation focused on two aspects: identification of the concepts included in conversation and who in the family group (adult or child) was responsible for generating talk. We will refer to the identification of concepts as "content talk." Content talk was initially divided into seven categories: paleontology concepts, dinosaur behavior, form and function, descriptive comparison, feature description, emotion comments, and museum navigation (see Table 1 for a more detailed description and examples

TABLE 1
Content Talk Coding Categories

Categories of Talk	Descriptions	Examples
Paleontology related	Paleontology processes, age and distribution of dinosaur species	"This is a stone with a fossil in it. Remember the little animal is not there anymore. Just the stone is left"
Dinosaur behavior	Describing and explaining dinosaur interactions and behaviors	"The *T. rex* and this one would fight" "It was a fast runner"
Form and function	Identifying individual parts and connecting them with their uses	"The spiked tail was used to defend itself" "They have horns to protect their selves from meat eaters"
Descriptive comparison	Comparing specimens to everyday objects, animals, other dinosaurs or prior experiences	"The teeth are sharp, sharp like a steak knife" "There is a wing bone over there, like a chicken wing"
Feature description	Describing physical characteristics of dinosaur specimens	"Look at that, it's so big!" "That's a long tail" "That one had sharp spikes"
Emotion	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*!"

of each code). Prior research on children's conversations about static and animatronic dinosaur exhibits suggested that the majority of content talk would be focused on anatomical features, labeling and descriptions of species, dinosaur behaviors, and emotion comments (Tunnicliffe, 2000). While our coding categories included these forms of talk, we also accounted for patterns in the transcripts that lead to the inclusion of paleontology concept talk. By measuring what families talked about, the level of analysis included in the talk, and who participated in the conversation, we determined the patterns of discourse that could be considered powerful learning conversations (Ash, 2002, 2003a, 2003b; Ash & Wells, 2006).

Dinosaur Knowledge Assessment Interview. The dinosaur knowledge assessment interview included questions designed to elicit three types of knowledge: *identification, dinosaur behaviors,* and *paleontology concepts and theories*. With this approach, we directly investigated the kinds of knowledge associated with dinosaur naming expertise. The assessment stimuli were 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. Researchers sat with a table that displayed 10 dinosaur models (*Tyrannosaurus rex, Triceratops, Stegosaurus, Velociraptor, Diplodocus, Brachiosaurus, Allosaurus, Apatosaurus, Iguanodon, Maiasaura*), four model of nondinosaurs (*Giraffe, Tiger, Pteranodon, Elasmosaurus*), and a rotating platform used to focus attention on a subset of figures during individual questions. Of the nondinosaur models: two 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 nondinosaurian. Mesozoic reptile examples were included to assess whether children could recognize and identify these figures as nondinosaurs despite their similarity of appearance and frequent inclusion in "dinosaur" books, movies, TV programs, and museum exhibits. The interview began with a confidence-building activity where participants were asked to identify the figures that were not dinosaurs.

Identification. One of the necessary features of childhood dinosaur expertise is the ability to correctly label representations of dinosaurs. Prior studies of dinosaur expertise have constructed identification sets of dinosaur figures to include examples of "high-frequency" and "low-frequency" dinosaurs (Chi et al., 1989; Chi & Koeske, 1983). In these cases, high-frequency figures were representations of dinosaurs that were prominently featured in children's dinosaur books, movies, and TV programs. Low-frequency figures were representations of those dinosaurs that were familiar, but often less prominently featured in the available dinosaur resources. Extending this strategy, we constructed our identification set with examples of the top 10 most frequently featured dinosaurs in children's books (*Tyrannosaurus rex, Triceratops, Stegosaurus, Velociraptor, Diplodocus, Brachiosaurus, Allosaurus, Apatosaurus, Iguanodon, Maiasaura*). Based on preliminary testing at the local children's museum, it was clear that, despite the frequency with which these dinosaurs appeared in children's books, there was considerable variation in children's dinosaur naming ability.

The interviewer always indicated the *T. rex* figure first and asked participants to identify this dinosaur. Beginning with *T. rex* was consistent across subjects because *T. rex* is the single most recognizable and easily identified dinosaur species. If participants were familiar with dinosaurs, beginning with this figure was a confidence builder. However, if participants were unable to identify *T. rex*, this provided an early cue for the researcher that the participant was not very familiar with dinosaurs. All participants named as many figures as they could and when they could name no more, the interviewer cleared the table and proceeded to the next section of the assessment.

Dinosaur Behavior Questions. On the basis of 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. In this section, participants were asked questions about dinosaur diet, species interaction, and locomotion. The experimenter used a rotating platform to focus participants' attention on three to four dinosaur figures at a time. Children were questioned about the featured dinosaurs and 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 fern) was a good meal? [Figures on platform: *Allosaurus, Brachiosaurus, Raptor*] How come?

Paleontology Concepts and Theories. Prior research of childhood expertise in dinosaurs has often restricted questions to dinosaur identification and descriptions of individual species characteristics. Children's knowledge of the concepts and processes of paleontology have not often been investigated. In response to this gap in the literature, we were interested in measuring children's awareness of concepts and theories related to dinosaurs and the science of paleontology. In our assessment, questions were included that focused on categorical relationships between dinosaurs, coexistence, how we know about dinosaurs, extinction theories, and generating the name of the scientists who study dinosaurs.

Parent Questionnaire. The parent questionnaire consisted of 12 questions divided into three parts: a pair of 7-point Likert scales rating children's interest and knowledge about dinosaurs, a pair of 7-point Likert scales rating parent interest and knowledge about dinosaurs, and 8 open-ended questions focused on the origins of children's dinosaur knowledge, the frequency of annual family visits to the natural history museum, the kinds of material support for dinosaur interests available at home (toys, figures, books, games), and children's other interests, favorite toys, and topics.

Coding

Family Conversations. Our primary interest was in the ways that adults and target children interacted in the museum. For parent–child dyads (49% of family groups), capturing and analyzing conversations required minimal data reduction. In family groups that included a single adult, target child, and additional children (15% of groups), the conversational contributions of the other child(ren) were not included in the coding because these children were outside of the age range of interest for this study. When more than a single adult was present with the target child (18% of family groups), it was typically the pattern that one adult took the lead in the interaction with the target child, while the other adult only occasionally joined the conversation. Therefore, in cases in which additional adults were present, the codes for all adults were combined to represent a total number for the types of comments and interpretations offered during the visit. In the remaining cases where additional adults and children were present in the visit groups (18%), adult comments were combined into a single adult contribution and other children's comments were excluded as discussed above.

Following data reduction, line-by-line analysis focused on 3,641 conversational turns between adults and target children. Adults and target children generated an average of 82 coded conversational turns per visit. These turns at talk reflect 77% of the total content talk generated during family visits to Dinosaur Hall and the total set that will be used for subsequent conversation analysis. Families generated the remaining 23% of talk by reading verbatim from printed labels or discussing content unrelated to learning in Dinosaur Hall. For example, we determined that comments about wanting to stop at the gift shop or the museum cafe, being tired, or deciding on which hall to visit next, would be coded in the museum navigation category and would not be likely to support family learning about dinosaurs. Interrater reliability was calculated based on the assignment of turns at talk to one of the seven mutually exclusive categories described in Table 1. One researcher coded the entire data set, and a second researcher coded 20% of the transcripts to verify the reliability of the coded data. The two raters agreed on 87% of the codes. All disagreements were resolved through discussion.

Assessment Interview. These questions were scored in two iterations. Forced choice questions were scored as correct or incorrect. Participants were awarded one point for each correct answer. Each forced choice question was followed-up with a request for an explanation. Explanations were coded on a 0–3 point scale, where 0 represented "no answer" or "don't know" responses and 3 represented a plausible causal explanation often with more sophisticated vocabulary included. For open-ended questions, responses were coded on a similar 0–3 point scale. The exceptions to this scoring were questions about dinosaur coexistence and extinction theories in which a finer grained coding scale was generated (0–6) in order to reflect the degrees of increasing sophistication indicated by causal links included in participant responses. Participant's scores for each question reflect the addition of the forced choice score and the explanation score. These total scores were weighted for accuracy (e.g., if a child answered the forced choice question wrong, but then provided a sophisticated explanation for their misconception, they were not awarded points for the quality of the explanation).

For analysis, questions were grouped into two general categories of knowledge: dinosaur behavior and paleontology concepts. Dinosaur behavior knowledge questions addressed issues of diet, locomotion, and species interaction. Paleontology concept knowledge questions addressed issues of categorical-family relationships between dinosaurs, coexistence in specific time periods of the Mesozoic, identifying evidence of dinosaur existence, recognition of the names of scientists who study dinosaurs, and theories of extinction.

Parent Questionnaires. These questions generated four kinds of data: ratings of children's knowledge and interest in dinosaurs, ratings of parents' knowledge and interest in dinosaurs, information about annual visit frequency to the natural history museum, and information about the material support for children's dinosaur interests available in the home. Likert-scale ratings for children and parents' dinosaur interest and knowledge were entered directly into statistical analysis. Visit frequency was coded into three categories: 1–2 times per year, 3–5 times per year, and 5 times or more per year. Material and experiential support for children's interests in dinosaurs were coded for presence or absence in the home. Categorical kinds of materials and opportunities that were available (books, movies, toys, access to relevant Web sites) were awarded one point if they were present. For analysis, the presence of these experiences and materials were combined to form a dinosaur resources score.

RESULTS

We first present findings from the knowledge assessment, which was used to divide the sample into children who know relatively more or less about dinosaurs. We then present analyses of the videotaped visits to Dinosaur Hall, comparing both parent and child talk in families in which children are relative experts or novices in dinosaurs.

Knowledge Assessment Findings

The number of dinosaurs children can name has often been used as a factor to determine their level of knowledge in the topic (Chi et al., 1989; Gobbo & Chi, 1986; Johnson et al., 2004). Most children in our study successfully named at least one of the 10 dinosaur models, with the number of dinosaurs named ranging from 0 to 10. The most well-known dinosaur was *Tyrannosaurus rex* (91% of children identified it) followed by *Triceratops* (61%). The most obscure dinosaurs were *Apatosaurus* and *Maiasaura* (tied at 9%). Using a median split, participants were initially divided into expert and novice groups based on the number of dinosaurs they named. The eight participants who named the median of three dinosaurs were excluded from further analysis.[1] The 15 children above the median were placed in the expert group while the 18 children below the median were considered novices. Children in the expert group could name a mean of 6.5 ($SD = 2.3$) of the 10 dinosaurs while novices could name 1.5 ($SD = 0.7$).

What do child dinosaur experts know about the topic beyond the names of dinosaurs? The assessment focused on two general classes of knowledge: dinosaur behavior and paleontology. Experts were consistently more successful at associating dinosaurs with their diet, locomotion, and interaction patterns than novices. A t-test on children's dinosaur behavior scores revealed significant differences between experts (62% correct) and novices (45%), $t(31) = 3.14$, $p = .004$. Experts also were more likely to give correct answers to the paleontology questions, including which dinosaurs coexisted, which scientists study dinosaurs, how it is that we know about dinosaurs, and different theories to explain dinosaur extinction. A t-test showed significant differences on the paleontology questions between experts (79% correct) and novices (39%), $t(31) = 4.28$, $p < .001$.

Were there features that distinguished our experts and novices beyond what they knew about dinosaurs? First, we asked whether they differed consistently in terms of age. We did not expect age differences in this study given that prior literature on child expertise suggested that 5-year-olds are old enough to acquire significant expertise in dinosaurs when they are interested in the topic. Consistent with prior work, we found no age differences between experts and novices: The mean age of children in the expert group was 6.0 years while the mean for novices was 5.9 years. Thus, any differences we observed in family talk were not due to age differences between these groups.

Second, we examined gender. Prior literature suggested that boys might be more likely to be interested in dinosaurs (Johnson et al., 2004), and consistent with previous findings, our expert group included 14 boys and only 1 girl, while our novice group included 5 boys and 13 girls. The unbalanced gender distribution of the expert group precluded any analyses of these data that separate gender and expertise. Thus, all analyses collapse across gender.

Third, we looked to the parent survey data to see whether experts and novices were differentially familiar with the museum as a learning environment. When we examined the parent responses to the annual visit frequency question, we found that differences between experts and novices were not significant, with 39% of novice families and 27% of expert families saying they visited 1–2 times per year,[2] 50% novices and 46% experts reporting 3–5 visits per year, and 11% novices and 27% experts reporting more than 5 visits per year. ANOVAs comparing these three visiting-frequency groups in terms of overall talk or time in the hall revealed no significant differences.

Finally, we examined the parent surveys to determine whether experts might have social-support advantages such as parents with more interest and knowledge about the topic or home environments enriched with a wider range of information resources. Findings suggested that they did. Parents with expert children reported significantly higher interest in dinosaurs ($M = 4.8$ of 7 on the Likert scale) than parents with novice children ($M = 3.7$), $t(31) = 2.09$, $p < .05$, and significantly higher knowledge of dinosaurs ($M = 5.1$ of 7) than parents with novice children ($M = 3.5$), $t(31) = 2.95$, $p = .006$. Experts also appeared to have more dinosaur learning opportunities at home. The parents of experts also reported significantly more access to dinosaur books, games, toys, videos, and Web sites at home

[1] One additional subject who could name four dinosaurs was removed from the expert group because family-talk analysis revealed scores that were more than 3 standard deviations above the expert means for each category of coded talk.

[2] Only two of our subjects were first-time visitors to the hall: one was an expert and one was a novice.

($M = 4.0$) than parents of novices ($M = 2.6$), $t(31) = 3.18$, $p = .003$. Perhaps not surprisingly then, parents of experts told us that their children were significantly more interested in dinosaurs ($M = 5.5$ of 7 on the Likert scale) than the parents of novice children reported their children were ($M = 3.5$), $t(31) = 4.36$, $p < .001$.

The knowledge assessment was intended to split our sample into the families with children who were relatively expert or novice in the topic of dinosaurs. However, beyond assigning the families to groups, the data also provide confirmation for two pieces of the islands of expertise theory. First, we had predicted that children who are able to name more dinosaurs would not just be amassing a collection of species names. We also expected that the process of learning about dinosaurs in everyday settings would result in our dinosaur experts having learned more about larger themes such as dinosaur behavior and paleontology. Our findings confirmed that this was the case. Second, a fundamental assumption of the islands of expertise approach is that child expertise should be viewed primarily as a sociocultural phenomenon that emerges from everyday activity in the home. In support of this, our findings suggested that expert children had parents who were more interested and knowledgeable about dinosaurs and that the experts also had access to more dinosaur books, toys, videos, Web sites, and other dinosaur-learning resources. Our data cannot determine whether the rich home environment was the cause or effect of children's budding dinosaur interest. However, these data reinforce the idea that child experts do not develop in a vacuum. Instead, they have parents and learning resources that support and reflect their interests.

Family Visits to Dinosaur Hall

No prior studies of childhood expertise have examined the relation of children's expertise to parent–child talk in museum settings. What differences might we expect to see? The knowledge assessment suggested that children who are dinosaur experts know more dinosaur species, more about dinosaur behavior, and more about paleontology concepts. Furthermore, parents of these children report being more interested in and knowledgeable about dinosaurs than parents of children who are dinosaur novices. Thus, we expected to see more intense engagement and richer learning talk among the expert families.

We looked first at the most general behavioral measure of engagement—time spent exploring Dinosaur Hall. Contrary to our expectations, families spent the same amount of time exploring the hall whether they had novice (8 minutes 30 seconds) or expert children (8 minutes 16 seconds), $t(31) = 0.14$.[3] Families also stopped at and talked about the same number of displays during their visits to the hall, with expert families interacting with an average of 7.4 of the 20 possible exhibits and novice families interacting with 7.9. There were also no significant differences in the particular exhibits that expert and novice families chose to visit. A comparison of the percentages of families who stopped at each of the 20 different exhibits in the hall suggested that all families preferred to visit the large three-dimensional fossil skeletons and were less likely to visit partial skeletons, skulls, or other kinds of fossils (e.g., fossilized leaf impressions).

Findings from such broad measures of engagement are influenced by the physical layout of the hall and the particular characteristics of the specimens on display. Mounts such as the *T. rex* or *Diplodocus* at CMNH are truly spectacular and would probably always attract a

[3] We have no reason to believe that the presence of the camera influenced the amount of time novice or expert groups spent visiting Dinosaur Hall. The conversations and interactions included in our analysis were well with in the range of expected patterns, suggesting the camera did not have an adverse impact on family visit experience.

TABLE 2
Mean Number of Conversational Exchanges for Novice and Expert Families

Talk Categories	Families With Novices	Families With Experts
Paleontology concepts	16	10
Dinosaur behavior	7	7
Form and function	3	4
Descriptive comparison	23	14
Feature description	24	12
Emotion	19	12
Total	92	59

visit from families regardless of their prior interest in or knowledge of dinosaurs. However, we might have expected experts to be wider ranging in their visit or to understand the significance of some of the less spectacular but still scientifically significant specimens on display. One of these, for example, is an unusually complete juvenile *Camarasaurus* preserved in its matrix. This *Camarasaurus* is considered an invaluable piece of fossil evidence by the paleontology community; however, only 33% of the experts stopped at this mount, which was actually slightly less than the 39% of novices who stopped.

We turn next to the analysis of the videotaped conversations while families visited the hall. The islands of expertise theory predicted that children who have an island of expertise would have developed more advanced knowledge around the topic of dinosaurs and would be more likely to be observed having rich learning conversations that included conceptual and/or scientific content.

Table 2 contains the mean turns at talk observed in expert and novice families, divided by the six categories of content talk: paleontology, dinosaur behavior, form and function, descriptive comparison, feature description, and emotion. On first inspection, the table does not support the hypothesis that expert families have richer conversations in dinosaur hall. Summing across the six categories of talk, we found that novice families ($M = 92$ turns, $SD = 63$) actually engaged in more overall learning talk than expert families ($M = 59$ turns, $SD = 46$), although, due to the large standard deviations, the difference was not significant, $t(31) = 1.7$. Furthermore, for each of the six individual categories of talk, families with novices consistently generated quantities of talk that were close to or above experts. For feature description talk, the difference in favor of novice families was significant, $t(31) = 3.15$, $p = .004$.

Differences do emerge, however, when we consider who does the talking in expert or novice families. In expert families, children appear to be doing most of the talking while their parents remain relatively quiet (Table 3). Summing across all six categories,

TABLE 3
Mean Number of Conversational Exchanges Among Adults and Expert Children

Talk Categories	Adult	Expert Child	Paired *t*-Value (14)	Two-Tailed *p*-Value
Paleontology concepts	2.33	7.93	3.54	.003
Dinosaur behavior	0.47	6.87	2.51	.025
Form and function	0.47	3.47	1.93	.07
Descriptive comparison	3.40	10.20	2.87	.012
Feature description	3.27	8.33	2.07	.06
Emotion	2.27	9.53	2.70	.017

TABLE 4
Mean Number of Conversational Exchanges Among Adults and Novice Children

Talk Categories	Adult	Novice Child	Paired *t*-Value (17)	Two-Tailed *p*-Value
Paleontology concepts	9.39	6.67	1.10	.287
Dinosaur behavior	3.78	3.11	0.80	.434
Form and function	2.50	0.56	3.20	.005
Descriptive comparison	13.33	10.11	0.73	.477
Feature description	14.17	9.94	1.61	.127
Emotion	7.78	10.72	1.84	.084

expert children talked much more (79% of all turns) than their parents (21%), paired t-test $(14) = 3.73$, $p = .002$. Looking at each category of talk separately, we found that differences between expert children and parents were significant for paleontology, dinosaur behavior, descriptive comparison, and emotion talk. The patterns were in the same direction, but the differences only marginally significant, for form and function and feature description talk.

In contrast, Table 4 shows that talk was shared more equally in novice families, with children (45% of turns) and parents (55%) each contributing about half of the overall talk. Examining each of the six individual categories of talk revealed only one category where novice parents did more talking than children: Parents were observed contributing more form and function talk.

The significant differences between parents and children in the expert group appeared to be due mostly to the silence of the expert parents rather than the expert children doing more talking than the novice children. Comparing Tables 3 and 4, children appeared to talk about the same amount in Dinosaur Hall regardless of whether they were experts ($M = 46$ turns, $SD = 40$) or novices ($M = 41$, $SD = 35$). This generally held for each of the categories of individual child talk except for form and function talk, when the difference between expert and novice children was marginally significant, $t(31) = 2.01$, $p = .053$.

Parents, however, were much more likely to talk if they were with novices ($M = 51$ turns, $SD = 39$) than with experts ($M = 12$, $SD = 9$), paired t-test $(31) = 3.68$, $p = .001$. Looking at the parent columns in Tables 3 and 4, this pattern held for talk about paleontology, paired t-test $(31) = 2.26$, $p = .031$, dinosaur behavior, paired t-test $(31) = 3.40$, $p = .002$, descriptive comparisons, paired t-test $(31) = 3.00$, $p = .005$, form and function, paired t-test $(31) = 2.51$, $p = .017$, feature description, paired t-test $(31) = 4.29$, $p < .001$, and emotion, paired t-test $(31) = 2.66$, $p = .012$.

It was surprising to us that there were so few significant differences observed between the conversation patterns of children in expert and novice groups. It was possible that identifying experts and novices by a median split did not provide enough of a contrast in children's knowledge to identify differences. Thus, we conducted a second set of analyses with our novice group being defined as the children in the bottom quartile (they could name zero or one dinosaurs) and our experts defined as the top quartile (they could name eight or more dinosaurs). The two main patterns of findings were essentially unchanged. Children still generally contributed similar amounts of talk regardless of whether they were experts or novices. Parents of novice children were engaged in equal amounts of talk with their children while the parents of experts were relatively quiet.

Exploring the Role of Parents

The quantitative findings suggest that, as children develop an island of expertise in dinosaurs, their parents become less active contributors to learning conversations in informal settings. This runs counter to our initial expectation that parents and children developing an island of expertise would be able to use their shared knowledge and experience to have richer science learning conversations in the museum. However, one way to consider our novice and expert groups are as snapshots of children at different points in the process of developing an island of expertise in dinosaurs. Although novice families in our study may not have known a lot about dinosaurs, they were interested enough in the topic to walk into Dinosaur Hall. With no one being the obvious expert on the topic, novice families appeared to use the hall as a collaborative learning opportunity—parents and children both appeared to contribute to conversations that focused in largest part upon the features of the objects on display (feature description and descriptive comparison talk) but also provided some broader interpretive context for the objects (paleontology, dinosaur behavior, form and function). In other words, they appeared to be learning together and building the beginnings of what might become an island of expertise in dinosaurs. And, since we were studying a learning environment that had been intentionally constructed to promote interpretation of the objects, there was sufficient information from signage and other forms of mediation for parents to introduce some of the higher level interpretive context into the conversation.

Consider this father with a 5-year-old novice as they decide to stop and find out about the *Stegosaurus*:

> Dad: This one's called a *Stegosaurus*.
> Daughter: Oh.
> Dad: See, with a *Stegosaurus,* it ate plants. It wasn't a meat eater like *Tyrannosaurus*. See? See his mouth?
> Daughter: Oh. . . yeah.
> Dad: See how he doesn't have the real big teeth like *Tyrannosaurus* does? (They both lean close to the skull of the mount) That's because he ate plants. He didn't need real big sharp teeth because all he ate was plants.
> Daughter: Oh.
> Dad: See these big bones up here? (Dad traces the shape of the plates)
> Daughter: Yeah, the points?
> Dad: This is his spine right here, and these are called plates. And these plates went. . . see if you look at this picture (Dad points to the line-drawing on the sign), see they went all the way down his back, all the way to his tail, and that was for protection, and then his tail had big spikes on it. See the big spikes on the back of his tail?
> Daughter: Yeah, those are for protection, too.
> Dad: That's right, come down here, we can see them (they walk to the tail)
> Daughter: Spike!
> Dad: See those big spikes?
> Daughter: Those were for protection, too.
> Dad: That's right, he could swing his tail around to try to keep the bigger dinosaurs that wanted to eat him, away from him.

The father began by labeling the dinosaur and describing its diet behavior by comparing it to *T. rex*, which we learn later from the videotape is the girl's very favorite dinosaur. The father moved the diet conversation to talk about the form and function relationship between the shape of a dinosaur's teeth and its diet (recall from Table 4 that when form and function was discussed by novice families, it was almost always the parents who talked about this topic). Halfway through the conversation, the daughter moved from being a receptive listener to a more active contributor around morphologic features that might have been used for defense. It is worth noting that the father completes only a partial interpretation of the potential functions of the *Stegosaurus* plates. While he discusses the use of the spikes and plates for defense, the blood vessels in *Stegosaurus'* plates may have also been used for thermoregulation; an interpretation that was noted on the bottom of the sign but that the father did not apparently notice or chose not to address with his daughter. This example provides a reminder that parents are often learning, interpreting, and teaching on the spot, with little time for personal reflection, in informal settings.

In contrast, when expert families walked into Dinosaur Hall, we observed parents and children who were much farther along in developing islands of expertise around dinosaurs. These were the families who reported they already had lots of dinosaur-learning materials at home, so they were also the families who may have had more prior opportunities to talk together about dinosaurs and to establish roles for both the parent and the child. One of the features of early topic expertise is that it is probably one of the first times that young children can experience the power of knowledge. In addition, it also may be one of the first times that they can control large amounts of facts, potentially know more than their parents, and even correct their parents when they say something wrong. And, at least for some parents, children's islands of expertise may be unique opportunities to realize that their children can think about detailed content, develop passion in a subject matter, and sound impressively smart when they talk. Parents are proud of their children's intellectual achievement and might naturally want to reinforce the island of expertise by giving children opportunities to demonstrate their knowledge and to praise them for it. Thus, it is perhaps not surprising that expert families evolved into an interaction style in which the museum becomes a test rather than an opportunity to learn; i.e., it becomes a place where children can demonstrate their competence and parents can reward their knowledge performance with praise.

Consider this mother and 5-year-old expert, who also stopped in front of the *Stegosaurus*:

> Mom: So what do you know about *Stegosaurus*?
> Son: Umm, I know it's a plated dinosaur, and its plates are for cooling it.
> Mom: Should I read? (she moves over to the sign)
> Son: The spiked tail was used to defend itself whenever it was in danger.
> Mom: Uh huh, right, and (reading from the sign) *it was 25 feet long*.
> Son: And the *Stegosaurus* was a very slow creature.
> Mom: It was slow?
> Son: Yeah, but it was very good at standing up on its hind heels and pushing down the littlest trees. . . to eat.
> Mom: It doesn't even say any of that here. (Gestures at sign)
> Son: Well, it's supposed to!
> Mom: It's supposed to? Hahaha. What did it eat?
> Son: It ate plants and it ate. . .
> Mom: It's a plant eater?
> Son: . . . leaves.

In contrast to the novice conversation, the mother begins with a request for her son to tell her what he knows about *Stegosaurus*. As he recites the information, she checks it out on the sign next to the mount, noticing approvingly when her son recites things that are not included on the sign. Like the novice family above, this family discusses diet and self-defense. But unlike the novice family, this particular expert family does not connect many of the interpretive pieces of information directly to the features of the fossilized skeleton in front of them. The mount in this case seems to serve as a reminder to talk about the species as opposed to engage in an interpretation of the displayed fossilized skeleton. We would argue that this conversation, like many of the expert conversations we observed, was a missed learning opportunity. The parent in this instance has given up the chance to challenge and extend the child's knowledge of dinosaurs. This is unfortunate because the role of the tester could be very powerful if following the assessment of what the child knows, a parent used that knowledge to connect and integrate new facts or approaches for understanding a particular dinosaur specimen. In this example, the role of tester may be valuable as surface reinforcement for children's work in building an island; however, there are many examples in which parents with experts did even less than this to support children's engagement with dinosaur content or the learning environment.

Although many parents conceded the conversation space to their expert children, we also observed parents who were able to enrich learning conversations by continuing to interrogate Dinosaur Hall for information that could connect and extend the discussion. Consider this example of a 5-year-old expert and his mother who had just noticed the *Quetzalcoatlus,* an impressive pterosaur specimen with a 30-foot wingspan, suspended from the ceiling, approximately two stories above this pair:

> Son: (glances up to the ceiling) Hey!
> Mom: Whoa!
> Son: I didn't see him (pauses) *Quetzalcoatlus* was a flying reptile that soared over the sky and was very strong when it caught stuff with its strong, strong beak. It was a very big hunter.
> Mom: What did it eat?
> Son: Fish!
> [*3-minutes later after looking for a sign with information about Quetzalcoatlus*]
> Mom: Hey, what's going on here? (Points to the cases on the back wall) Let's see, umm, let's see, how do you say that umm (uses the sign to sound out) *Pter-o-saur? Pterosaur?*
> Son: *Pterosaur* was a very good flying hunter.
> Mom: But look at the different kinds of wings. (Mom points at each level of the display and traces the shape of the wings) They're showing that the *Pterosaur* wing is one long line in the back and the next one down, the second one down is the bat wing, and see how it has bones that come out into it? And then the bird wing... which one is the *Pterosaur*-wing more like, the bird-wing or the bat-wing?
> Son: Umm, the bird
> Mom: Yeah, it is. (Gestures back to the cases) It has, it doesn't have bones that come down into the wing, does it? Cool.
> Son: So I'd say this *pterosaur* is a very good winged-flyer. You know it's a fish eater, same as *Quetzalcoatlus*.

Unlike the typical expert pattern, the parent and child in this example equally shared turns at talk and responsibility for interpreting the information available from the exhibit. In the first segment of this example, the expert child noticed a large flying reptile specimen suspended from the ceiling. After they both indicated how impressed they were with the specimen, the child provided the correct name and emphasized that this is an example of a "flying reptile." Although this is a secondary identification and a feature description, this comment indicated that the expert child understood the categorical difference between dinosaurs and other creatures that coexisted with them, but would not be considered dinosaurs. This is a subtle point lost to most visitors to the hall.

The expert continued his explanation and included two examples of behavior codes when he commented that it "soared" and that it was a "strong hunter." The mother followed-up on his comment about *Quetzalcoatlus'* diet behavior to ask what kinds of things it might have eaten. The son answered with confidence that this specimen would have eaten fish. At this point, the mother looks to the learning environment to provide her with some additional information that she could use to extend the conversation. Unfortunately, the information label for this specimen was on the second floor and there was no available label that directly addressed this specimen on the first floor of the exhibit. Without content help from the environment, this families' conversation transitioned to other dinosaur specimens as they walked through the space and looked for information relevant to the *Quetzalcoatlus*.

In the second segment, the mother noticed a set of exhibit cases at the back of the hall that displayed smaller pterosaurs. As they approached the cases, the expert child once again volunteered his prior knowledge about the behaviors of the displayed specimens (good flying hunter). However, his mother was able to go beyond that piece of knowledge and focused her son's attention on the salient features of the wing structures displayed. She labeled the wings and used a set of feature descriptions to provide detailed information that allowed her son to recognize the comparative nature of the display. Building off of the design of information presented, she used a specific question to challenge her son to notice the similarities and differences between the wing structures. He answered her question correctly, and the mother agreed with his answer and indicated the evidence for how the pterosaur wing and the bat wing differ. She concluded this exchange by noticing that this connection between winged Mesozoic reptiles and birds is "cool." The son reiterated his point from earlier that the *Pterosaur* would be a "good flyer" and then made the explicit descriptive comparison between the diet of these examples of smaller *Pterosaurs* and the *Quetzalcoatlus* featured soaring above the central dinosaur mounts.

DISCUSSION

This study has been a first step to extend our accounts of children's development of expertise that brought together and considered the relationships between interest, knowledge, motivation, and family settings where learning occurs. We need to understand the dynamics and affordances of a range of learning environments where children spend their days. Our findings seem to point to a gap in our knowledge of how to support and extend learning trajectories in informal environments. Children who become budding dinosaur experts may consume all they can read, see, and do concerning dinosaurs. However, we suspect that children's books and other similar resources may continue to tell the same kinds of stories over and over. Rather than seeing our experts engage in more complex disciplinary reasoning when they were in an extremely rich learning setting, we saw them reciting their favorite facts and stories but not really interrogating the environment for new pieces of information or reasoning strategies to add to their collections. And we saw their parents supporting and reinforcing this behavior.

This was a very surprising outcome of our research. For us it raised the question: Once interest and knowledge come together to form an island of expertise, what are the learning implications for parents and children? Our analysis indicated that islands of expertise shape patterns of learning conversations between parents and children in unexpected ways. While all families talked about similar content during their visits, more knowledgeable children had more turns at talk than their parents. Expert children assumed more of an information interpretation role in the museum, creating one-sided conversations in which their parents were often silent visit companions. While in contrast, parents' with novice children guided interpretations of specimens and novices actively participated as responsive learning partners. In families with expert children, parents no longer acted as a teacher or a coinvestigator. Instead, the role of the parent with an expert child seemed to be one of a tester or an evaluator of knowledge. The parent of the expert child often acted as an interested audience member, asked questions that encouraged knowledge rehearsal, and offered positive reinforcement for their children's knowledge performance, but rarely shared the responsibility for interpreting the information presented in the museum-learning environment.

What could account for this shift in parents' role? Why would parents who describe themselves as more knowledgeable and more interested in dinosaurs become so absent in these situations? Parents with expert children repeatedly seemed to miss learning opportunities. While these parents created opportunities for their children to tell them what they know, they rarely challenged or encouraged their children to make new connections or integrate a novel idea new into their existing knowledge base.

We propose that these data indicate that expert children and their families are encountering a glass ceiling above their island of expertise. Many children's dinosaur-learning resources seem to present the same set of facts and stories. Once the family has mastered this information, it may be the case that parents struggle to find new sources of accessible dinosaur data to support children's interest and desire to further explore this topic. As a result, expert dinosaur knowledge may become tightly organized according to categorical structures or popular anecdotes and remain disconnected from the development of other biological or paleontology knowledge. This outcome of childhood expertise is not unique to the museum environment. Prior childhood expertise studies have indicated that while children can possess sophisticated knowledge and understanding within their domain of interest, they are often unable to connect this knowledge to other domains (Johnson et al., 2004). In this way, childhood experts in categorization and problem-solving tasks also seem to have encountered a glass ceiling in their knowledge application.

How do we provide parents and children with the mechanisms to break through this barrier and instead use their knowledge as a platform for learning? Museums and everyday learning resources need to provide parents and children with models for how to connect their knowledge within a domain of interest to other related domains. Without explicit support and mediation from parents and from learning environments, children are unlikely to make these generalizations on their own. More research is required to give parents of expert children the tools to continue to deepen and extend children's interest in and knowledge about dinosaurs. For example, at the professional level dinosaur fossils are the evidence and the objects of study for paleontologists and as a result these two topics are inseparable. However, for a young child and their family, dinosaurs and paleontology can become artificially separated by their treatment in museum exhibits, books, and movies. As a result, a young child's interest in dinosaurs can support the development of a monolithic set of knowledge if there are no explicit connections to the practices of paleontology included in the available learning resources. Understanding the relationship between the objects of study (dinosaurs) and the scientific processes of their study (paleontology) is an element of childhood dinosaur expertise that has the potential to influence more generalized science understanding and requires further study.

As we continue to explore the characteristics of child experts, it will also be important to investigate the causes for the underrepresentation of girls in our expert group. While these data and previous work on intense interests and early childhood expertise provide us with a good starting point, future work needs to consider the implications of girls disengagement with topics such as dinosaurs in terms of the development of early science literacy. Informal environments could provide powerful opportunities to foster all children's identification with and interest in science topics such as dinosaurs. It would be valuable to explore whether parent–child conversation and interaction in museums are providing boys and girls with equitable opportunities to develop critical thinking skills that can lead to positive habits of learning. One approach to investigating that question is currently underway. We have designed additional discourse analysis to consider whether patterns of gendered pronoun usage, questioning types, and scaffolding opportunities are distributed differently between boys and girls with novice levels of knowledge about dinosaurs.

Researchers are beginning to suggest that the role of museums in society is changing. If informal learning environments are to support the transition from sparking interest and teaching some of the basic terminology about a subject to helping children and families participate in discipline-specific reasoning, we will need to explore novel mediation strategies and participation structures to accomplish this agenda. Researchers in partnership with museums will need to develop ways to encourage child experts to become more central participants in broader disciplinary discourses. In order for museums and informal learning institutions to continue to provide opportunities for visitors to engage in lifelong learning, Falk and Shephard (2006) suggest that museums may need to redefine their exhibit goals in order to provide deeply meaningful experiences to smaller, more targeted affinity groups. Shaffer and Gee (2005) make a similar argument about the need for formal education institutions to adapt to the needs of a changing society. To accomplish these shifts, Shaffer and Gee identify the need for environments such as games to augment traditional curriculum and operate as places where learners can develop sufficient islands of expertise to engage in discipline-specific process skills (what they call epistemic frames) that can support learning across contexts.

We think the most interesting work will be the work that is used to engineer learning environments to support the seeding, growth, and use of islands of expertise. Future work should trace the development of islands of expertise across time and location to better understand how this knowledge is collected, consolidated, and applied in new settings. In addition, design research should be conducted to optimize informal experiences to develop the most powerful kinds of islands of expertise that give young learners and their families the most leverage in terms of promoting education and lifelong learning.

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