FROM DINOSAURS TO DISCIPLINARY THINKING: EXPLORING THE IMPACT OF CHILDREN'S KNOWLEDGE ON FAMILY LEARNING TALK IN A DESIGNED LEARNING ENVIRONMENT

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This study explored the influence of young children's dinosaur knowledge on parent-child learning talk in a dinosaur exhibition designed to support visitor engagement with disciplinary concepts. A knowledge assessment interview identified children between the age of 5 and 8 years old with expert and novice levels of dinosaur knowledge. Families completed a pre-test, a visit to a museum exhibition, and a post-test. Content and discourse analysis were used to examine the patterns of learning talk generated by 30 families—15 with experts and 15 with novices. Findings suggest the designed learning environment effectively supported parent engagement in a wide range of learning talk regardless of children's level of dinosaur knowledge. However, findings also indicated that expert children initiated and engaged in disciplinary learning talk more than novice children. In addition, expert children and their parents were more equally engaged in disciplinary learning talk while in contrast novice parents initiated and managed significantly more of this kind of learning talk than their children. Taken together, these findings indicate that child knowledge can influence family opportunities to engage in learning talk about disciplinary concepts and suggest implications for the design of informal learning environments that can support increased family engagement with complex science concepts like ecology and evolution.

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1.0 INTRODUCTION

Research on early childhood expertise has explored the implications of developing focused, topic based knowledge. This literature has suggested that relatively young children are capable of building well integrated knowledge networks that can support new instance learning, refined categorization, and improved memory and reasoning (Chi, Hutchinson, Robin, 1989; Chi & Koeske, 1983; Gobbo & Chi, 1986; Johnson & Mervis, 1994, Mervis, 1994). Researchers have examined young children's early competence in declarative, categorical thinking across a range of topics including birds, fish, dinosaurs, and dogs (Boster & Johnson, 1986; Johnson & Mervis, 1994; Mervis, 1994; Johnson, Scott, Mervis, 2004; Hmelo-Silver & Pfeffer, 2004; Tanaka & Taylor, 1991). Investigations of dinosaur knowledge have found that child experts distinguish themselves from novices in their ability to organize dinosaur knowledge, reason hierarchically, generate inferences about behaviors, and categorize novel dinosaur examples (Chi, Hutchinson, and Robin, 1989; Gobbo & Chi, 1986).

However, researchers have also suggested that child experts' knowledge is somewhat limited in its ability to support future learning. Comparisons between childhood experts and adults categorical understanding suggests that children can demonstrate equal performance with adults in their area of expertise. However, children are less successful than adults when attempting to extend this knowledge to other biological domains. Adults are consistently more successful than children in laboratory assessments that measure knowledge transfer, inference, and reasoning across biological topics (Johnson & Mervis, 1998; Johnson, Scott & Mervis, 2004). One possible explanation for this performance difference is that adults in test settings access both domain specific and domain general knowledge to help them reason strategically about more and less familiar biological domains. In contrast, young children do not seem to spontaneously recognize how to use strategies to support reasoning without explicit instruction (Alexander, et.al. 2008; Alexander, Johnson, Leibham, DeBauge, 2005; Siegler, 2005). This research suggests that when examined in isolation, childhood expertise seems to have the potential to support subsequent learning, but only within the topic of focus. However, these findings may underestimate children's ability to use their prior knowledge by focusing on transfer between domains. It may be the case that early childhood topic expertise would be better suited to support the development of disciplinary thinking and reasoning if there were opportunities to draw directly on existing knowledge to support new knowledge construction and interpretation. In addition, children's ability to use prior knowledge may be more likely to occur in learning settings where physical and social contexts are designed to support knowledge activation and application as opposed to de-contextualized research settings (Sanford, 2010).

For young children, prior to significant experiences in school, parents play a critical role in supporting the acquisition, organization, and synthesis of information (Callanan, 1990; Keil, 1998). Parents are often well positioned to provide explanations during conversations with their children that have the potential to support scientific thinking and reasoning (Callanan & Oakes, 1992; Callanan & Valle, 2008). Depending on the opportunities available in different contexts, parent-child conversations and experiences could support early science learning and the development of scientific literacy (Callanan & Jipson, 2001; Crowley et. al, 2001). When parents and children engage in shared scientific activities, parents often assume the more demanding roles of planning comparisons and interpreting evidence. Their discussions with children in these setting often provide surface level explanations of how to interpret evidence, but fall short of elaborating the intermediate steps that children would need to more fully understand certain relationships and phenomenon. Research suggests that parents are capable of engaging in more effective learning talk and providing more explicit links between causal mechanisms and outcomes, however, they often need prompts, guidance, or explicit training to engage in these practices (Eberbach, 2009; Gleason & Schauble, 1999).

This research study was designed to explore whether informal, interest driven learning about dinosaurs can be used by children and parents as a developmental resource to support engagement in learning talk about dinosaur fossils as evidence of disciplinary concepts. The study will consider whether learning conversations in a dinosaur exhibition could begin to connect children's dinosaur knowledge to the ways that paleontologists' reason about the ecological and evolutionary relationships of dinosaurs. Using quantitative and qualitative methods, three research questions will be investigated:

- How does child knowledge influence the content of parent-child learning talk?
- How does child knowledge influence who participates in learning talk within families?
- How does the design of the museum learning environment shape opportunities for learning talk across families with expert and novice children?

1.1 APPROACHES TO DEVELOPING EXPERTISE

Research suggests that knowledge organization and accessibility for individuals' with biological topic expertise is often specialized around the ways that knowledge was learned and is regularly used. For example, Medin, Lynch, Coley, and Atran (1997) described the differences in the ways that tree expertise is used to support categorization and reasoning among landscapers, park maintenance workers, and taxonomists. Participants with landscape expertise applied a local, ecological perspective when sorting examples and reasoning about potential causes and impacts of the spread of a hypothetical disease. In contrast, taxonomists used features that indicated evolutionary relationships to inform sorting categories and used this relational network to consider how infection might impact the environment. Similarly, Hmelo-Silver & Pfeffer (2004) described how the expertise developed by aquarium hobbyists and biologists shapes the ways that they understand and explain complex systems relationships. Hobbyists often referenced practical issues of maintaining the aquarium system like monitoring the chemical balance of the water in order to keep fish healthy. In contrast, biologists often referenced abstract principles, focusing on the processes involved in maintaining the chemical balance in the water rather than the ways to accomplish this in the aquarium system. In addition, hobbyists' explanations of the aquarium system focused on the local relationships between elements while biologists discussed the importance of maintaining equilibrium in systems more generally and used the aquarium as an example case. These findings suggest that while topic experts are often highly knowledgeable about a similar set of concepts, the ways that they use that knowledge to support reasoning reflects the differences in how that knowledge was learned, organized, and typically used.

Considering this relationship between the organization and application of expert knowledge, this research will help to inform whether there is the potential to create alignment between the ways that paleontologists understand and use dinosaur fossils and the ways that parents and children with varying dinosaur expertise make sense of this information in the context of a visit to a dinosaur exhibition. Intuitively, one might think that children and their families have a less sophisticated understanding of the domain of dinosaurs than professional scientists. However, to understand the knowledge relationship between these two groups, it is important to consider the contexts in which they learn about and use their knowledge of dinosaurs. Consider first the perspective of a student preparing for a career as paleontologist. Learning about dinosaurs occurs primarily in an evolutionary context through a curriculum designed to present information and examples that reinforce these relationships. This is an example of a top-down approach to learning categories and concepts that reflects the theoretical structure and organization of the discipline being studied (Bassok & Holyoak, 1993). When encountering new fossil discoveries, paleontologists' first task is to place them in a phylogenetic context. This placement represents a hypothesis about where this specimen fits in the larger evolutionary tree of vertebrate ancestry. After this designation has been made, dinosaur fossils can be used to support three primary types of inferences: functional, chronological, and geographic. Functional inferences address the question: How did this extinct animal live and behave? Chronological inferences address the question: When did the lineage to which an extinct animal belongs originate? And geographical inferences address the question: Where did the group of organisms to which an extinct species belongs originate and live? (Gould, 2002; Mayr, 1982). This approach to investigating and interpreting fossil evidence is reflective of the training that vertebrate paleontologists have acquired through many years of formal study. This top down approach to thinking and reasoning about dinosaurs is defined in the context of disciplinary study. From this perspective dinosaurs are just one example of the evidence of past life on earth, preserved in the fossil record that supports the continued study and understanding of evolution.

In contrast, parents and children could be described as learning about dinosaurs through a bottom up process—one in which categorical learning is induced from a set of examples (Bassok & Holyoak, 1993). Research on categorical learning, problem solving, and transfer through bottom up processes suggests that learners' ability to distinguish salient from non-salient features is often influenced by the amount and quality of the examples that are available for direct comparison (Detterman, 1993; Medin, 1989). Individuals with limited prior knowledge refine their understanding of categorical relationships by comparing and integrating information across examples. The use of contrasting cases can support refined categorical understanding as well as preparation for future learning that builds on these knowledge relationships (Schwartz & Bransford, 1999). To extend this definition to the experiences of parents and children, initial learning about a topic like dinosaurs likely occurs in a bottom-up fashion through engagement with available learning resources and experiences. Parents and children often interact with a range of representations of dinosaurs that include: authentic fossil remains, casts, artistic renditions, scientific illustrations, and photographic images of fossil specimens. Activities around these representations focus on identification, categorization, and incorporation of available facts about the featured specimen. These experiences with dinosaurs could be characterized as knowledge collection as opposed to knowledge generation. It is likely that parents and children develop habits of topic learning that are directly reflective of the opportunities and experiences from which they collect knowledge. Through available information resources like books, toys, games, DVDs, TV programs, the Internet, and visits to museums, parents and children accumulate piecemeal knowledge, often at the grain size of interesting or novel examples.

For some families, this experience of topic focused knowledge collection and co-construction can support the development of an island of expertise. Crowley and Jacobs (2002) defined an island of expertise as a relatively sophisticated knowledge and interest structure that supports the development of positive informal learning habits. In these cases, islands emerge through the convergence of parent-child activity and engagement with a topic like dinosaurs.

Over time, parents and children refine the piecemeal knowledge accumulated from available learning resources and through conversation and reflection they begin to co-construct rich knowledge and sustained interest that can support categorical and conceptual understanding. Islands of expertise provide a framework for investigating the dynamic learning system that is created through the coordination of parent-child activity and engagement with learning resources around a topic of interest. Crowley and Jacobs (2002) example of the development of a child's island of expertise around trains illustrated the potential of everyday activity and conversations to foster conceptual understanding. The focal topic of trains provided opportunities to coordinate family activity, support conversations about specific forms of mechanical causality, and promote the child's recognition of the similarities between concepts related to trains and familiar aspects of everyday experience (e.g. a steaming kettle on the stove prompting a discussion of a steam driven locomotive). Through the use of objects like the teakettle, islands of expertise can incorporate many mundane opportunities for noticing that can support learning conversations.

As children and their parents develop expertise about dinosaurs, both bottom up and top down processes influence their learning opportunities. However, for many families the presence of top-down organization in dinosaur learning resources could easily be over looked. For example, many popular dinosaur books are organized as "field-guides" designed to identify and describe individual species characteristics. Information about chronological relationships (when dinosaurs lived), ecological relationships (what dinosaurs ate), and evolutionary relationships (what family of dinosaurs a species belongs to) are often included in guides as individual facts. However, this information is rarely presented in a way that highlights its larger scientific implications. Viewing dinosaurs as evidence of evolutionary processes that operate in the natural world is fundamental to a paleontologist's understanding of dinosaurs. However, this perspective does not seem to be an obvious organizing principle for parents and children as they turn the pages of their favorite dinosaur guide, or wander through their local natural history museum. As a result, families may be missing opportunities to engage in learning talk that could expand their understanding of dinosaurs and position it in ways that would be more consistent with disciplinary thinking.

1.2 COORDINATING KNOWLEDGE AND INTEREST

The research literature on relatively young children's interests suggests areas where the islands of expertise framework could provide further insights into the relationship between interest and knowledge development. It is often the case that young children's interests emerge around topics like dinosaurs rather than disciplines like paleontology or larger domains like biology (Johnson, Alexander, Spencer, Leibham, Neitzel, 2004). This emergence helps to organize experiences and provide opportunities for learning a thematically coherent set of information. Researchers seem to agree that interest has important connections to cognitive factors like increased attention, memory, and reasoning (Hidi, 1990; 2000). The distinction between children's situational interests and individual interests has helped to further contextualize the relationship between interest and knowledge development (Renninger, 1992; 2000). Among young children, as interests move along the continuum from situational (those that are more externally motivated, temporary, and determined by the characteristics of a given context) to more individual (internally motivated, sustained over time and across contexts), the motivation to seek out knowledge and maintain engagement in these topics intensifies (Renninger, 2000; 2004). Free-play environments have provided opportunities to explore how preschool children and their peers express this personal investment through toy preference (Renninger, 1992). In addition, models of interest development have suggested some of the characteristics that might predict the shift of an interest from situational to individual and the implications of moving through these difference phases for motivation and learning (Hidi & Renninger, 2006; Krapp, 2002).

While research has investigated many of the factors and behaviors associated with interest development, the coordination of these individual characteristics and particular learning environments has been less extensively studied. The islands of expertise framework hypothesizes that it is critical to consider the relationship between interest and knowledge development embedded in social contexts and learning environments. Consistent with the islands of expertise approach, Johnson, Alexander, Spencer, Leibham, Neitzel (2004) have discussed the relationship between early interest maintenance in children and role of parents' beliefs about supporting child initiated topic knowledge development. Their findings suggest that parents' topic-relevant conversations and willingness to support children's free play activities are critical to the emergence and maintenance of intense interests. Barron (2006) also suggests that parents continue to play an important role in the construction and maintenance of information ecologies during adolescence that influence the development of children's interest, knowledge and identity.

While much of the literature suggests that the development of expertise in a topic area is positively related to the maintenance of interest, Kintsch (1980) argues that the design and content of individual learning contexts might also influence their ability to sustain interest. Kintsch suggested that interest in a text depends on three primary factors: prior knowledge, novelty or surprise, and postdictability. In this model, prior knowledge refers to the information that an individual brings with them to a learning opportunity. The second and third factors, surprise and postdictability refer to the features of the text or learning context itself. In the case of surprise, an idea is presented in a way that is unusual and as a result is intrinsically interesting. In the case of postdictability, elements of a text or activities in a larger context gain additional meaning and become interpretable in light of the completed experience. Considering the first factor, Kintsch suggested that there is an inverted U-shaped relationship between prior knowledge and interest, with novices and experts having similarly low interest in a text that could be generated for very different reasons. For experts, texts may lose interest when there is no new information to be gained from the passage. In contrast, for novices, the absence of prior knowledge provides minimal support to spark their interest. Extending this model to informal learning environments suggests that capturing and sustaining the interests of children with a range of topic expertise would require a learning environment to provide flexible information delivery. In this setting, parents with novice children would be supported with ways to introduce this topic while parents with expert children would also have access to more sophisticated extensions of concepts that could maintain the interest of more knowledgeable children.

1.3 CONTEXTS TO SUPPORT PARENT CHILD DISCIPLINARY TALK

Museums are learning contexts that have the potential to provide powerful opportunities to make explicit connections between topic interests and the disciplines that they represent. Visitors to museums have unique access to a wide variety of information and the opportunity for self-directed exploration of personal topic interests in environments designed to support learning. Research has consistently found that educational goals are one of the primary motivations for family visits to museums. Adults and children typically seek out and engage in learning activities in these settings (Borun, Cleghorn, and Garfield, 1995; Falk & Dierking, 2000; NRC, 2009;

Hein, 1998). Learning research across a range of biological topics like dinosaurs, marine animals, mammals, plants, bugs and many others suggests that museums are well positioned to communicate the knowledge of professional scientists and curators in ways that are engaging and understandable to family visitors (Allen, 2002; Ash, 2003; Borun, & Dritsas, 1997; Eberbach & Crowley, 2005; Rigney & Callanan, 2011; Tunnicliffe, 1996; 2000). This mediation around objects, specimens, models, and demonstrations supports critical links between topics and disciplines that visitors can choose to experience in self-directed ways (Paris, 2002). The conceptual and physical design of museum exhibitions shape opportunities for visitor learning (Knutson, 2002; Borun, Chambers, Dritsas, & Johnson, 1997).

Museums provide dynamic opportunities for intergenerational learning through conversation (e.g. learning talk) where children and adults are more equitably empowered to adopt the roles of knowledge presentation and reception (Hilke, 1989; Sanford, Knutson, & Crowley, 2007). Exhibits designed to enhance family learning often encourage opportunities for multiple entry points into a topic that can support conversations between parents and children (Borun, Chambers, Dritsas, & Johnson, 1997). Learning talk has been defined as both a process and a product of experiences in informal learning environments that includes the refinement of conceptual knowledge, co-construction of interpretations of observed and inferred processes, and engagement in evidence based argumentation (Allen, 2002; Leinhardt & Knutson, 2004). Research has successfully provided training for parents in conversational elaboration strategies that facilitate deeper engagement with informal learning environments through learning talk (Eberbach, 2009). In addition, inquiry learning can be successfully facilitated in museums as demonstrated through research on systematic prototyping of exhibit designs and strategies for supporting family learning talk (Gutwill & Allen, 2010). In their initial exploration of islands of expertise, Crowley and Jacobs (2002) demonstrated that parents used a range of explanatory strategies to support children's understanding of a set of labeled dinosaur fossils in a children's museum setting. The positive relationship between parent strategy use and children's ability to correctly remember and identify fossils suggested that parent scaffolding influences young children's ability to coordinate learning opportunities over time into a coherent body of knowledge.

To further explore the ways that an island of expertise in dinosaurs might shape learning experiences in designed learning environments, Palmquist & Crowley (2007) considered the influence of islands of expertise on parent child learning conversations in the dinosaur hall of a natural history museum. Unlike a children's museum or a science center, most natural history museums provide visitors direct access to real fossil specimens, the objects of scientific study for vertebrate paleontologists. Palmquist & Crowley (2007) explored the hypothesis that children with islands of expertise in dinosaurs and their parents would use the natural history museum environment as a place in which to have more active learning conversations than novice children and their parents. Expert children and their parents were expected to make deeper conceptual connections between their prior knowledge and the kinds of disciplinary thinking and reasoning that was presented through the display of specimens in dinosaur hall. Based on their experiences with multiple representations of dinosaurs that populate books, DVDs, web pages, and TV programs, the assumption was that the opportunities to co-construct knowledge that were available to families with expert children would encourage them to engage in a variety of rich thematic conversations that would build on their prior knowledge. In contrast, novice families were expected to discuss the visual features of the dinosaurs on display and be less likely to engage with deeper conceptual or thematic topics.

Contrary to these expectations, expert children and their parents did not use the museum exhibition as a place to construct new knowledge or further extend their existing knowledge about the dinosaurs on display. Instead, expert children used the museum as a place to rehearse their prior knowledge and received very little additional input from parents. Often these conversations illustrated conceptual connections between form and function as well as comparisons between dinosaurs. However, with expert children generating the majority of talk, and parents listening intently, but rarely talking, there seemed to be limited opportunities to co-construct new knowledge through conversation. In addition, in the few cases where a parent with an expert child looked to the learning environment (e.g. signage and the design of the exhibition) to provide additional information that could be used to enrich the conversation, the options were limited. In contrast, novice families used the dinosaur exhibition as a more active learning environment than expected. Novice children and their parents engaged more equally in conversations and used the displayed specimens to illustrate explanations about surface features like size and scale as well as more conceptual connections like form and function that linked features to diet and self-defense behaviors.

These patterns of engagement were interpreted as evidence that expert children and their parents seemed to have encountered a *glass ceiling* that prevented them from using the museum environment as a place where shared knowledge and interest could support learning new ideas or ways of thinking about dinosaurs. Instead, for these families, the museum was a place that did not provide them with any additional information about their topic of interest. As a result, families used the exhibition as a place to quiz themselves and reinforce their existing knowledge. This was somewhat surprising since the fossil specimens are capable of supporting multiple levels of interpretation as evidence of the history of life on earth when viewed by museum curators. However, despite being knowledgeable about dinosaurs, these expert children and their parents did not seem to have the ability to do much more than use the fossil specimens as cues for activating their well-organized set of known facts. While this kind of activity might provide positive reinforcement for the development of a child's identity as an expert, it seemed like a missed opportunity to build and extend expert children's understanding of dinosaur fossils as evidence of ancient ecological systems and evolutionary history—disciplinary ways of thinking that are central to the scientific practice of paleontologists.

1.4 DEFINING DISCIPLINARY THINKING

Based on interactions with parents of child dinosaur experts, it is clear that finding learning resources and opportunities that can continue to support the interest and engagement of expert children is an ongoing challenge. While there are a multitude of books, TV programs, and internet resources about dinosaurs, many of them feature the same or very similar information. One hypothesis for how to address this challenge is to design experiences in informal learning environments like museums to provide parents and children with opportunities to connect their extensive dinosaur knowledge with the broader disciplinary contexts used by paleontologists. In order for this approach to be successful, an important first step is to identify the kinds of disciplinary thinking that could be productively supported among child dinosaur experts and their parents during a relatively brief experience in an informal learning environment.

The National Research Council has articulated and refined the importance of supporting the development of scientific literacy across formal and informal learning environments (2007; 2009). The *Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core*

Ideas identify learning trajectories for supporting understanding of ecosystems and biological evolution as core disciplinary concepts. In addition, cross cutting concepts like scale, systems & systems models, structure & function, and stability and change are identified as critical to begin to introduce in the earliest grade bands (NRC, 2011). Many of the strategies and suggestions for productive engagement with these disciplinary concepts are consistent with the kinds of learning opportunities available in informal learning environments. Natural history museums in particular are well positioned to use their collections and active scientific research to engage visitors in learning talk about ecology and evolution. Analysis of science learning frameworks suggests that during early elementary school children should be establishing a foundation for evolutionary thinking through lessons that focus on learning the features of living things, their behaviors, and their relationships to their environments (Evans, 2005). These recommendations highlight that both ecological and evolutionary understanding are built on more basic knowledge of living things. In later grades, the current frameworks emphasize the importance of recognizing the similarities and differences between ancient and present day life forms, the ability to categorize living things scientifically, the recognition that fossils represent evidence of past life on earth, and that many life forms have become extinct over time. A focus on Darwinian mechanisms of evolutionary change is not recommended until high school (NRC, 2011).

Across the grade level recommendations, several of the concepts identified as being core to ecological and evolutionary understanding reflect the kinds of knowledge structures that children with islands of expertise in dinosaurs seem to possess. These children have demonstrated extensive understanding of dinosaur categorization, the ability to reason about behaviors, and identify both taxonomic (family relationships) and hierarchical groupings (ecological relationships) (Chi, Hutchinson, Robin, 1989; Gobbo & Chi, 1986; Johnson, Scott, Mervis, 2004; Palmquist & Crowley, 2007). In museum settings, dinosaur expert and novice children and their parents often discuss form and function relationships connected to topics like diet and self-defense. However, expert children were more likely to initiate these conversations than their parents and their novice peers. In addition, during knowledge assessments, expert children were better able than novice children to discuss relationships between dinosaur features and their functions, identify fossils as evidence of ancient life, and generate theories for the extinction of the dinosaurs (Palmquist & Crowley, 2007).

Research in folk biology has repeatedly indicated that cultural context and prior experience with the natural environment are factors that can significantly influence performance on biological categorization, reasoning, and inference tasks (Unsworth, Levin, & Bang, 2012; Waxman & Medin, 2007; Winkler-Rhoades & Medin, 2010). Informal learning environments have the potential to increase opportunities for children living in urban environments to experience and explore systems relationships in the natural world and begin to address misconceptions (Coley, 2012). Natural history museums in particular play an important role in presenting scientific evidence that supports understanding of ecological systems and the theory of evolution and communicating these complex ideas to visitors. Reviews of the variety of ways that museum's exhibit evolution had provided an analysis of the alignment of museum presentation strategies with the AAAS (2001) and National Science Education Standards (NRC, 1996) to suggest ways that museums' support evolution education (Diamond & Scotchmoor, 2006). Evolution exhibits were described according to five organizational themes: geologic time, fossil assemblages, systematics, mechanisms of evolution, and historical approaches. Each presentation style has a unique set of affordances that make different aspects of the theory of evolution more salient to visitors. Diamond & Scotchmoor (2006) conclude that museums effectively bring visitors into contact with active paleontological research, highlight the scientists currently engaged in this work, and provide access to the authentic evidence for what has changed through time, preserved in the fossil record. Children with dinosaur expertise and their parents are well positioned to take advantage of the strengths of natural history museums' presentation of fossilized evidence of evolutionary history.

However, research in both formal and informal contexts has repeatedly demonstrated the challenges associated with teaching and learning evolution (Rosengren, Brem, Evans, & Sinatra, 2012). Research conducted in school contexts consistently identifies difficulties that students have understanding mechanisms of evolution including natural selection, variation, and inheritance (Bishop & Anderson, 1990; Demastes, Settlage, & Good, 1995; Brumby, 1984, Clough & Wood-Robinson, 1985; Deadman & Kelly, 1978; Greene, 1990; Jensen & Finley, 1994). In addition, research with pre-service and more experienced science teachers suggests that this population does not uniformly accept or feel well prepared to explain evolution to their students (Scharmann, & Harris, 1992; Schindel, 1999). Research in museums has suggested that visitor understanding of evolution is reflective of national patterns of comprehension (Evans et. al, 2010). Spiegel, Evans, Gram, and Diamond (2006) review of visitor studies reveals that while museum visitors are generally more interested in learning about evolution and more accepting of this concept than the general public, their understanding of evolution is incomplete. For example, in a front-end evaluation of the *Explore Evolution* exhibition, visitors' ability to successfully explain evolutionary concepts was found to vary in relation to different species. Visitors generated more informed naturalistic explanations about evolutionary processes in finches than any other species featured in the exhibit. In contrast, visitors' explanations of evolutionary processes in the virus, ant, diatom, and fly were most often coded as novice naturalistic. Finally, visitors' were most likely to produce creationist explanations in reference to evolutionary processes and relationships between chimp and human DNA (Evans, et al., 2005). In response to these findings, Spiegel, et al. (2006) propose a conceptual framework that encourages museum exhibit design to focus on the development of informed naturalistic explanations for evolutionary processes.

The combination of the conceptual complexity of the processes of evolution as well as the influence of belief systems on the acceptance of the theory continues to generate intense social debate (Scott, 2004). One of the outcomes of this discussion has been the identification of micro and macro evolutionary concepts. Microevolution refers to the mechanisms that produce change including variation, inheritance, and selection, and time. Macroevolution refers to concepts like the origin of species and common descent (common ancestors) that generate hypotheses about evolutionary relationships. In research that has explored the influence of belief systems on evolutionary understanding, Evans (2005) suggests that there are different developmental trajectories associated with micro evolutionary and macro evolutionary concepts. For communities that have strong beliefs in special creation, micro evolutionary processes seem to be more readily accepted and understood than macro evolutionary concepts (Poling & Evans, 2004). However, cognitive psychology research has suggested that one of the core challenges to understanding micro evolutionary processes like natural selection is an apparent learner bias to categorize and explain processes exclusively in terms of direct causality. Ferrari & Chi (1998) demonstrated that for complex processes that are produced through emergent causality like natural selection and diffusion, students consistently generated explanations that suggested an ontological conflict that is difficult to revise.

This research suggests that educators in formal and informal learning environments continue to struggle with how to best support the development of an understanding of the concepts and processes of evolution. However, there is some evidence suggesting that museums support conversations about biological themes like form and function relationships that could develop into understanding of ecological systems as well as more sophisticated biological principles like adaptation or natural selection (Ash, 2000; Ash & Brown, 1996). In addition, for families with young children, focusing on macro evolutionary concepts (e.g. the products of evolution) might be more accessible than focusing on micro evolutionary concepts (e.g. the processes of evolution). Consistent with this hypothesis, analysis of parent-child conversations at museum exhibits suggests that families make form and function connections when discussing themes like diet, defense behaviors, and change over time (Ash, 2002; Palmquist & Crowley, 2007). However, these conversations often remain at a surface level where relationships between sharp teeth and eating meat are identified, but not placed in broader evolutionary or ecological contexts. While some informal science learning environments have successfully designed exhibitions to support visitors engagement with ecological or evolutionary concepts, there are very few that successfully engage visitors in learning talk about both of these disciplines.

1.5 DESIGNING TO SUPPORT DISCIPLINARY TALK

The original dinosaur hall at the Carnegie Museum of Natural History represented a 19th century approach to museum exhibition design. A collection of 10 complete dinosaur and 17 associated non-dinosaur fossils were displayed in rows of casework in a single large room with minimal interpretative signage beyond the name of the specimen and few key facts. Fossil specimens of *Stegosaurus, Allosaurus, Apatosaurus, Diplodocus, Protoceratops,* and *T.rex* were free standing 3-dimentional reconstructions. The remaining dinosaur and non-dinosaur fossils were displayed in casework that lined the walls of both sides of the hall. In preparation for the 100^{th} anniversary of the original dinosaur hall, the museum committed to a dramatic and highly ambitious re-design plan that would nearly triple the space in which to exhibit their world class collection of Mesozoic fossils. In the process, the dinosaur fossils would be completely disassembled, cleaned, preserved, and repositioned in poses that reflected current scientific understanding. The new exhibition, *Dinosaurs in Their Time* would take visitors on a journey through the three time periods of the Mesozoic era where they would encounter dinosaurs in the ecological and temporal contexts in which they would have lived.

During this time, I had the opportunity to work as an evaluator for this project. As a member of the design team, I attended monthly meetings and participated in decision making discussions with museum administrators, curators, educators, and exhibit staff members. Findings from research, front-end, and formative evaluations that I conducted with others from the University of Pittsburgh Center for Learning in Out-of-School Environments (UPCLOSE) directly informed design decisions and shaped the target learning outcomes for the exhibition. Early in the design process, the team identified families as their primary audience and carefully considered the kinds of learning experiences that they wanted to provide for this group. The findings from Palmquist & Crowley (2007) helped to motivate the development of a layered information strategy that could support learning conversations for children with a range of dinosaur expertise. There was a strong commitment to ensuring that the new exhibition would be an active learning environment for all families. Iterative rounds of formative evaluation provided feedback on the design and usability of printed labels, touch screens, and how these different kinds of learning resources would work together to support family learning talk.

A turning point in the design development process was the museum's acquisition of a new fossil and cast of an unnamed giant *Oviraptorosaur.* This dinosaur reconstruction became the centerpiece of a working prototype that was refined and tested over nearly two years during the renovation process. With this high fidelity platform to work with, we were able to explore a range of strategies for supporting family engagement with ecological and evolutionary learning talk. In addition, this fossil in particular provided easily observable shared features that provide evidence of the common ancestry between dinosaurs and birds. The combination of implicit and explicit learning resources available in *Dinosaurs in Their Time* had the potential to support a significant increase in disciplinary learning talk compared to the original dinosaur hall. It was in this context that the research study was conducted.

1.6 RESEARCH SETTING

The completed *Dinosaurs in Their Time* exhibition highlighted the Carnegie Collection of Mesozoic fossils, displaying dinosaurs in the ecological and temporal contexts that they would have lived in millions of years ago. Each platform featured a three dimensional scene that suggested a narrative of interactions that could have occurred between different species of dinosaurs, other animals, and plants. Murals illustrate each time period and offer a complimentary artistic representation of how dinosaurs might have looked and interacted along with other species like pterosaurs, early mammals, reptiles, and birds.

Informed by front end and formative evaluation (discussed above) the available learning resources in the exhibition were designed to support visitor engagement with the fossil specimens both individually and in their broader ecological and evolutionary contexts. At the beginning of each time period, an introductory station featured a large globe that illustrated the changing distribution of land masses and oceans. Surrounding each globe were a set of touch screens and labels that provided an overview of what life was like on earth during that time period. These stations introduced the ecological and evolutionary contexts of each of the three periods of the Mesozoic Era. Specimens from each period are displayed on platforms with printed labels as well as touch screens that offer visitors information about the plants and animals featured. Printed labels highlight a significant specimen on the platform and provide information about features, behaviors, and details of where the fossil was discovered. Touch screens provided thematic context for the featured specimen and identified the associated fossils and reconstructions of plants and animals displayed on each platform that did not have a printed label. Touch screens were designed to allow visitors' to pick and choose which topics to explore. This layered information strategy supported a free-choice, self-guided exploration of the species featured on the platforms and allowed visitors to personalize their information access experience. For example, in front of the *Stegosaurus* fossil the printed label features a scientific illustration that that describes the connections between features and how they would have helped it to survive in its environment. This presentation was designed to help answer questions like why a dinosaur like *Stegosaurus* might have developed its distinctive back plates. In order to learn more about which of the displayed plants *Stegosaurus* might have eaten, the touch screen would provide those answers.

The labels and touch screens throughout the exhibition present a variety of entry points to begin conversations about dinosaurs as animals that lived in specific ecological and evolutionary contexts. In addition to the scientific illustration at the center of each label, there are other sections that provide brief descriptions of the ecological context in which the focal specimen lived, a scale figure comparing the size of dinosaurs to average heights of men, women, and children, a map that highlights where the fossil on display was discovered, and a final section that describes scientific discoveries that have been made about the specimen. The touch screens used a consistent layout to facilitate intuitive navigation. Each screen features an illustration of a fossil platform with a set of six icons that provided information about: appearance, location, climate of that time period, evolutionary relationships, scientific discoveries made about the specimen, and which of the displayed fossil elements are real.

1.7 CONTENT OVERVIEW

In the *Dinosaurs in Their Time* exhibition, visitors walk through the Triassic, Jurassic and Cretaceous time periods in chronological order and experience the changes in animals, plants, and environments that occurred throughout the Mesozoic era. The Triassic platform illustrates the Chinle formation and the beginning of the age of dinosaurs. The combination of the mural and mounted fossils suggests that the earliest dinosaurs like *Coelophysis* were small land reptiles that were far from the top of the food chain when compared with species like *Redondasaurus*, a very large land reptile represented on the platform. On the opposite wall from the main platform there are two wall cases that display marine plant and animal fossils from the Triassic period. The beginning of the Jurassic period features a nearly complete juvenile *Camarasaurus* specimen still embedded in some of the original rock matrix in which it was found. Next, a small platform features *Dryosaurus* being stalked by a *Ceratosaurus.* In addition to the ecological relationship highlighted here, *Dryosaurus* and *Ceratosaurus* also provide the opportunity to compare examples of the two main branches of the dinosaur evolutionary tree: the lizard-hipped and the bird-hipped dinosaurs. On the opposite wall from these fossil specimens are a wall case with early Jurassic marine fossils and a set of three monitors that make-up the DinoMorph interactive. DinoMorph uses short animations paired with scrolling text to describe how scientists' analyzed the stances of three iconic dinosaurs (*T.rex, Triceratops,* and *Apatosaurus*) and revised their hypothesis about their posture based on the functional requirement that each needed to be able to walk on land.

The Jurassic atrium illustrates the proportions of the large sauropods, *Diplodocus* & *Apatosaurus*, while also suggesting that their young were small and vulnerable to attack by predators like *Allosaurus*. In addition, the Jurassic atrium presents the broad diversity of herbivorous dinosaur species and how these different families were adapted to the environment. Distinct diet, self-defense features, and behaviors are illustrated by the specimens of *Stegosaurus* and *Camptosaurus*. In addition, a large wall case features late Jurassic marine fossils reinforcing the message that the Mesozoic ecosystem was highly diverse. The transition from the Late Jurassic to the Early Cretaceous time period displays fossils and reconstructions of the first feathered dinosaurs like *Caudipteryx* and examples of the first modern birds like *Confuciusornis* found in the Liaoning formation. This section also features information on early mammals as well as fossils of early examples of the Ceratopsian family including *Protoceratops and Psittacosaurus.*

The *T.rex* platform is the central focus of the late Cretaceous period. It features a dramatic confrontation between two *T.rex* specimens over the remains of an *Edmontosaurus.* In addition, the Cretaceous section of the exhibition features a large pterosaur, *Quetzalcoatlus* suspended from the ceiling, and a display of ceratopsian skulls including *Pachyrhinosaurus, Styracosaurus,* and *Torosaurus* and others that demonstrate the diversity that evolved in this family of dinosaurs. Other dinosaurs included in this section are the *Pachycephalosaurus*, *Triceratops,* a giant *Oviraptorosaur,* and *Corythosaurus*. This final time period opened to the public in late June, 2008 and several families saw this section of the exhibition for the first time while participating in this study. A floor plan of the exhibition is included in Appendix A.

2.0 METHODS

Using a combination of quantitative and qualitative methods, this study was designed to investigate three research questions:

- **How does child knowledge influence the content of parent-child learning talk?**

  This question explores what topics are included in the learning talk observed between parents and children in this study. Comparisons of the content of learning talk are made between children with expert and novice levels of dinosaur knowledge and between parents of expert and novice children. Understanding the content of learning talk that parents' and children engage in is critical for describing what learning is and how learning occurs in informal learning environments like museums.

- **How does child knowledge influence who participates in learning talk within families?**

  This question investigates who is producing learning talk with in families and considers whether child knowledge influences patterns of parent and child learning talk. Comparisons are made between expert children and their parents as well as novice children and their parents. Understanding the dynamics of who initiates learning talk within family groups can provide insight into how child knowledge may shape opportunities for children and parents to engage in learning talk.

- **How does the design of the museum learning environment shape opportunities for learning talk across families with expert and novice children?**

  This question considers the affordances of the designed learning environment to support learning talk and explores the way that child knowledge may influence how parents and children choose to engage with the range of available learning resources. Case study analysis of an expert and a novice family is used to highlight the interaction between child knowledge and the learning talk that families engage in during a visit to *Dinosaurs in Their Time.*

2.1.1 Participants

A total of 50 families with children between the ages of 5-8 years old participated in this study. Families were described as 56% parent-child dyads, 18% two parents with more than one child, 16% two parents and one child, and 10% one parent with more than one child. In cases where the family group was larger than a parent-child dyad, a target child and parent were identified as the primary participants and the additional talk generated by other members of the visit group was excluded from analysis.[1] Target children included 30 boys and 20 girls with a mean age of 6 years, 9 months. The majority of participants completed the study on weekdays (58%) and the remainder on weekends (42%). Museum members accounted for 46% of families and the remaining 54% were not members. A total of 68% of participants had previously visited the museum with their child while 32% were visiting the museum for the first time with their child on the day of the study. Pre-recruited families accounted for 62% of the sample and the remaining 38% were families recruited on site.

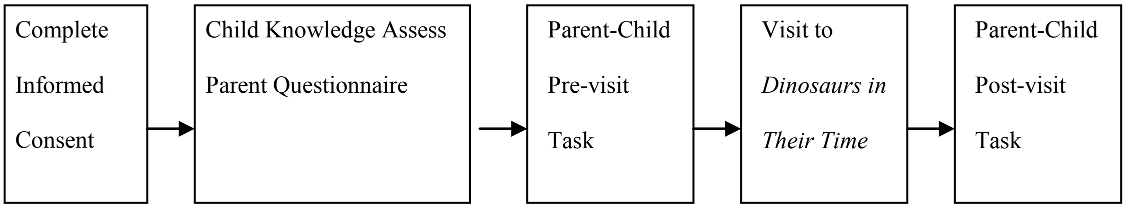
[1] This approach was used successfully in Palmquist & Crowley (2007) to produce a more targeted and conservative measure of family learning talk for groups of different sizes and configurations.

2.1.2 Procedure

Participant families were recruited through direct invitation at museum summer camp sign in, on-site invitation of museum visitors, and word of mouth. Approximately 100 families were contacted through these methods and 50 chose to participate in the study. Families from the summer camp typically gave one of three reasons for declining to participate in this study: conflicts with parent work schedules, child activity schedules (sports and other camps), and vacations. Families approached on site at the museum most often declined to participate in the study because of lack of interest or time constraints on their visit to the museum.

For those parents and children who expressed interest in the study, the researcher described the activities that parents and children would be asked to complete (See figure 1 for a summary of study procedures). In accordance with the University of Pittsburgh IRB requirement, the researcher obtained written informed consent from parents and verbal assent from children. Following the consent procedure, parents and children were lead to an area of the museum where the materials for a dinosaur knowledge assessment were laid out and a video camera was positioned to record study activities. Parents completed a background interest questionnaire while children completed the knowledge assessment interview. Together, parents and children completed a pre-visit task where they discussed six images of the exhibit (two from each time period). Parents and children were fitted with a wireless microphone and videotaped while they visited the *Dinosaurs in Their Time* exhibition. Families were encouraged to visit the exhibition as they usually would and then to return to the interview location for a post visit activity. The post-visit task was the same as the pre-visit task.

Figure 1. Summary of Data Collection Procedures



2.1.2.1 Knowledge Assessment

The knowledge assessment interview measured children's knowledge of dinosaur names, familiarity with the causal relationship between features and behaviors, awareness of extinction theories, familiarity with paleontology practices, and temporal relationships between dinosaurs. These items represent an adapted subset of the items developed by Palmquist & Crowley (2007) that were found to be most diagnostic of childhood dinosaur expertise. The assessment used a combination of dinosaur figures and scientific illustrations to support children's ability to use dinosaur knowledge to generate causal explanations and functional inferences using observational evidence. At the beginning of the interview, children were invited to a table that displayed 17 resin figures (5 non-dinosaurs and 12 dinosaurs). Children were asked to look at all the figures and point out any that were not dinosaurs and if possible identify those figures by name. Once they had indicated that they had found all of the non-dinosaurs, they were asked to explain how they knew that the selected figures were not dinosaurs and how they knew the remaining figures were dinosaurs. Following this explanation, the selected figures were removed from the table. No feedback for correct or incorrect selections was provided. The non-dinosaur models included two mammals (*Tiger* and *Giraffe*) and three prehistoric reptiles (*Pteranodon, Dimetrodon,* and *Elasmosaurus)*.

Next, children were asked to identify the remaining figures, beginning with the *T.rex*. The experimenter always began with this figure because *T.rex* is the most well-known dinosaur and for the majority of children this question helped to build confidence for the rest of the assessment. The dinosaur models included: *Allosaurus, Ankylosaurus, Apatosaurus, Brachiosaurus, Camarasaurus, Diplodocus, Iguanodon, Maiasaura, Stegosaurus, T.rex, Triceratops and Velociraptor.* All dinosaur models were figures from the Carnegie Collection that represented dinosaurs featured in the exhibition as well as those that are commonly found in children's dinosaur books. Once children had named as many figures as they could, the experimenter cleared the table and moved on to the next section of the assessment. Children were asked to look closely at laminated images of three dinosaur skulls (*Diplodocus, Camarasaurus, and Allosaurus)* and choose which of the dinosaurs ate meat, which of the dinosaurs ate plants, and to describe how they could identify the diet category of the dinosaur based on the images. Children were also asked to describe what was similar and what was different about the skulls as well as to describe how a scientist might group these skulls in different ways. Questions asked in relation to the laminated illustrations produced inferences and explanations about diet, patterns of scientific grouping, extinction theories, and paleontology practices. Finally, to assess their familiarity with patterns of dinosaur coexistence, children were asked to look at models of *Stegosaurus, Triceratops, Ankylosaurus, Allosaurus*, and a cave person and choose which of the displayed figures lived at the same time as *Stegosaurus.* Children were then asked to explain their choice and whether the remaining animals would have lived before or after the *Stegosaurus.*

2.1.2.2 Parent Questionnaire

This instrument measured background information about family interest and knowledge about dinosaurs as well as the material support (learning resources) available in the home to support interest and knowledge development. Items were adapted from the parent questionnaire used in Palmquist & Crowley (2007). Parents' completed four Likert-like scales about their children's interest and knowledge about dinosaurs, as well as their own level of interest and knowledge about dinosaurs. In addition, approximately ten questions were designed to measure interest indicators (materials, coordination of experiences and opportunities that could support interest and knowledge development) around a range of topics including dinosaurs. Parents were asked to complete this paper-based survey while children completed the knowledge assessment interview. This questionnaire provided a general indication of family engagement with different kinds of learning resources. In addition, this instrument requested information about museum membership, frequency of annual attendance museums, and parents' highest level of education completed.

2.1.2.3 Parent-Child Activity

Following the completion of the knowledge assessment interview and parent questionnaire, parents and children were briefly oriented to *Dinosaurs in Their Time* through a set of six images. For each of the time periods featured in the exhibit, two images were provided to support discussion. The two images of the Triassic focused on the fossils of the large land reptile, *Redondosaurus,* as it pursues a pack of *Coelophysis*, small meat eating dinosaurs, into a forest of large horsetail-like plants. In one image of the Jurassic, a medium sized meat-eater, *Ceratosaurus,* is poised to attack a smaller plant-eater, *Dryosaurus.* The second Jurassic image showed the long-necked, long-tailed sauropods *Diplodocus* and *Apatosaurus* guarding a baby

Apatosaurus as the meat eating *Allosaurus* approaches. Finally, one of the Cretaceous images captures the two *T.rex* fossils in a confrontation over the remains of an *Edmontosaurus.* The second Cretaceous image showed the mural image of a *Hadrosaurus* herd moving away from the *T.rex* confrontation as well as a *Triceratops* fossil. As they were shown these images, parents and children were reminded of the name of the exhibition and asked to identify each of the three time periods when the dinosaurs lived. If they did not know the names of the three time periods, the researcher would label them. Next, parents and children were asked five questions and encouraged to discuss their answers in relation to the sets of pictures. Each question was presented individually on a laminated card, read to the participants by the interviewer, and then left on the table as a reminder. The five questions are listed below in table 1. These questions can be divided into two categories: those that encouraged ecological explanations (Qs 1-3) and those that encouraged evolutionary explanations (Qs 4-5). The same procedure was repeated following the family visit to *Dinosaurs in Their Time.*

Table 1. Questions used during the parent child pre and post museum visit experience

Ecology Questions	What was life like for the plant eating and meat eating dinosaurs during each of these time periods?
	If you were a plant eating dinosaur, which period would you want to live in?
	If you were a meat eating dinosaur, which period would you want to live in?
Evolution Questions	Between which periods did the world change the most?
	In which periods could you find relatives of modern plants and animals?

2.1.2.4 Museum Visit Experience

Before visiting *Dinosaurs in Their Time,* parents and children were fitted with wireless microphones and the audio quality was tested. Parents' were given a laminated topic card that listed four questions that addressed ecological and evolutionary themes. They were encouraged to take the card with them as they explored the exhibition (figure 2 provides a copy of the card). The card was intended to encourage parents to look for opportunities to engage in conversations about ecological and evolutionary relationships in a way that would be consistent with typical museum practice. Informal learning environments often provide family guides that offer suggestions for topics to investigate or ways to engage with different learning environments. In some cases these guides are associated with tools like hand magnifiers (Zimmerman, 2012) while in others they are paper brochures or laminated cards (e.g. CA Academy of Sciences; National Museum of Natural History). The decision to explicitly cue parents and children to engage with questions that highlighted ecological and evolutionary relationships encouraged alignment between family conversations and the themes the exhibition was designed to support. This provided a best case scenario to investigate how differences in children's prior dinosaur knowledge might influence the frequency of parent-child conversations around ecological and evolutionary relationships.

Figure 2.Topic Card

Each room of the exhibition is a snapshot of a different time period and a different location. As you visit please discuss:

a- What was life like for plant-eating and meat-eating dinosaurs in each time period?

b- What kinds of features helped dinosaurs to survive in each time period?

c- What kinds of changes do you notice in dinosaurs, plants, and animals between time periods?

d- What kinds of modern plants and animals might be related to the dinosaurs, plants, and animals in the exhibit?

2.1.3 Data reduction: Identifying Experts and Novices

In order to determine the final data set, videos and questionnaires were reviewed to ensure that subjects had fully completed the outlined tasks. Analysis of the rating scales completed by parents about children's dinosaur knowledge combined with coding of the child knowledge assessment interview determined whether children were dinosaur experts or novices. This analysis generated a final data set of 30 families that included 15 experts and 15 novices. The remaining 20 families were excluded from further analysis in this study because children's scores on the knowledge assessment fell between the target ranges of the expert and novice categories. Data reduction techniques like this are often used in research where differences in the learning behaviors of a group based on knowledge or performance levels are being investigated (Fuchs et al., 1994, Roscoe & Chi, 2007).

The maximum possible score on the child knowledge assessment was 68 points. Points were earned based on the ability to correctly recognize and identify dinosaur and non-dinosaur figures, to use observational evidence to identify dinosaur diets, to discuss scientific groupings, to describe theories of extinction and identify species of dinosaurs that coexisted. Answers to assessment questions and quality of explanations were coded. Children were assigned to the novice category when they scored 18 points or fewer on the knowledge assessment. Novice scores ranged from 7 to 18 (M=13, SD=3.72). On average, novices named 2 dinosaurs and non-dinosaurs, had difficulty using observational evidence to determine dinosaur diet categories, were inconsistent in their ability to generate a theory of extinction, and were unfamiliar with patterns of dinosaur coexistence. Children were assigned to the expert category when they scored 30 points or higher on the knowledge assessment. Expert scores ranged from 30 to 57 (M=43, SD=8.72). On average, experts named 14 dinosaurs and non-dinosaurs, successfully used observational evidence to determine diet categories, consistently provided one or more theories for the extinction of the dinosaurs, and correctly identified patterns of dinosaur coexistence. Parent ratings of children's dinosaur knowledge were consistent with novice and expert groups. Based on a seven-point scale where one was not very knowledgeable and seven was extremely knowledgeable, parents consistently rated expert children's knowledge (M=6, SD=1.55) significantly higher than novices (M=3, SD=1.06) [$F(1, 28)=40.03$, $p<.001$].

2.1.4 Coding Parent-Child Conversation

Parent-child conversations were video recorded and transcribed for analysis of learning talk. In order to quantify the content of these conversations a combination of emergent and deductive approaches were applied to these transcripts (Chi, 1997). Informed by coding of parent-child learning talk in the original dinosaur hall (Palmquist & Crowley, 2007), three over-arching coding categories were developed to explore patterns of topic and thematic engagement:

identification talk, descriptive talk, and disciplinary talk. Each category is described in more detail below.

2.1.4.1 Identification Talk

Research on parent-child conversations in informal learning environments has demonstrated that labeling and naming are primary features of these experiences (Ash, 2003; Borun, 2002; Tunicliffe, 2000; Zimmerman, Reeve, & Bell, 2010). Consistent with previous research, coding focused on the presence or absence of identification and does not reflect accuracy. Engagement in identification talk was of particular importance in this analysis because of the central role that this knowledge has been shown to play in early childhood expertise studies in declarative domains (Chi & Koeske, 1983; Gobbo & Chi, 1986; Johnson & Mervis, 1997). The ability to recognize and apply basic and subordinate level categories within the dinosaur domain in particular has been shown to positively correlate with meta-cognition and inferential reasoning (Alexander, Johnson, Scott, & Meyer, 2008). Identification was defined in three ways: through labeling features, diet behaviors, and use of scientific names. These categories are described in more detail in table 2.

Table 2. Definition and examples of identification codes

Identification Talk	**Definition**	**Examples**
Feature Label	Features used to indicate a particular dinosaur or fossil specimen	"It's a long neck; Look at that big one; See the flying one up there?"
Diet Behavior	Diet behavior used to indicate a particular dinosaur or fossil specimen	"I think that one is a plant eater; So which one of these is the meat eater?"
Scientific Name	Scientific name used to indicate a particular dinosaur or fossil specimen	"Do you see the Triceratops over there?; Look up, it's *Quetzalcoatlus* above us"

2.1.4.2 Descriptive Talk

The second over-arching category measured instances when parents and children described the specimens on display and the features of the environment. Descriptive talk captured three types of conversations about the specimens and features of the exhibition. These included: dinosaur comparisons (with other dinosaurs and with non-dinosaur species), form & function relationships (diet and non-diet features and how they would support survival), and affective talk (favorite species and expressions of awe, wonder, and fear). Research in informal learning environments has focused on aspects of descriptive talk as evidence of prior knowledge, distributed expertise, and learning (Allen, 2001; Palmquist & Crowley, 2007; Zimmerman, Reeve, & Bell, 2008). These categories are described in more detail in table 3.

Table 3. Definition and examples of descriptive codes

Descriptive Talk	Definition	Examples
Form & Function	FF Diet: Identified specific features and how they are used for eating	"sharp teeth were good for tearing meat; it doesn't have those back teeth for grinding plants"
	FF Other: Identified specific features and how they are used for survival	"The horns were used to defend itself; Plates might have helped it to stay warm"
Comparison	Dino-Dino: Described specimens in relation to another dinosaur	"This is a meat eater [*Allosaurus*], but it's not the same as *T.rex*; *Camptosaurus* and *Dryosaurus* are the same size"
	Dino-Other: Described specimens in relation to another animal or inanimate object	"I think that leg bone is as big as you!; This dinosaur was as tall as our house"
Affective	Expressed an emotional responses or identified a favorite species	"Triceratops has always been my favorite; Wow, these fossils are just amazing"

2.1.4.3 Disciplinary Talk

The *Dinosaurs in Their Time* exhibition was designed to highlight the ecological and evolutionary contexts in which paleontologists interpret dinosaur fossil specimens. The third over-arching coding category was created to measure the degree to which family visitors to the exhibition were able to engage with these themes. Disciplinary coding categories include: ecological connections (recognizes predator-prey relationships or connections between species and the environment), evolutionary relationships as change over time (notices specific differences between the different time periods like the size of dinosaurs), evolutionary relationships as common features (notices shared features between Mesozoic species and modern species), and evolutionary relationships as common ancestors (explicitly identifies species as relatives using terms like descendants or ancestors).

Table 4. Definition and examples of disciplinary codes

Disciplinary Talk	Definition	Examples
Ecology	Makes one or more connection between species or species and the environment	"Life was tough for plant eaters b/c meat eaters would hunt them; It would be good to be a plant eater here [Jurassic] b/c there are lots of plants and the meat eaters are generally smaller than I would be"
Evolution	Change over time: Identify change in dinosaurs and/ or their environments; Links change with environmental context in which it occurred	"Dinosaurs seemed to get bigger in the different times, huh?; Plant eaters get more armor like horns and spikes; So in this time there was an explosion of plants and with so many plants there were more plant eaters and many different kinds of them"
	Common features: Identify a specimen that "looks like" a species alive today	"*Redondosaurus* looks like an alligator; horsetails look like bamboo; *Triceratops* looks like a rhino"
	Common ancestors: Identifies connections between related species; uses terms like ancestors, descendants, or evolved	*"Caudipteryx* is an ancestor of modern birds; Mammals were first shown to evolve in the Triassic, and the first birds evolved in the Jurassic, like *Archyopteryx"*

In order to establish that these coding categories could be recognized and consistently applied to transcripts of family conversations, one researcher coded the entire data set and a second researcher coded 20% of the data. Cohen's Kappa was used to calculate interrater reliability. Analysis indicated that substantial agreement existed between the two researchers across the 10 sub-codes. [Kappa=0.89 ($p<.001$), 95% CI (0.87, 0.91)]. All remaining disagreements were resolved through discussion and data adjusted to reflect those decisions.

3.0 RESULTS

3.1 DESCRIPTIVE ANALYSIS

The final data set of 30 families included 15 expert children and 15 novice children. Consistent with previous studies of childhood dinosaur knowledge (Johnson, Scott, Mervis, 2004; Palmquist & Crowley, 2007), the expert category included more boys than girls (11 boys and 4 girls) while the novice category included more girls than boys (9 girls and 6 boys). Experts ranged in age from 5 years to 8 years old with a mean age of 7 years and 1 month. Novices ranged in age from 5 years to 8 years old with a mean age of 6 years and 7 months. An independent samples t-test indicated no significant difference between the ages of children in the novice and expert groups [t (28)=-1.19, p=.25]. As a result, age will not be included in any further analysis. Families were described as 53% parent-child dyads, 20% two parents with more than one child, 17% two parents and one child, and 10% one parent with more than one child. Chi Square analysis indicated that there were no significant relationships between group composition and children's knowledge category [$X^2(2, N = 30) = 4.20$, p=.24]. As a result, group composition will not be included in any further analysis.

Parent questionnaire responses provided some additional context with which to describe this sample of families. As anticipated parent ratings of children's interest in dinosaurs on a 7-point scale where one was not interested at all and seven was extremely interested suggested that on average experts (M=6.33, SD=0.82) were significantly more interested in dinosaurs than novices (M=3.67, SD=0.90) [t(28)=-8.50, p<.001]. Parents also rated their own interest about dinosaurs using the same 7-point scale. Though parents of dinosaur experts (M=4.33, SD=1.63) rated their interest in dinosaurs higher than parents of novices (M=3.27, SD=1.22), an independent samples t-test indicated that there was only a marginally significant differences between these levels of dinosaur interest [t(28)=-2.03, p=.052]. However, parents of expert children rated themselves significantly more knowledgeable about dinosaurs (M=5.27, SD=1.22) than parents of novices (M=3.47, SD=1.19) [t(28)= -4.09, p<.001]. Consistent with research and evaluation studies conducted with adult visitors to informal learning environments (Eberbach, 2009; Evans et al., 2010; Korn, 1995; Palmquist, Yalowitz, Danter, 2011), the parents in this sample were highly educated. Sixty percent (n=18) of parents had a graduate degree; 27% (n=8) had a college degree; and 13% (n=4) had completed High School or earned a GED. Chi Square analysis indicated that there were no significant relationships between parents' education level and children's knowledge category [X^2 (3, N = 30) = 1.50, p = .47]. As a result, parent education level will not be included in any further analysis.

Parents also reported that expert children had access to significantly more dinosaur learning resources (M=4, SD=0.63) like books, DVD's, toys, and games than novice children (M=2, SD= 0.83) [t(28)=-4.46, p<.001]. The most popular dinosaur learning resources used by families were books (80%), videos and DVDs (63%), and visits to museums (57%). Overall, families in this study were frequent museum visitors. When asked about their museum visitation in the last 12 months, 53% of families reported visiting 4 or more museums, 30% reported visiting 2-3 museums, and the remaining 17% had visited at least one museum. Members of the Carnegie Museum of Natural History (CMNH) accounted for 53% of families and the remaining

47% were not members. Chi Square analysis indicated that there were no significant relationships between family membership at CMNH and children's knowledge category [$X^2(1, N = 30) = 2.14, p = .14$].

3.2 CONTENT ANALYSIS OF LEARNING TALK

Families in this study generated a total of 7,736 instances of learning talk. The majority of learning talk was generated during family visits to *Dinosaur in Their Time* where families engaged in a total of 5,909 instances of learning talk (M= 197, SD =105.77). Families engaged in a total of 955 instances of learning talk during the pre-test (M=32, SD=19.06) and 872 instances of learning talk during the post-test (M=29, SD=13.41). Consistent with this distribution of observed learning talk, families spent an average of 36 minutes and 10 seconds in dinosaur hall, 8 minutes and 42 seconds on the pre-test, and 8 minutes on the post-test. Further analysis revealed that parent self-ratings of interest and knowledge were not correlated with time spent across the three phases of the study. However, child knowledge category determined by the assessment interview was significantly correlated with time spent in the museum exhibition (r (28)=.47, p<.01) and on the post-test (r (28)=.38, p<.05). On average, families with expert children (M=42 minutes and 39 seconds, SD=16 minutes, 18 seconds) spent significantly more time visiting dinosaur hall than families with novice children (M=29 minutes, SD=10 minutes, 25 seconds) [t(28)=-2.78, p=.010]. Families with expert children spent more time on the pre-test (M=9 minutes and 12 seconds, SD=2 minutes) than families with novice children (M=8 minutes, 11 seconds, SD=3 minutes, 36 seconds) though this difference was not significant [t(28)= -1.52, p=.139]. And families with expert children spent significantly more time on the post-test (M=9 minutes and 10 seconds, SD=2 minutes) than novice children (M=7 minutes and 31 seconds, SD=2 minutes, 24 seconds) [t(28)=-2.17, p=.039].

The significant differences observed between families with expert and novice children in the amount of time spent during the visit to dinosaur hall are not surprising given that expert families have more prior knowledge and individual interest in this topic than novice families that could be used to support learning talk. In addition, research suggests that factors like interest level, prior knowledge, and visit agenda often influence learning behaviors and outcomes in free-choice informal learning environments like museums (Allen, 2002; Crowley et al. 2001; Falk & Dierking, 2000; Leinhardt, Crowley, Knutson, 2002). However, these significant differences in time also present a complication for the comparison and interpretation of the average amounts of learning talk generated by families with expert and novice children. To address this issue and standardize the data set for time on task, the metric comments per hour (CPH) was created. CPH was calculated by dividing the raw codes in each category of talk by the total time spent on a task in seconds, divided by 60 seconds, divided by 60 minutes. Standardizing the data in this way allows for a more accurate comparison of the amount of learning talk generated by families with expert and novice children. The results of all of the discourse analysis for learning talk during the museum visit, pre-test, and post-test are reported in CPH (See Appendix C, tables C1-C4 for raw means of parent and child learning talk).

The results of the discourse analysis will be used to address two of the three research questions that framed this study: How does child knowledge influence the content of parent-child learning talk?; How does child knowledge influence who participates in learning talk within families? Results from the museum visit will be presented first, followed by the results from the pre-test, the post-test, and the comparisons of pre-test and post-test learning talk.

3.2.1 Museum Visit Results

How does child knowledge influence the content of parent-child learning talk?

Understanding the content of learning talk that parents and children engage in is critical for describing what learning is and how learning occurs in informal learning environments like museums. The first analysis of learning talk in the museum examined this dependent variable at the largest grain size: total family learning talk. A one-way between subjects ANOVA indicated that there was not a significant effect of child knowledge on total museum visit talk [$F(1,28)=1.40$, $p=.240$]. This was an encouraging finding because it suggests at the broadest level that the museum exhibition is an equally effective context to support learning talk for families with expert and novice children.

3.2.1.1 Comparisons between child learning talk

A one-way between subjects ANOVA indicated that there was a significant effect of child knowledge on total children's learning talk during the museum visit at the $p<.05$ level (See table 5 for means (CPH), standard deviations, and patterns of significance). Expert children were consistently engaging in more total learning talk than novice children while in the museum exhibition. In order to better understand what kinds of learning talk were accounting for this difference, conversations were identified as one of the three over-arching categories: identification talk, descriptive talk, and disciplinary talk. One-way between subjects ANOVAs indicated that there were significant differences between expert and novice children's overall identification talk and disciplinary talk. Expert children were consistently producing more identification talk than novice children. And interestingly, expert children were generating approximately twice as much disciplinary learning talk as novice children. In contrast, novice children produced slightly more overall descriptive learning talk than expert children, but this difference was not significant at the $p<.05$ level.

Taking a closer look within these three over-arching categories provided additional details about the kinds of learning talk children produced during their visit to *Dinosaur in Their Time.* For each category of talk, a one-way between subjects ANOVA was conducted to compare the effect of child knowledge on children's learning talk. Analysis of the three subcategories within identification learning talk indicated that there were significant expert-novice differences at the $p<.05$ level only for scientific naming. Expert children were more likely to identify dinosaurs and non-dinosaurs by their scientific names than novice children. In contrast, novice children were more likely to identify dinosaurs using feature labels, but this difference was not significant. Analysis of the subcategories within descriptive learning talk indicated that there were significant expert-novice differences at the $p<.05$ level only for form and function (non-diet). Expert children more often talked about how dinosaurs used specific features like back plates, horns, and spikes to survive than novice children. However, novice children generated more than double the affective learning talk as expert children, though this difference was not significant due to large standard deviations. Analysis of the four subcategories within disciplinary learning talk indicated that there were significant expert-novice differences at the $p<.05$ level for ecology, evolution as change over time, and evolution as common ancestors. Expert children recognized more predator-prey, plant-animal relationships, and impacts of environmental conditions like climate on other species of plants and animals than novice children. Expert children also identified more variations in the plants, animals, and environments across the three time periods of the Mesozoic than novice children. Finally, expert children were more likely to use terms like relatives, ancestors, descendants, or to say that a species evolved than novice children. Taken together, analysis suggests that expert children are engaging in learning talk significantly more than novice children in the categories where prior knowledge might be particularly useful to support these kinds of conversations (e.g. scientific names, form and function (non-diet), ecology, evolution as change over time, and evolution as common ancestors).

Table 5. Learning talk means (CPH), standard deviations, and significance levels for expert and novice children during the museum visit

Types of Learning Talk (CPH)	Expert Child		Novice Child			
	Mean	SD	Mean	SD	F(1, 28)	P<.05
Learning Talk (Total)	**166.57**	**90.65**	**103.85**	**67.33**	**4.63**	*
Identification Talk	**102.76**	**57.84**	**54.24**	**39.36**	**5.60**	*
Feature Label	25.69	12.99	33.93	23.86	1.38	NS
Diet Behavior	5.80	3.84	5.95	7.27	0.01	NS
Scientific Name	71.27	68.44	14.36	13.92	9.96	*
Descriptive Talk	**32.90**	**15.76**	**34.66**	**37.44**	**0.03**	NS
Form & Function: Diet	3.13	2.79	3.16	6.76	0.00	NS
Form & Function: Non-Diet[2]	7.47	8.17	1.95	3.93	5.56	*
Comparison: Dino-Dino	6.32	3.96	3.83	6.22	1.71	NS
Comparison: Dino-Other	7.58	4.27	7.09	8.27	0.04	NS
Affective	8.40	8.18	18.63	26.30	2.07	NS
Disciplinary Talk	**30.91**	**15.59**	**14.95**	**10.88**	**10.58**	*
Ecology	15.94	0.51	7.92	.37	5.41	*
Evolution: Change Over time	5.64	8.28	1.44	6.49	6.58	*
Evolution: Common Features	6.05	6.23	5.34	5.72	.107	NS
Evolution: Common Ancestors	3.28	0.18	0.25	0.65	13.08	*

[2] Violation of homogeneity of variance assumption requires that that the degrees of freedom for this test are adjusted to (1,20). With this correction, the significant difference between experts and novices remains at p<.05.

3.2.1.2 Comparisons between parent learning talk

A one-way between subjects ANOVA was conducted to compare the effects of child knowledge on total parent learning talk during the museum visit and found no significant effect of child knowledge on total parent learning talk (see table 6 for means (CPH), standard deviations, and patterns of significance). Parents with expert children were engaged in slightly more learning talk than parents with novice children though this difference was not significant. To further explore whether child knowledge had an impact on parent learning talk, one-way between subjects ANOVAs were conducted for the three over arching categories of learning talk: identification talk, descriptive talk, and disciplinary talk. Consistent with the pattern for total parent learning talk, no significant differences were found across three over-arching categories of learning talk at the $p<.05$ level. Parents with expert children were producing slightly more identification learning talk and descriptive learning talk than parents with novice children. And parents with novice children were producing slightly more disciplinary learning talk than parents with expert children.

Taking a closer look within these three over-arching categories revealed which kinds of learning talk parents produced during their visit to *Dinosaurs in Their Time.* For each category of talk, a one-way between subjects ANOVA was conducted to compare the effect of child knowledge on parent learning talk. Analysis of the subcategories within identification learning talk indicated that there were no significant differences based on child knowledge at the $p<.05$ level. However, the distribution of parent learning talk within this category was consistent with the patterns observed between expert and novice children. Parents with expert children were more likely to identify dinosaurs and non-dinosaurs by their scientific names and parents with novice children were more likely to identify dinosaurs using feature labels. Analysis of the subcategories within descriptive learning talk indicated that there were no significant expert-novice differences at the $p<.05$ level. Again, consistent with the pattern observed in children's learning talk, parents with expert children more often talked about form and function (non-diet) relationship between dinosaur features and how they helped a particular species to survive than parents with novice children. However, in contrast to the pattern observed in children's learning talk, parents with expert children generated more affective learning talk than parents with novice children. Analysis of the subcategories within disciplinary learning talk indicated that there were no significant expert-novice differences at the $p<.05$ level. Parents with expert children generated more learning talk about ecology, evolution as change over time and evolution as common ancestors than parents with novice children. In contrast, parents with novice children generated more evolution as common features learning talk than parents with expert children. Taken together, these data suggest that while child knowledge significantly impacts the amount of child learning talk observed in *Dinosaurs in Their Time* it does not have the same degree of influence on the amount of learning talk parents produced.

Table 6. Learning talk means (CPH), standard deviations, and significance levels for parents with expert and novice children during the museum visit

Category of Learning Talk (CPH)	Parent with Expert		Parent with Novice			
	Mean	SD	Mean	SD	F (1, 28)	p<.05
Learning Talk (Total)	**214.45**	**94.93**	**207.89**	**111.90**	**0.00**	NS
Identification Talk	**110.57**	**55.19**	**104.32**	**67.46**	**0.08**	NS
Feature Label	42.11	24.23	52.53	35.59	0.88	NS
Diet Behavior	11.93	5.59	13.23	8.03	0.27	NS
Scientific Name	56.53	34.48	38.56	38.78	1.80	NS
Descriptive Talk	**56.15**	**29.53**	**54.94**	**42.07**	**0.01**	NS
Form & Function Diet[3]	5.66	6.80	5.80	5.25	0.04	NS
Form & Function Non-Diet	11.94	10.65	9.64	7.43	0.47	NS
Comparison: Dino-Dino	7.65	4.52	7.05	7.53	0.07	NS
Comparison: Dino-Other	12.00	6.78	16.70	11.99	1.74	NS
Affective	18.90	19.58	15.75	24.99	0.15	NS
Disciplinary Talk	**47.74**	**23.19**	**48.62**	**24.02**	**0.01**	NS
Ecology	18.97	14.40	18.23	17.10	0.01	NS
Evolution: Change Over time	14.31	8.28	11.63	6.49	0.97	NS
Evolution: Common Features	9.48	10.00	15.55	8.66	3.16	NS
Evolution:Common Ancestors	4.98	3.03	3.21	3.10	2.47	NS

How does child knowledge influence who participates in learning talk within families?

Understanding the dynamics of who participates in learning talk within family groups can provide insight into how child knowledge may shape opportunities for children and parents to co-construct meaning in these learning settings. A paired sample t-test indicated that there was a significant difference in the amount of total learning talk generated by parents (M=211.17, SD=102.02) and children (M=135.21, SD=84.70) during their visit to the museum

[3] Violation of homogeneity of variance assumption requires that that the degrees of freedom for this test are adjusted to (1,26). With this correction, the results of the significance test (NS) do not change.

[t(29)=4.21, p<.001]. When looking at the sample as a whole, this indicates that parents produced the majority of learning talk.

3.2.1.3 Comparisons between parents and expert children

Consistent with the pattern revealed in analysis of total museum talk across the full sample, a paired sample t-test indicated that parents visiting the museum with expert children also generated significantly more learning talk than children. (See table 7 for means, standard deviations, and significance values). Paired sample t-tests were also used to investigate differences between parents and children across the three overarching categories of learning talk: identification, descriptive, and disciplinary. Analysis indicated that while parents generated slightly more total identification talk than expert children, this difference was not significant at the p<.05 level. However, parents generated significantly more total descriptive talk and more total disciplinary talk than expert children.

Analysis within these over-arching categories of learning talk identified a relatively small proportion of sub-categories where parents produced significantly more learning talk than expert children. Within total identification talk parents generated significantly more feature labels and diet behavior learning talk than expert children. However, this pattern was reversed for scientific naming where children were identifying dinosaur and non-dinosaur species in this way more than their parents. While this difference was not significant, it is worth mentioning because it demonstrates a type of learning talk where the pattern of conversational agency is beginning to shift from parents to children. That this pattern should emerge in connection with identification talk might be expected given the role that identification and categorization plays in the development of childhood expertise in declarative domains like dinosaurs. Analysis of the sub-categories within descriptive learning talk indicated that parents produced significantly more affective learning talk than children. Finally, analysis of the sub-categories within disciplinary learning talk indicated that parents also produced significantly more evolution as change over time learning talk than children. These findings suggest that across the majority of learning talk categories expert children and their parents were equally engaged in learning talk.

Table 7. Learning talk means (CPH), standard deviations, and significance levels for parents and expert children while visiting Dinosaurs in Their Time

Category of Learning Talk (CPH)	Parent with Expert		Expert Child			
	Mean	S.D.	Mean	S.D.	t (14)	P<.05
Learning Talk (Total)	**214.46**	**94.93**	**166.57**	**90.65**	**1.61**	**NS**
Identification Talk	**110.57**	**55.19**	**102.76**	**57.84**	**0.87**	**NS**
Feature Labels	42.11	24.23	25.69	12.99	3.23	*
Diet Behavior	11.93	5.59	5.80	3.84	4.87	*
Scientific name	56.53	34.48	71.27	68.44	-0.61	NS
Descriptive Talk	**56.15**	**29.53**	**32.90**	**15.76**	**3.23**	*
Form & Function: Diet	5.66	6.80	3.13	2.79	1.33	NS
Form & Function: Non-Diet	11.94	10.65	7.47	8.17	1.95	NS
Comparison: Dino-Dino	7.65	4.52	6.32	3.96	1.07	NS
Comparison: Dino-Other	12.00	6.78	7.58	4.27	2.10	NS
Affective	18.90	19.58	8.40	8.18	2.53	*
Disciplinary Talk	**47.74**	**23.19**	**30.91**	**15.59**	**2.35**	*
Ecology	18.97	14.40	15.94	9.51	0.71	NS
Evolution: Change Over time	14.31	8.28	5.64	8.28	3.98	*
Evolution: Common Features	9.48	10.00	6.0	6.23	1.50	NS
Evolution: Common Ancestors	4.98	3.03	3.28	3.18	1.97	NS

Consistent with the pattern revealed in analysis of total museum talk across the full sample, parents visiting the museum with novice children also generated significantly more learning talk than children. (See table 8 for a summary of means, standard deviations, and significance values). Paired sample t-tests were used to investigate differences between parents and children across the three overarching categories of learning talk: identification, descriptive, and disciplinary. Analysis indicated that parents with novice children generated significantly more total identification learning talk, total descriptive learning talk, and total disciplinary learning talk than their children.

Analysis within these over-arching categories of learning talk revealed that parents talked significantly more than novice children across the majority of learning talk categories. Within the total identification talk category parents generated significantly more feature labels, diet behaviors, and scientific naming than novice children. Within the total descriptive talk category parents generated significantly more form and function (non-diet), comparisons between dinosaur species, and comparisons between dinosaurs and other species learning talk than novice children. Within the total disciplinary talk category parents generated more ecology, evolution as change over time, evolution as common features and evolution as common ancestors learning talk than novice children. These findings suggest that on average parents with novice children are consistently generating and guiding the majority of the conversation during the museum visit whether focused on identification, descriptive, or disciplinary learning talk.

The exception to this pattern of parent-child talk is in the descriptive sub-category: affective talk. Novice children are expressing wonder, awe or fear more often than their parents. While this difference is not significant, it is worth mentioning because it is a type of learning talk that is particularly accessible to novice children who by definition have limited prior knowledge about dinosaurs. That this pattern should emerge in connection with descriptive talk might be expected given the physically impressive nature of this collection of dinosaur fossils. In addition, affective engagement could serve as a motivational factor to support subsequent learning.

Table 8. Learning talk means (CPH), standard deviations, and significance levels for parents and novice children while visiting Dinosaurs in Their Time

Category of Learning Talk (CPH)	**Parent**		**Novice Child**			
	Mean	SD	Mean	S.D.	t (14)	P<.05
Learning Talk (Total)	**207.88**	**111.90**	**103.85**	**67.33**	**5.51**	*
Identification Talk	**104.32**	**67.46**	**54.24**	**39.36**	**4.35**	*
Feature Labels	52.53	35.59	33.93	23.86	2.81	*
Diet Behavior	13.23	8.03	5.95	7.27	3.22	*
Scientific Name	38.56	38.78	14.36	13.92	3.35	*
Descriptive Talk	**54.94**	**42.07**	**34.66**	**37.44**	**2.16**	*
Form & Function: Diet	5.80	5.25	3.16	6.76	1.34	NS
Form & Function: Non-Diet	9.64	7.43	1.95	3.93	3.14	*
Comparison: Dino-Dino	7.05	7.53	3.83	6.22	2.94	*
Comparison: Dino-Other	16.70	11.99	7.09	8.27	4.32	*
Affective	15.75	24.99	18.63	6.30	-0.49	NS
Disciplinary Talk	**48.62**	**24.02**	**14.95**	**10.88**	**5.38**	*
Ecology	18.23	17.10	7.92	9.37	2.92	*
Evolution: Change over time	11.63	6.49	1.44	6.49	5.34	*
Evolution: Common features	15.55	8.66	5.34	5.72	3.75	*
Evolution: Common Ancestors	3.21	3.10	0.25	0.65	3.89	*

Museum visit results summary: Analysis of the content of parent-child learning talk indicated that child knowledge significantly impacts what categories of learning talk children engage in when visiting *Dinosaurs in Their Time*. However, regardless of child knowledge, parents are able to engage with similar frequency across the full range of learning talk categories included in the analysis. A closer look at these conversations revealed that expert children are generating more learning talk than novice children across categories where prior dinosaur knowledge might be particularly useful (identification using scientific names, non-diet form and function relationships, and ecology, evolution as change over time and evolution as common ancestors). In contrast, parents of both expert and novice children seemed equally able to draw from their prior knowledge and the available learning environment to engage their children in learning conversations during their museum visits. This is an encouraging outcome as it suggests that the learning environment is successfully supporting parent engagement in learning talk regardless of children's knowledge level.

Analysis of total within family learning talk in *Dinosaurs in Their Time* indicated that parents are producing the majority of learning talk during the museum visit. A closer look at this pattern of engagement indicated that parents with expert children were only producing significantly more learning talk than their children in a small proportion of learning talk categories. These included: two identification sub-categories (feature labels and diet behaviors), total descriptive talk, affective, total disciplinary talk, and evolution as change over time. This suggests that parents with expert children initiate the majority of more basic level categorical learning talk and then are more equitably engaged across the majority of disciplinary and descriptive categories of learning talk. In contrast, parents with novice children initiate and support significantly more learning talk across all three over-arching learning talk categories and the majority of the subcategories included in this content analysis. This suggests that novice parents are consistently assuming the responsibility to introduce and support learning conversations during the museum visit. These findings offer evidence that all parents are highly engaged in learning talk and that *Dinosaurs in Their Time* provides opportunities for expert children to assume a more equal role with their parents for initiating and supporting learning talk than novice children.

3.2.2 Pre-Test Analysis

Understanding the content of learning talk generated during the pre-test provided a rough baseline measure of the range of learning talk that children and adults could produce outside of the designed learning environment of the museum exhibition. Of particular interest during the pre-test was whether child knowledge would have an impact on disciplinary learning talk encouraged by the questions presented during the pre-test (See table 1). Analysis began with a one-way between subjects ANOVA that compared the effect of child knowledge on total family talk during the pretest assessment. There was a significant effect of child knowledge on total pre-test talk [$F(1,28)=4.87$, $p = .036$]. Families that included expert children generated significantly more codes during the pre-test (CPH M=255.26, SD=107.59) than families that included novice children (CPH M=183.07, SD=66.82)[4]. This suggests that families with expert children were able to use their shared knowledge to generate more learning talk when viewing the images of *Dinosaurs in Their Time*.

3.2.2.1 Comparisons between child learning talk

A one-way between subjects ANOVA was conducted to compare the effects of child knowledge on total children's learning talk during pretest. Analysis indicated that expert children generated significantly more learning talk on the pre-test than novice children (See table 9 for all CPH means, standard deviations, and significance). To better understand what kinds of learning talk accounted for this difference, one-way between subjects ANOVAs were conducted to compare children's total learning talk for: identification, descriptive, and disciplinary categories. While

[4] All analysis of pre-test patterns of learning talk will be reported in comments per hour (CPH). Raw means for pre-test learning talk can be found in Appendix C, tables C1-C4.

expert children were consistently producing more learning talk across all three categories, these differences were not significant for identification or descriptive talk. However, there was a significant difference between expert and novice children's overall disciplinary talk. Expert children generated more than twice as much disciplinary learning talk as novice children on the pre-test.

Taking a closer look within these three over-arching categories provided additional details about the kinds of learning talk children produced during the pre-test. For each category of talk, a one-way between subjects ANOVA was conducted to compare the effect of child knowledge on children's learning talk. Analysis of the subcategories within identification learning talk indicated that there were significant expert-novice differences at $p<.05$ only for scientific naming. Expert children were more likely to identify dinosaurs and non-dinosaurs by their scientific names than novice children. And as one might expect, novice children were more likely to identify dinosaurs using descriptive labels, but this difference was not significant. Analysis of the subcategories within descriptive learning talk indicated that there were no significant expert-novice differences at the $p<.05$ level. Analysis of the subcategories within disciplinary learning talk indicated that there were significant expert-novice differences for ecology, evolution as change over time, and evolution as common ancestors. Expert children recognized more predator-prey, plant-animal relationships, and impacts of environmental conditions like climate on other species of plants and animals than novice children. Expert children identified more variations in the plants, animals, and environments across the three time periods of the Mesozoic than novice children. Finally, expert children were more likely to use terms like relatives, ancestors, descendants, or to say that a species evolved than novice children.

Pre-test analysis suggests that expert children engaged in learning talk significantly more than novice children and utilized prior knowledge to support disciplinary learning talk in particular.

Table 9. Learning talk means (CPH), standard deviations, and significance levels for expert and novice children during the pre-test

Category of Learning Talk (CPH)	Expert Child		Novice Child			
	Mean	S.D.	Mean	S.D.	F (1, 28)	P<.05
Learning Talk (Total)	149.10	**64.11**	84.08	**37.73**	**11.45**	*
Identification Talk	**63.48**	**40.94**	**44.50**	**34.15**	**1.90**	**NS**
Feature Labels	10.14	9.61	16.06	13.25	1.96	NS
Diet Behavior	17.34	19.95	14.44	22.75	0.14	NS
Scientific Name	36.00	39.02	14.00	16.92	4.01	*
Descriptive Talk	**12.09**	**10.74**	**9.16**	**8.45**	**0.69**	**NS**
Form & Function: Diet	0.48	1.84	1.43	3.81	0.76	NS
Form & Function: Non-Diet	1.91	4.64	0.62	2.40	0.92	**NS**
Comparison: Dino-Dino	4.14	8.11	1.35	3.00	1.56	NS
Comparison: Dino-Other	2.27	3.40	1.59	3.34	0.30	NS
Affective	3.29	7.99	4.17	7.19	0.10	NS
Disciplinary Talk	**73.53**	**38.12**	**30.42**	**14.17**	**16.86**	*
Ecology	38.75	24.84	20.45	11.76	6.65	*
Evolution: Change over time	17.92	16.37	6.62	6.41	6.20	*
Evolution: Common Features	11.13	13.45	3.35	7.41	3.85	NS
Evolution: Common Ancestors	5.73	7.15	0.00	0.00	9.64	*

3.2.2.2 Comparisons between parent learning talk

Analysis was also conducted to explore the impact of child knowledge on parent learning talk during the pre-test. A one-way between subjects ANOVA was conducted to compare the effects of child knowledge on total parent learning talk during pre-test. Analysis indicated that while parents with expert children (CPH M=106.15, SD=81.18) are generating more learning talk than parents with novice children (CPH M=98.98, SD=62.57) this difference was not significant. To further explore whether child knowledge had an impact on parent learning talk, one-way between subjects ANOVAs were conducted for the three over-arching categories of learning talk: identification talk, descriptive talk, and disciplinary talk. Consistent with the pattern for total parent learning talk, no significant differences were found across the over-arching categories of learning talk at $p<.05$. Parents with expert and novice children were producing nearly identical amounts of identification learning talk. Parents with novices were producing more descriptive learning talk than parents with expert children. And parents with expert children were producing more disciplinary learning talk than parents with novice children (See appendix C, tables C5-C8 for all parent learning talk means during the pre-test). Looking within these overarching categories of talk, a one-way between subjects ANOVA indicated that parents with expert children were using significantly more scientific names for dinosaurs and non-dinosaurs (CPH M=18.31, SD=19.45) than parents with novice children (CPH M=6.60, SD=8.41)[$F(1.28)=4.58$, $p=0.041$]. There were no additional significant differences across the remaining subcategories of learning talk for parents of experts and novices during the pre-test. These analyses suggest that while child knowledge impacts the amount of child learning talk on the pre-test, parents of both expert and novice children are generating similar amounts of learning talk prior to visiting *Dinosaurs in Their Time.*

Pre-test results summary: Child knowledge impacts the amount of child learning talk generated during the pre-test assessment. In addition, children's prior knowledge seems to support more learning talk for expert families than novice families. A closer look at these conversations revealed that expert children are engaging in more learning talk than novice children across categories of talk where prior knowledge might be particularly useful (scientific naming, ecology and evolution talk). In contrast, across all but one category (scientific naming), parents of expert and novice children were generating similar amounts of learning talk. This suggests that while child knowledge had a strong influence on the amount of child learning talk that was produced, parents were equally able to engage their children in conversations during the pre-test assessment prior to their visit to *Dinosaurs in Their Time.*

3.2.3 Post Test Analysis

Analysis began with a one-way between subjects ANOVA that compared the effect of child knowledge on total family talk during the post-test assessment Analysis indicated that while parents with expert children (CPH M=228.30, SD=113.33) are generating more total learning talk than parents with novice children (CPH M=210.77, SD=67.35)[5] this difference was not significant. This suggests that following their visit to *Dinosaurs in Their Time*, families with expert and novice children generated similar amounts of learning talk.

3.2.3.1 Comparisons between child learning talk

A one-way between subjects ANOVA was conducted to compare the effects of child knowledge on total children's learning talk during post-test. Analysis indicated that expert children did not generate significantly more learning talk on the post-test than novice children (See table 10 for all CPH means, standard deviations, and significance). Taking a closer look at these data, one-way between subjects ANOVAs were conducted to compare children's total learning talk for: identification, descriptive, and disciplinary categories. While expert children were consistently producing more learning talk across all three categories, these differences were not significant

[5] All analysis of post-test patterns of learning talk will be reported in comments per hour (CPH). Raw means for post-test learning talk can be found in Appendix C, tables C1-C4.

for identification or descriptive talk during the post-test. However, there was a significant difference between expert and novice children's overall disciplinary talk. Expert children generated nearly twice as much disciplinary learning talk as novice children on the post-test.

Analysis within these three over-arching categories provided additional details about the kinds of learning talk children produced during the post-test. For each category of talk, a one-way between subjects ANOVA was conducted to compare the effect of child knowledge on children's learning talk. Analysis of the subcategories within identification learning talk indicated that there were no significant expert-novice differences at the $p<.05$ level. Expert children were more likely to identify dinosaurs and non-dinosaurs by their scientific names than novice children. Novice children continued to identify dinosaurs using descriptive labels more than expert children but these differences were not significant. Analysis of the subcategories within descriptive learning talk indicated that there was one significant expert-novice differences at the $p<.05$ level for form and function non-diet learning talk. This difference emerged primarily because novice children did not produce any instances of this category of learning talk during the post-test. Analysis of the four subcategories within disciplinary learning talk indicated that there were significant expert-novice differences for evolution as change over time and a marginally significant difference for evolution as common ancestors ($p=.052$). Expert children identified more variations in the plants, animals, and environments across the three time periods of the Mesozoic than novice children. Finally, expert children were more likely to use terms like relatives, ancestors, descendants, or to say that a species evolved than novice children. It is important to note that across the majority of categories of learning talk, the frequency of contributions declined for children who were experts and novices during the post-test. This was most likely an effect of fatigue.

Table 10. Learning talk means (CPH), standard deviations, and significance levels for expert and novice children during the post-test

Category of Learning Talk (CPH)	Expert Child		Novice Child			
	Mean	SD	Mean	SD	F (1, 28)	P<.05
Learning Talk (Total)	**132.08**	**5.22**	**93.44**	**53.61**	**2.63**	**NS**
Identification Talk	**55.49**	**42.09**	**48.45**	**33.50**	**0.26**	**NS**
Feature Labels	11.03	10.84	19.63	18.85	2.35	NS
Diet Behavior	9.68	19.98	11.91	20.24	0.09	NS
Scientific Names	34.78	31.84	16.91	16.13	3.76	NS
Descriptive Talk	**14.30**	**12.13**	**10.41**	**14.89**	**0.62**	**NS**
Form & Function: Diet	0.97	3.74	2.23	5.31	0.57	NS
Form & Function: Non-Diet	2.48	3.79	0.00	0.00	6.45	*
Comparison: Dino-Dino	1.72	2.98	1.56	3.27	0.02	NS
Comparison: Dino-Other	4.48	7.49	1.53	3.23	1.97	NS
Affective	4.65	7.07	5.09	7.73	0.03	NS
Disciplinary Talk	**62.29**	**34.30**	**34.58**	**23.76**	**6.62**	*****
Ecology	22.77	18.48	18.69	12.17	0.51	NS
Evolution: Change over time	18.87	13.51	6.70	9.18	8.33	*
Evolution: Common Features	14.38	10.42	8.72	15.76	1.34	NS
Evolution: Common Ancestors	6.27	10.91	0.47	1.80	4.14	NS

3.2.3.2 Comparisons between parent learning talk

Analysis was also conducted to explore the impact of child knowledge on parent learning talk during the post-test. A one-way between subjects ANOVA was conducted to compare the effects of child knowledge on total parent learning talk during post-test. Analysis indicated that while parents with novice children (CPH M=117.31, SD=51.42) are generating more learning talk than parents with expert children (CPH M=96.20, SD=70.93) this difference was not significant. To further explore whether child knowledge had an impact on parent learning talk, one-way between subjects ANOVAs were conducted for the three over-arching categories of learning talk: identification talk, descriptive talk, and disciplinary talk. Consistent with the pattern for total parent learning talk, no significant differences were found across three over-arching categories of learning talk at the $p<.05$ level during the post-test. Parents with expert children were producing more identification and descriptive learning talk, than parents with novices. And parents with novices were producing more disciplinary learning talk than parents with expert children (See appendix C, tables C5-C8 for all parent learning talk means during the pre-test). Looking within these overarching categories of talk, a one-way between subjects ANOVA indicated that parents with novice children were generating significantly more ecology connections (CPH M=25.42, SD=19.81) than parents with expert children (CPH M=11.57, SD=16.76)[$F(1, 28)=4.27$, $p=.048$]. In addition, novice parents were also producing more evolution as common features learning talk during the post-test than expert parents though this difference was not significant due to large standard deviations. There were no additional significant differences across the remaining subcategories of learning talk for parents of experts and novices during the post-test.

Comparison of Pre-test and Post-Test Results: The decision to use a pre-test/post-test design was to provide a complementary mechanism to explore how families engaged in learning talk. In order to determine whether there were any immediate post-visit changes in the ways that parents and children engaged in learning conversations, paired sample t-tests were conducted to compare the content of talk between pre-test and post-test. This analysis revealed significant pre-post gains for expert children and their parents only on total descriptive talk [($t(14)=3.59$ $p=.002$ and $t(14)-3.94$, $p=.016$ respectively] (See appendix C, tables C5-C8 for all CPH pre-test and post-test means). These changes were mostly accounted for by increased affective comments on the post-test as compared to the pre-test. These findings suggest that on average expert children and their families did not change the overall content of their learning conversations from pre-test to post-test.

Novice children also significantly increased in only one category of learning talk (total descriptive talk) from pre-test to post-test [t(14)-3.94, p=.001]. And like expert children, this change was primarily accounted for by increased affective comments on the post-test as compared to the pre-test. However, in contrast to these patterns, novice parents had a significant increase in the disciplinary sub-category evolution as shared features from pre-test to post-test [t(14)=-2.98, p=.010]. In addition, they had a significant decrease in total descriptive talk [t(14)=3.59, p=.003]. These analyses suggest that for novice parents the experience in *Dinosaurs in Their Time* supported a change in their learning conversations that produced an increase in noticing and discussing common features like similarities between ancient species and modern species. Documenting an increase in this type of disciplinary learning talk is exciting because it suggests a first step towards engaging in learning conversations about common ancestry.

3.3 CASE STUDY ANALYSIS

Case study analysis will be used to address the third research question: How does the design of the learning environment shape opportunities for learning talk across families with expert and novice children? The two case studies will use discourse analysis to illustrate the interaction between child knowledge level and the implicit and explicit learning resources available in

Dinosaurs in Their Time. Both the expert and novice case studies feature parent-child dyads that reflect the kinds of interactions that occurred across the full data set.

3.3.1 Expert Case Study

The expert case study describes the interactions between a mother and her 8 years old son (97 months). On the parent survey, the mother rated her son's interest in dinosaurs as above average (5 on a 7 point likert-like scale) and rated his knowledge as extremely high (7 on a 7 point likert-like scale). In contrast she rated her own interest in dinosaurs as below average and her dinosaur knowledge as average (3 and 4 respectively on the same 7-point scale). Both on the parent survey and in conversation, the mother indicated that they frequently visited museums. This year they had visited 4-5 museums already and they were likely to visit several more. They were members of CMNH, but the mother had not yet seen the completed third section of *Dinosaurs in Their Time,* though the son had spent time in the exhibition as a part of dinosaur camp. This child expert had regular access to a wide range of dinosaur learning resources and throughout their museum visit he referenced information that he had learned from the CMNH dinosaur-themed summer camp, dinosaur movies borrowed from the library, and a variety of dinosaur books. Interestingly, the mother reported that her son had a strong interest in dinosaurs, but was currently most interested in robots, Legos, building, and inventing.

The mother and son spent approximately 52 minutes visiting *Dinosaurs in Their Time.* This was longer than the average time for expert participants in this study (M=42 minutes, 39 seconds). This dyad was very comfortable in the museum learning context and moved through each of the time periods noticing different features of the fossil specimens and the broader contexts in which they were displayed. The son was strongly positioned in the dinosaur expert role, with the mother asking questions that provided her son with opportunities to demonstrate his knowledge. However, unlike in previous analysis of parents interacting with expert children where parents stayed relatively quiet (Palmquist & Crowley, 2007), this mother regularly interrupted her son to ask questions and comment on things she noticed in the exhibition. As a result, there were many examples of active interpretation of the learning environment and knowledge construction during their museum visit. Consistent with the patterns observed in the discourse analysis, conversational contributions were equitably shared across most categories of talk. However, identification of scientific names was a type of learning talk that the son seemed to dominate while the mother typically identified dinosaurs through feature labels and diet behaviors. Overall, whether discussing basic or more sophisticated topics, both mother and son actively used the learning environment as well as their prior knowledge to interpret and make meaning from their experience in the *Dinosaurs in Their Time* exhibition.

The following excerpts illustrate patterns of learning talk and interaction with the environment that are typical of families with expert children: analysis and discussion of a range of salient features; interpretation of the learning environment that is more holistic and consistent with disciplinary practice; and parents and children sharing the responsibility for content interpretation and visit management.

3.3.1.1 Excerpt 1: Creating a holistic interpretation of the learning environment [Jurassic Atrium]

In this excerpt, the mother and son have just entered the Jurassic Atrium and finished a discussion about *Stegosaurus.* As they make their way further into the room, they begin to discuss the different features of the learning environment and how they fit together.

C: Look, its *Dryosaurus*. [narrating the mural]

P: Oh, in the background? [looks over her shoulder] Didn't we meet him over there?

C: Yes, we met *Dryosaurus* over there. [points back to the *Dryosaurus* platform]

P: Okay.

C: Hey mom, other *Stegosauruses* [points them out as they walk by]

P: That's a nice mural.

C: Yeah. Look, *Allosaurus* is fighting another dinosaur like here [points between the mural and the mounted fossils]. And there's more longnecks like a herd [gestures back to the mural]. Mom can we go over that way, to that part of the mural? I want to check out this one dinosaur.

P: Mmm hmm. [they walk over]

C: Mom, look, meat-eaters.

P: Which ones are the meat-eaters?

C: Those ones with the sharp teeth there [points to a pair of *Allosaurus* in mural].

P: And the other ones eat plants?

C: Yes, they're plant eaters [gestures to *Apatosaurus* and *Diplodocus* fossil specimens] and while they look like they have sharp teeth from here, those *Diplodocus*—

P: But they don't have those back teeth.

C: Right, they don't have like the back teeth AND they don't have sharp teeth. And this guy has a long tail [points to *Apatosaurus* tail above them] so that's good for fighting off enemies. So that helps it survive by killing other enemies so it doesn't die.

P: Do you think that's what they did with that tail?

C: Yes. How else could they fight? They [walks into the center of the Jurassic atrium and points to *Apatosaurus* and *Diplodocus* fossil specimens] whipped them [points to Allosaurus fossil and images in the mural] with their tails.

There are several interesting things to notice here. First, the mother began this exchange by making a general affective comment about the mural that covers two full walls of the Jurassic Atrium. This provided an opportunity for her son to choose something that he found interesting in the mural to talk about as their next topic of conversation. Second, consistent with many experts, the son quickly identified and described an ecological relationship that is suggested in the mural (a pack of *Allosaurus* hunting a herd of sauropods). However, what this expert does more explicitly than most children was to connect the mural images to the way that the fossil specimens are positioned in the three-dimensional scene in the middle of the room. For this expert, the mural, the fossils, and his prior knowledge work together seamlessly to illustrate what life was like during the Jurassic period. As he goes on to describe form and function relationships between teeth and tails, he flexibly uses both the mural images and fossil specimens as evidence to support his interpretation. This ability to recognize the relationships between components in the exhibitions and successfully use them to tell a story is reflective of traditional definitions of experts' ability to synthesize and adaptively use information to solve problems (Hatano & Inagaki, 1986; Chi, Feltovich, Glaser, 1981; Feltovich et. al, 1987). Third, it is interesting to note that this expert child interacted with the designed learning environment precisely the way that the exhibition design team intended for visitors to use the space. The expectation was that visitors would experience each of the three-dimensional scenes depicted by the positions of the mounted fossils as extensions of the environments depicted in the murals. This was intended as an implicit information resource that would allow visitors to tell stories about what life was like in each time period. This analysis suggests that expert children may have been better positioned than novice children to recognize and use this design feature of the exhibition. As was the case with this expert, the mural combined with the arrangement of the fossils activated his prior knowledge about ecological, predator-prey relationships between dinosaurs. The narrative of the ways that carnivores like *Allosaurus* and herbivores like *Diplodocus* and *Apatosaurus* would have interacted helped to shape this experts' interpretation of the available fossil evidence. The exhibition provided an opportunity for this expert to use his prior knowledge in an adaptive and applied way that is reflected in the learning talk that he produced.

Finally, this exchange provides insight into the patterns of parent-child talk observed through the discourse analysis. When parents visit *Dinosaurs in Their Time* with expert children, they use questions and clarification statements to focus attention and prompt children to elaborate on their statements. While this expert began his interpretation of the Jurassic scene with a description of ecological connections, the mother interrupts his description of the *Diplodocus*' teeth when she thinks he might be misinterpreting the evidence. This request for clarification encourages her son to be more explicit about the form and function relationships between teeth and diet behaviors. As a result, however, the analysis of parent talk suggests that her contributions are primarily identification oriented—focused on feature labels and diet behaviors—and only include minimal descriptive talk and no disciplinary talk. Instead, her role in this part of the conversation was to support an enable her son to articulate his knowledge of form and function relationships and ecological connections. This provides one possible explanation for why parents with expert children use significantly more feature labels and diet behavior references to identify dinosaurs than their children. This excerpt also illustrated that both the mother and the son used scientific names frequently during their conversation. Discourse analysis indicated that for expert children, scientific identification was a category of learning talk that they engaged in more than their parents. And though this difference was not statistically significant, the family commitment to learning scientific names for species and using them consistently in a learning environment like a museum is likely to be important for the ongoing refinement of expert categorization and organization of declarative knowledge.

3.3.1.2 Excerpt 2: Recognizing common features [Jurassic Atrium]

In this excerpt, the mother and son have made their way to the center of the Jurassic Atrium and are discussing the sauropods (*Diplodocus and Apatosaurus).* The mother notices a distinctive feature of the *Diplodocus* hip girdle and mentions it to her son.

> P: I always wonder about that bone that sticks out underneath the tail of almost every dinosaur…
> C: Oh that's like, um, I think like the hipbone or something.
> P: It looks like it could be a piece of the hip
> C: Well, that one's a lizard bone. I mean, that one's a lizard-hipped dinosaur because they're [points to structures on the hip socket] not sticking out both ways [the way they would be on a bird-hipped dinosaur], they are sticking different ways. Bird-hipped dinosaurs are plant eaters except for long necks. Lizard-hipped dinosaurs are meat eaters and long necks.

This location in the exhibition is one that supports particularly rich learning conversations facilitated by the physical arrangement of the fossil specimens. Descriptive learning talk is very common as parents and children make comparisons between the dinosaur species displayed in the room. Consistent with this pattern, in this exchange, the mother focused her son's attention on a critical feature for determining species membership in one of the two families of dinosaurs described on the evolutionary tree. It is interesting to note that the learning resources in this section of the exhibition do not provide direct support for how to interpret this feature. However, when the mother clarifies what part of the hip she is referring to, the son recognizes an opportunity to highlight his categorical knowledge about the two families of dinosaurs and how you can tell them apart. While many families notice common features in dinosaurs like long necks and long tails when they stand in the middle of the Jurassic Atrium, only expert families notice and engage in learning talk about common hip structures and their significance. In another location in the dinosaur exhibition, the information about lizard-hipped and bird-hipped dinosaurs is explained in a printed label, however this mother and son did not explicitly discuss that information when they were in that location during this visit. This expert's ability to recognize the critical feature and correctly interpret it based only on the fossil evidence demonstrates the sophistication of his knowledge and his ability to apply it to novel cases (Chi, Hutchinson, Robin, 1989; Johnson, Scott, & Mervis, 2004).

3.3.1.3 Excerpt 3: Evidence for Common Ancestors [Cretaceous]

In this final excerpt the mother and son are almost at the end of their visit to *Dinosaurs in Their Time*. The mother has never been in the Cretaceous section of the exhibition and is more interested in reading the labels in this section than in previous sections. She sees an image of the *Oviraptor* on the touch screen designed to provide information about the Triceratops (the exhibits are adjacent) and her son helps her to find the location in the hall where they can learn about *Oviraptor*. He previously visited this section of the exhibition during dinosaur camp.

> C: Mom. You learn about *Oviraptor* over there [points to the corner display] over in the *Oviraptor* exhibit.
>
> P: Oh, okay. [mother and son walk over and stand in front of *Oviraptor*] He's got another interesting skull. [referencing a discussion they just had about the unique features of the *Pachycephalosaurus* dinosaur]

C: He's got eye bones.

P: I know. What is up with that eye bone thing? Let's find out [reads label to herself]

C: But guess what? I know something. All dinosaurs have those eye bones [son activates screen, navigates to dinosaur features icon, and selects eyes]. Right, Eyes. So…

P: [mom reads over his shoulder] Sclerotic ring [term for the bones that support the eye]

C: Sclerotic ring, Sclerotic ring. [repeats and seems to be practicing pronunciation]

P: [reads quietly] Oh, this is a nice fact [points to a line of text on the screen]

C: [son ignores where she is pointing] It's common in dinosaurs. But guess what—

P: It says it's commonly found in modern birds.

C: Right, because the ostrich, the ostrich is related to it. It has like one claw, one tiny claw that's useful for nothing in the ostrich. It's like one artifact left from its old cousin the *Oviraptor*

P: Okay [mom listens but continues to read the screen]

C: So ostriches are related to them [points to the *Oviraptor*].

P: Very interesting.

C: And guess what? Guess what? [son repeats question to get mother's attention]

P: That goes along with what this says [points back to the screen again]

C: Even more interesting, ostriches have the sclerotic ring, too, I think.

P: I believe that, 'cause that's what it says here. And if you heard that and we're reading it here, it must be correct [son smiles broadly]

One interesting aspect of this excerpt is the way that the analysis of fossil features leads to disciplinary learning talk about common ancestry between dinosaurs and birds. This particular dinosaur specimen is one of the best opportunities in *Dinosaurs in Their Time* to notice this evolutionary relationship because it highlights easily observable fossil evidence that supports this interpretation. While the son is initially interested in using the sclerotic ring to discuss a common feature shared by many dinosaurs, the mother uses the information on the touch screen to challenge the son's initial interpretation. This alternative way to interpret the sclerotic ring as feature-based evidence of the relationship between dinosaurs and birds seems to be engaging for the expert child. He recalls additional knowledge that he can contribute to a conversation about the relationship between dinosaurs and birds that is also based on shared features. Once he has made this association, he emphatically wants to explain the ostrich example to his mother and further emphasize the convergent evidence for the evolutionary relationship between dinosaurs like *Oviraptor* and modern flightless birds. This exchange demonstrates the more balanced conversations between experts and their parents around disciplinary topics and the way that the learning environment can provide just in time information that shifted the content of the conversation from a descriptive, dinosaur to dinosaur comparison to a disciplinary conversation about evolution as common ancestors.

This interaction also demonstrates an exchange of roles for this expert and his mother where instead of following the interest of the child, the pair explored the *Oviraptor* exhibit because the mother expressed curiosity and interest in this fossil. One reason for this shift may have been because the mother had not been in this section of the exhibition before and more of the information and displayed fossils were relatively new to her. As a result, the mother makes a point to use both the printed labels and the touch screens more than in previous sections of the exhibition. While the son is mostly supportive of following his mother's interest, he uses several strategies (accessing the touch screen and asking questions) to re-direct his mother's attention to topics that he wants to discuss about this dinosaur species. When the son expressed interest in a particular feature, the eye bones, both mother and son seek additional information from the learning environment. While both read information from the screen and the printed label to themselves, they made a point to articulate the scientific term for the feature that was the focus of their attention: the sclerotic ring. This is consistent with the practice observed in expert families of using scientific terms and species names frequently during their learning conversations in the museum.

At the very end of this excerpt, the mother offers strong positive reinforcement for her son's position in their interaction as the dinosaur expert. She highlights the agreement between what he knows and has articulated about the evolutionary relationship between dinosaurs and birds and the information provided by the museum's learning resources. This acknowledgement supports and encourages his self-image and identity as an expert in this topic area.

3.3.2 Novice Case Study

The novice case study describes the interactions and conversations between a mother and her 7 year old daughter (94 months). On the parent survey, the mother rated her daughter's interest and knowledge about dinosaurs as average (4 on a 7 point likert-like scale) and her own interest and knowledge as relatively low (2 and 3 respectively on the same 7 points scale). Both on the parent survey and in conversation, the mother indicated that the family had visited 2-3 museums in the first eight months of the year and were likely to visit a few more. Although not members of CMNH both mother and daughter had recently visited *Dinosaurs in Their Time* and were back to see it again. Though the mother reported that her daughter did not have a specific interest in dinosaurs, she indicated that she was very interested in animals in general and especially horses.

The mother and daughter spent approximately 22 minutes visiting the exhibition which was a relatively brief interaction even for families with novice children (mean novice museum time was 29 minutes). During this visit the content of their conversations was typical of many novice children with their parents. The daughter regularly used descriptive labels to refer to fossil specimens, demonstrated situational interest in the features of the exhibition, and expressed affective engagement with the overall experience. Consistent with the patterns observed in the discourse analysis, the mother provided the majority of identification, descriptive, and disciplinary learning talk through her explanations and interpretations of the exhibition. Both mother and daughter lightly explored the learning resources available in the exhibition, typically stopping just long enough to interpret 1- 2 sections of the printed labels or to access 1-2 pages on a touch screen.

The following excerpts illustrate patterns of learning talk and interaction with the environment that are typical of families with novice children: thematic engagement around salient features like size and scale; interpretation of the learning environment that is more piecemeal and less holistic; and parents leading the majority of content interpretation and visit management.

3.3.2.1 Excerpt 1: Interpreting individual features of the learning environment [Jurassic period]

Like many visitors, this mother and daughter moved through the Triassic and early Jurassic sections of the exhibition fairly quickly. As they entered the late Jurassic Atrium, the daughter noticed the *Stegosaurus* fossil and her mother responded by guiding her over to the information label to find out more about this dinosaur.

> C: This one is actually really big [points to *Stegosaurus*]
>
> P: I don't know what that is [walks to the label rail and reads] *Stegosaurus*
>
> C: Oh, that is a *Stegosaurus*.
>
> P: That's a *Stegosaurus.* Okay. [They both glance up at the fossil and then turn and walk toward the *Apatosaurus* in the center of the room] This is where the little baby was, right? [referring to the baby *Apatosaurus* positioned on the other side of the platform from where they are standing]
>
> C: Yea, that's the little one [pointing the baby *Apatosaurus*] and that's the mom [pointing to the adult *Apatosaurus* standing above them].
>
> P: Are these the longest dinosaurs [pointing to *Apatosaurus* and *Diplodocus* fossils as she continues to walk into the room]?
>
> C: Yea, they're really big, the most-biggest animals in the whole entire Earth!
>
> P: [laughs] The biggest animals in the whole entire Earth?
>
> C: Uh huh, they're really big.
>
> P: They're really long.
>
> C: Yea.
>
> P: See how long? His tail goes way back there [pointing to the end of the tail that wraps around a tree at the far end of the room].
>
> C: Yea.
>
> P: Okay [mother and daughter stop walking, the daughter begins exploring the *Allosaurus* touch screen] Do you know what time frame we're in now? Can you go back for a second?
>
> C: Yes. [uses the back button on the touch screen to return to an earlier page]

> P: Okay, this is late Jurassic. [gestures to the room around her and then goes back to reading the touch screen]. Do you see horns? [she looks from the screen to the *Allosaurus* fossil] Oh, I see right up there, up to, right above the eye. [points out the ridges on the top of the *Allosaurus* skull, her daughter nods]. Right there. Okay? Come on. [They move away from the screen and walk between the *Apatosaurus* and *Diplodocus*]
>
> C: Oh my [looking up at *Apatosaurus*]
>
> P: He's really big in comparison to humans, isn't he?
>
> C: Uh huh.
>
> P: Look here [pointing to the printed label] nine feet at the hips, so nine feet from there to there. And up to thirty-two feet long. That's bigger than our house. Way bigger than our house.

This interaction highlights one of the first and most salient features that most novice children and their parents discuss when they enter the Jurassic Atrium—the impressive size and scale of dinosaurs. The daughter focused on this physical feature as soon as she entered the room and encountered the first dinosaur fossil on display, *Stegosaurus*. Given the other distinctive features of *Stegosaurus* (a row of vertical plates on its back, spikes on its tail, and a tiny skull) it was somewhat surprising that the conversation did not extend beyond size and labeling. However, one possible reason for this omission was that size and scale were the features that this novice found most compelling. For example, when the mother reminded the daughter about an implied family relationship between the adult and baby *Apatosaurus*, the daughter re-framed this relationship in terms of a size comparison. The mother also seemed to find size and scale a comfortable way to talk about dinosaurs, especially the long-necked, long-tailed sauropods. She elaborated on the idea of scale by questioning whether sauropods are the "longest" dinosaurs, comparing them to the size of humans, and connecting the average dimensions of the *Apatosaurus* with a large object that would be familiar to her daughter, their house.

Discussions of size and scale like this represent an accessible way to begin to interpret and understand dinosaur fossils in a museum context. In many dinosaur books, size is described in relative terms (e.g. biggest, longest, smallest etc.) or in terms of numeric measurements (e.g. feet and inches). When scale is addressed, often it is depicted implicitly through diagrams and illustrations of relative size that compare dinosaur species to other dinosaur species, through analogies to familiar objects like a school bus, or modern animals like whales and chickens (Cole, 1994; Holtz, 1994; McKay, 2004). In contrast to book-based strategies that use two dimensional representations and analogies, in a museum exhibition the concepts of size and scale are concrete and tangible for all visitors regardless of prior knowledge. The design of *Dinosaurs in Their Time* in particular iteratively supports opportunities to talk about size and scale each time a visitor approaches a 3-dimensional dinosaur fossil. Comparisons focused on scale were frequently observed in family learning talk with contrasts being made between visitors and dinosaurs, the murals which depict dinosaurs in relative scale to each other, and the specimen labels that include silhouetted illustrations of dinosaurs compared to an average man, woman, and child. For novices, noticing and discussing size and scale could be an important starting place for learning conversations about dinosaurs.

This excerpt also highlights the way that novice conversations are focused on individual specimens and features of the exhibition. Whether talking about size, scale, or locating specific features of a fossil like the "horns" on the *Allosaurus*, conversations were about noticing and describing species as individual objects. With the exception of the mother's comment about the baby and the adult *Apatosaurus* there was no explicit recognition of the ecological or evolutionary relationships between these species. This is consistent with a novice pattern of engagement with a topic where tangible features are noticed and then interpreted based on available knowledge resources. Through this piecemeal engagement with the information in the exhibition, the novice child and her mother begin to gather knowledge about individual dinosaurs but do not explicitly connect this information to broader disciplinary themes or relationships.

For novice children and their families the majority of identification learning talk consists of references to feature labels as opposed to scientific names or diet behaviors. Consistent with this pattern, the mother only labels one dinosaur with its species name (*Stegosaurus)* despite talking about four other dinosaurs during this short segment of learning talk. However, it is important to acknowledge that the omission of dinosaur names did not undermine the successful descriptive learning talk that occurred between this mother and daughter. For this novice family and many others curiosity often motivated someone in the visit group to read a particular species name from a touch screen or a printed label. For families without prior knowledge about a particular species the name itself is does not carry much meaning until it is connected to information about that animal. As a result, families with novices spend the majority of their time engaged in feature labeling and descriptive talk that can begin to form the basis for subsequent knowledge refinement. In this case, the mother initially labels the *Stegosaurus* with its scientific name but this labeling activity did not seem to interest her daughter nor draw her into conversation. As a result the mother did not continue associating names with fossils as they explored the Jurassic Atrium and instead engaged in learning talk that supported co-constructed interpretations of the learning environment.

Finally, the mother in this dyad controlled the flow and pacing of the visit. While she would follow the interests of her daughter when they were clearly articulated she often interrupted her daughter's individual exploration of a touch screen in order to focus her attention on another fossil specimen or to move to another area of the exhibition. An example of this visit management is included in the excerpt when the mother and daughter explore the *Allosaurus* touch screen. In reaction to her daughter flipping too quickly through the pages of the touch screen for the mother to read, she requests that they "go back" in order to answer her question about which time period they are in. The mother finds this information and then reads a section of the touch screen page that her daughter returned to about the features of the *Allosaurus'* skull. It is interesting to note that the mother has a consistent schema that she used throughout the visit to interpret information: she reads or re-phrases a small segment of text from a touch screen or a label, typically makes a connection between the information and a fossil, and then indicates that the "teachable moment" has ended by checking in with the daughter "Okay?" quickly followed by "Come on" or "Let's go". While this may have been a strategy intended to help focus her daughter's attention and make connections between the learning resources and the fossils on display, this pattern of behavior seemed to limit opportunities for further information exploration and learning conversations beyond what the mother had selected to highlight.

3.3.2.2 Excerpt 2: Making Ecological Connections [Cretaceous Period]

In this excerpt the mother and daughter have made their way into the Cretaceous section of the exhibition and begin to discuss the fossil on display in the center of this room.

> P: Look at that big *T.rex.*
>
> C: Yea, that one's bigger because of that [points to the platform and the relative heights of the two T.rex fossils].What kind of animal is that [points to *Edmontosaurus*] laying there?
>
> P: Well that's probably something that they ate, or maybe something that they killed and then ate. If you remember they were meat eaters. Look how big their teeth are.
>
> C: Wow. They're sharp.
>
> P: And that's probably just a – well it's just a baby one.

C: Oh.

P: Uh huh. See how big their teeth are in the adults. It's as long as your fingers are long.

C: Yea but is that the baby laying there? [points to *Edmontosaurus* again]

P: No, I think that's something that they killed and ate.

C: Well, I don't know where the baby is. [walking over to the wall of *Ceratopsian* skulls] Look, two horns. The other ones –

P: Is that a one horn or are they just two horns?

C: They're all two horns and one's a one horn.

P: [reads the printed label] *Ceratopsians* [continues reading quietly to herself]

C: That one's a two horn—right there on the top [points to the highest mounted fossil skull] and this one is a four horn. One, two, three, four, five, six – [counts the horns on another of the *Ceratopsian* skulls]

P: I don't think I'd want to get in a fight with this thing, he has too many horns to jab you.

C: I know.

P: Look at that. Look how many horns he has.

C: Whoa.

P: You think that helped him? Do you think the horns helped him if the *T.rex* was coming after him?

C: Uh huh 'cause he has a lot of horns.

P: Yea, but he would have to get close enough to jab the *T.rex* with his horns. By that time the *T.rex* probably already had a big bite taken out of him.

This excerpt illustrates the kinds of ecological connections made by novice families. While the daughter recognizes that there are two *T.rex* fossils on the central platform she is curious about what kind of animal is laying on the ground between them. Based on where they are standing, the mother does not have the information to help her to identify the "animal" on the ground, so instead she describes the larger ecological story of the scene and "identifies" the animal on the ground as prey "something they killed and ate". While this is a basic illustration of an ecological relationship, this is the depth of ecological connection that is typical in many novice family interactions. There is one explicit connection between predator and prey usually connected to a particular species (like the *T.rex)* and no added conversational engagement with the larger system in which that interaction would take place. As demonstrated in this excerpt, parents with novice children most often initiate conversations about ecological connections and they often connect these comments to illustrations in the designed environment (murals and mounted fossils) that support ecological interpretations. In addition, the ecological narrative is more often noticed and explicitly commented on in relation to the confrontation between the two *T.rex* fossils than almost any other area in the exhibition. This is true for all families regardless of knowledge level. One possible explanation for this is that *T.rex* is the most iconic meat-eating dinosaur species and since the position of the mounted fossils aligns with visitors' expectations about *T.rex* behavior, this provides a perfect opportunity to talk about ecological connections.

Once again, size and scale are central features of this learning conversation. In this excerpt, the mother initiates the conversation about the fossil specimens by pointing out their size. The daughter follows her lead and notices that the design of exhibit platform is the reason that one of the fossils looks bigger than the other. This comment highlights the extremely literal interpretations that the daughter often contributes to the conversation and suggests that like many novices she is most comfortable talking about topics that are tangible in the learning environment. As a further illustration of this point, when this parent attempts to draw a helpful analogy between size and family roles, the daughter becomes confused about how to interpret the displayed fossils. As the mother is talking about the relative size of *T.rex* teeth, she uses the term "baby" as a proxy for talking about size. This becomes a distraction for the daughter who is very interested in the relationships between "mothers" and "babies" and becomes focused on finding and identifying the "baby" in the scene as opposed to engaging with her mother's attempts to describe size and scale. This also emphasizes the challenge that many parents face when trying to find the best way to interpret the museum learning environment for their children.

Finally, this excerpt illustrates the different kinds of concepts that novices and their parents typically contribute to the learning conversations during their museum visit. As the mother and daughter examine the wall of *ceratopsian* skulls the daughter sees this as an opportunity to compare features and notice similarities and differences between species. And while she and her mother do not take the opportunity to connect sets of features with the names of these specimens, noticing, describing, and comparing features can support the interpretation fossil evidence and generated several productive examples of descriptive learning talk. The mother also introduces the form and function relationship between horns and self-defense and describes another example of an ecological relationship between the *ceratopsians* on display and the *T.rex.* Though this mother did not choose to use many of the learning resources in this excerpt overall she was able to build from her daughters' interest in identification and descriptive talk to introduce a few examples of disciplinary talk (ecological connections) that were meaningful in the museum context.

3.3.2.3 Excerpt 3: Managing the use of Learning Resources [Cretaceous]

In this final excerpt, the mother and daughter have made their way to the back corner of the Cretaceous section of the exhibition and begin to explore the last dinosaur of their visit.

> P: This says unnamed Ov-ri-a-rat-ores. [*Oviraptorosaurus]*
>
> C: That one's actually a plant-eater.
>
> P: You think? [mom watches as the daughter presses the touch screen multiple times and the screen seems to freeze]. You're pushing it too many times and it's

not able to keep up with you. [the mother lifts her daughters' hand off the screen for a moment and the screen loads]. There you go. Okay?

C: What's that (pointing to the *Oviraptor* fossil)?

P: [mom tries to read the species label again] *Ovi-ro-saur-us*…I'm sure I didn't say that right. *Ovi-saurous? Ovi-saur?* [sighs as she gives up trying to pronounce the scientific name] That's the newest dinosaur. [daughter starts advancing the pages on the screen] Can you go back for a minute? [reads from the touch screen] "Our newest dinosaur has a startling array of features that differ significantly from all the other relatives. The skeleton poses intriguing riddles to study about this new dinosaur. Here at the Carnegie Museum, paleontologists will attempt to answer these and many other questions." Okay. Look at the size difference (points to the scale comparison on the printed label between *Oviraptor* and a person). It's seven feet.

C: It's about the size of [pauses and looks at her mom]

P: It's a little bit bigger than a man, huh? About a foot bigger, but much longer.

C: Yea a little bit longer.

P: Look how much he weighs (reads from the printed label) Four hundred pounds!

C: Whoa

In this excerpt, the mother and daughter use both the printed label and the touch screen to support their interpretation of the *Oviraptorosaur* fossil. Unlike the conversation at *Stegosaurus,* the daughter is interested in identification talk—requesting the name for this dinosaur from her mother and suggesting that *Oviraptorosaur* might have a particular diet behavior (that one's actually a plant-eater). The mother provides the name for the dinosaur by reading it from the phonetic spelling on the printed label. Unfortunately, she seemed self-conscious about her pronunciation and expressed mild frustration about the complexity of dinosaur names. This seemed to happen more with parents with novices than parents with experts who were not surprisingly more familiar and more comfortable using dinosaur and other Mesozoic species names.

Consistent with her established approach to interpreting fossils in the exhibition, the mother read some of the intro text from the touch screen, but does not explore any addition pages on the touch screen or explain the implications of the text that she did read to her daughter. While this interaction supported several examples of identification and descriptive learning talk, there was also a missed opportunity to engage in disciplinary talk. The *Oviraptor* fossil provides some of the most explicit fossil evidence for the evolutionary relationships between dinosaurs and birds. In addition, the interpretation of this evidence is well supported in the learning resources associated with the *Oviraptorosaur*, but neither the mother nor the daughter notice or comment on this connection. Instead, after reading the touch screen excerpt, the mother refocuses her daughter's attention on the features that have been most salient and accessible throughout their visit—size and scale.

Case Study Synthesis: The analysis suggests that exhibition works well for expert and novice children and their families. The availability of a variety of layered learning resources supports conversations of topics that are of interest and accessible to families across a range of knowledge levels and in different phases of interest development (Hidi & Renninger, 2006). Child knowledge clearly plays a role in patterns of engagement with the exhibition and interpretation of the displayed fossils. As illustrated in the case study, novice families often organize their engagement with the exhibition around one or two themes and carry this through their conversations. Across knowledge categories, parents and children demonstrated remarkably consistent museum visit schemas (Ash, 2003; Allen, 2002; Borun, Cleghorn, Garfield 1995; Crowley et. al, 2001; Falk & Dierking, 2000; Hilke, 1989; Zimmerman, 2012). For the expert family, interpretation of fossil evidence and discussions of form and function were the recurring themes that were consistently applied across multiple examples of dinosaurs in the exhibition. For the novice family, size and scale were their primary themes and they iteratively addressed these ideas during their visit to *Dinosaurs in Their Time*.

Differences also emerged between families with expert and novice children in the ways that they made meaning in different exhibition areas. For the expert family, interpretation was often more holistic, drawing from multiple learning resources and integrating this information into a more coherent narrative. In contrast, the novice family adopted a more piecemeal approach typically shifting from section to section in the exhibition and learning about individual species without also making connections between them. Families of experts and novices also demonstrated distinct patterns of identification learning talk. Discourse analysis indicated that total identification talk was the most frequent type of learning talk that both expert and novice children and their parents generated during the museum visit. However, comparing the identification talk in the first excerpts of both the expert and novice families reveals that the expert family used scientific names five times compared to the novice family who only used one while exploring the same section of the hall. For expert children and their families using scientific names to label dinosaurs and other species depicted in the exhibition was central to their habits of museum learning talk. In contrast, for novice children and their families the majority of their identification learning talk is references to feature labels as opposed to species names or diet categories.

4.0 DISCUSSION

This research explored the potential for islands of expertise in dinosaurs to be leveraged to support the development of disciplinary thinking and reasoning skills through engagement in learning talk in a designed learning environment. The study identified and described the ways that children's prior knowledge shaped the kinds of learning talk that families engaged in during a visit to *Dinosaurs in Their Time.* Comparisons of the content of learning talk were made between children with expert and novice levels of dinosaur knowledge and between parents of expert and novice children. Analysis also explored the distribution of parent-child learning talk (e.g. who was producing learning talk within families) and the role of child knowledge on these patterns of parent-child learning talk. Finally, through a combination of content and discourse analysis this study explored the ways that the design of the museum learning environment shaped opportunities for learning talk across families with expert and novice children. The results provide evidence that islands of expertise can be used to support parent-child learning talk that includes engagement with disciplinary concepts like ecology and evolution in a museum setting.

Consistent with previous research, we found that identification learning talk was the most prevalent type of learning talk produced by parents and children (Ash, 2003; Borun, 2002; Palmquist & Crowley, 2007; Tunicliffe, 2000; Zimmerman, Reeve, & Bell, 2010). However, a closer look at this category of learning talk revealed that expert children and their families more frequently used scientific names for dinosaurs and non-dinosaur species (e.g. *Diplodocus or*

Pterodactyl), while novice children and their families more often used feature labels for dinosaurs (e.g. long necks). This pattern of engagement with identification learning talk was not surprising given that naming and categorization are fundamental aspects of early childhood expertise around dinosaurs (Chi & Koeske, 1983;Johnson, Scott, & Mervis, 2004; Palmquist & Crowley, 2007). In addition, dinosaur identification was a key component of the knowledge assessment that defined the expert and novice categories in this analysis. However, *Dinosaurs in Their Time* is also a learning environment that is well suited to support identification learning talk. Visitors have multiple opportunities to label familiar and less familiar dinosaur and non-dinosaur species that lived during the Mesozoic as they encounter representations in murals, printed labels, touch screens, and mounted fossils.

Expert children also produced more learning talk than novice children across form and function relationships that support survival and disciplinary topics (e.g. ecology and evolution). While previous research has suggested that children can engage in discussions of biological themes and form and function when visiting informal learning environments (Ash, 2004; Eberbach, 2009; Rowe & Kisiel, 2012), learning talk about evolution as change over time and common ancestors has been more challenging to support and measure across learning contexts (Rosengren et al., 2012; Evans et al., 2010). This study provided evidence that expert children and their parents were able to recognize opportunities in the designed learning environment to engage in disciplinary learning talk more than novice children and their parents. It is interesting to note that many of these disciplinary learning conversations included concepts and themes that are identified as goals for much older children (NRC, 2011). This suggests that children with islands of expertise in a topic like dinosaurs may be able to engage in significantly more complex scientific thinking and reasoning when disciplinary concepts are aligned with their interests and prior knowledge.

Throughout this study, conversation is positioned as both the process and the product of authentic family learning that occurs in the museum setting. In this way, this research is aligned with many other studies that have defined conversations as a primary mechanism of learning in informal learning environments (Allen, 2002, Eberbach, 2009; Leinhardt, Crowley, & Knutson, 2002; Leinhardt & Knutson, 2004). Better understanding the content of learning talk, how, and when parents and children engage in it is one approach that can be used to explore the value of free choice, informal learning experiences as an aspect of life-long and life-wide learning (Bell, 2008; Falk & Dierking, 2010). As the field continues to grapple with how to assess these learning impacts, a study like this could be used as a benchmark to help describe what disciplinary learning sounds like when it occurs through parent-child learning talk in a natural history museum.

The application of content and discourse analysis to this data set of parent-child learning talk provided findings that can help to inform the definition learning as it occurs in designed learning environments. However, in contrast the pre-test/post-test approach used in this study was not found to be a particularly effective mechanism for measuring learning. In many ways it lacked the sensitivity needed to detect the incremental learning that occurred during learning talk in the museum. For example, in the short excerpts included in the expert case study there were several instances of knowledge co-construction and refinement that occurred through learning talk during the museum visit. Particularly in the interaction around the *Oviraptorosaur,* there were new connections made between prior knowledge and displayed fossil evidence of common ancestry between dinosaurs and birds. The combination of content and discourse analysis highlighted these authentic learning conversations as they occurred in the museum exhibition. However, pre-test and post-test results did not capture those instances of learning.

In addition, research has suggested that immediate post-test measures also may fail to detect learning outcomes because of the dramatic change in contextual factors between the learning environment and the assessment. Learning that occurs in rich informal learning environments may be best activated and utilized in another informal or everyday learning context several days or weeks after the initial learning experience in a museum had occurred (Sanford, 2010). In this context, the fact that pre-post gains were observed across descriptive and disciplinary learning talk was encouraging. The significant increase in novice parents' engagement in evolution as common features learning talk suggests that a relatively short visit to *Dinosaurs in Their Time* may have provided parents with shared examples to support this kind of learning talk with their children that they lacked prior to their visit. This finding in addition to the content and discourse analysis of learning talk in the exhibition provides evidence of the success of the designed learning environment to provide support for increased engagement in disciplinary learning talk.

As mentioned in the introduction, *Dinosaurs in Their Time* was a dramatic re-design of the original dinosaur hall at the Carnegie Museum of Natural History. A brief review and comparison of the findings from Palmquist & Crowley (2007) conducted in the original dinosaur hall and the current study findings in the renovated exhibition provide insight into the ways that the renovation supported the target learning outcomes. Three indicators of how the visitor learning experience changed between the original dinosaur hall and *Dinosaurs in Their Time* are described below.

Both expert and novice parents are engaged in similar patterns of learning talk regardless of whether they visit *Dinosaurs in Their Time* with expert or novice children. In the original dinosaur hall, parents with expert children often enacted the role of attentive audience for their children's knowledge rehearsal and display. In contrast, in *Dinosaurs in Their Time* all parents were highly engaged in learning talk regardless of children's level of expertise. As a result, the patterns of within-family participation in learning talk completely changed from the original to the current dinosaur hall. In the current dinosaur hall, parents with expert children more equally shared the responsibility for initiating and maintaining learning talk with children while parents with novice children controlled most of the learning talk across categories.

Dinosaurs in Their Time provides a layered and complementary set of learning resources that effectively support learning talk for families with expert and novice children. For expert children and their parents instances of knowledge display were balanced by opportunities for knowledge co-construction. This is in sharp contrast to the expert experience in the original dinosaur hall which was almost exclusively knowledge display. In addition, expert children and their parents were able to engage in holistic interpretations like the one featured in the expert case study where a variety of evidence from the learning environment was synthesized and aligned with an ecological framework. While novice families interacted with specimens and learning resources in a more piecemeal way, the learning environment was able to provide them with accessible themes like size and scale to support active learning talk.

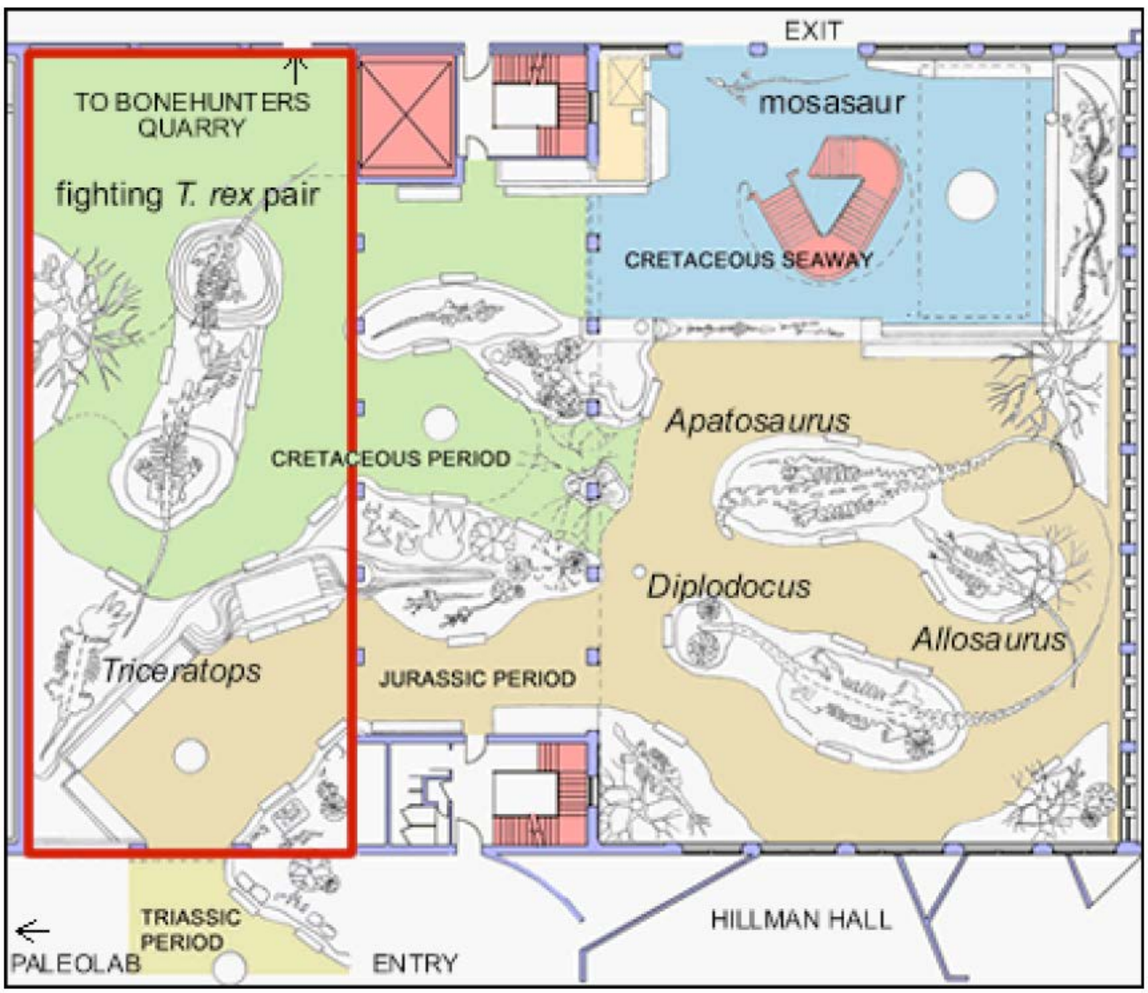
There are a wide range of opportunities to engage in disciplinary learning talk embedded in the design of *Dinosaurs in Their Time*. Families with novice and expert children described the ecological narratives suggested by the positions of the fossils (e.g. *T.rex vs. T.rex*), noticed evolution as change over time across different sections of the exhibition (e.g. Oh, now they have flowers and they didn't have flowers before), recognized evolution as common features (e.g. those feet look like chicken feet to me), and identified common ancestry (e.g. birds are descendants of dinosaurs). In *Dinosaurs in Their Time* expert children and their parents are engaging more equally in disciplinary learning talk while parents with novice children are primarily initiating and managing these conversations. While many of the same fossil specimens were featured in the original dinosaur hall, there was significantly less support in the learning environment to engage in disciplinary talk and as a result the majority of families regardless of knowledge level missed these learning opportunities in the original dinosaur hall. These findings indicate some of the critical ways that *Dinosaurs in Their Time* is a more effective learning environment than the original dinosaur hall.

Taken together, the results of this study suggested that islands of expertise can provide opportunities to engage with cross-cutting themes like scale, relationships between structure and function, systems thinking, and patterns of stability and change that are critical for the development of scientific literacy (NRC, 2012). These findings can contribute to the active and ongoing conversation in the field about the kinds of learning that can occur in informal learning environments (NRC, 2009) and more specifically the ways that Natural History Museums can be designed to support engagement and increased understanding of complex science concepts like ecology and evolution (21st Century Learning in Natural History Settings Project and Wiki, 2012).

APPENDIX A

The red rectangle indicates the position and size of the original dinosaur hall.

Figure 3. Floor plan of *Dinosaurs in Their Time*



APPENDIX B

DATA COLLECTION INSTRUMENTS

B.1 DINOSAUR KNOWLEDGE ASSESSMENT

Sub #___ Parent: Mother Father Child: Male Female Age: ____

1- Take a look at these figures. Which ones are not dinosaurs? How could you tell that these [selected] were not dinosaurs? How could you tell that these were dinosaurs?]

2- Let's see how many of these dinosaurs' names you know. [Begin with T.rex]

a-Are there any other dinosaur names that you know that you do not see here?

3-Take a look at these three pictures [Diplodocus, Camarasaurus, and Allosaurus skulls]

a-Which of these dinosaurs might eat plants? How come?

b-Which of these dinosaurs might eat meat? How come?

c-What makes these skulls look similar? (How are these the same?)

d-What makes these skulls look different? (How are these different?)

e-Which two of these skulls would a scientist group together? Why do these go together? Are there any other ways that you could group these skulls?

4- Fossils like these provide clues to what life was like on earth a long time ago. What kinds of things can we learn from fossils?

5- What is the name for the scientists who study dinosaurs?

6- Are there any dinosaurs like these alive today? Yes No

a- What happened to the dinosaurs ?

7- Take a look at these figures **[Stegosaurus, Ankylosaurus, Allosaurus, Triceratops, cave person].** Which of these figures lived at the same time at this dinosaur?

a-What time period did they live in?

b-Which of these figures **did not** live at the same time as this dinosaur?

For those that did not: Did they live before this dinosaur or after?

Dinosaur Figures to be Identified	Non-Dinosaur Figures to be Identified
Allosaurus*	Dimetrodon
Apatosaurus*	Elasmosaurus
Brachiosaurus	Pteranodon*
Camarasaurus*	Tiger
Diplodocus*	Giraffe
Iguanodon	
Maisaura	
Stegosaurus*	
T-rex*	
Triceratops	
Velociraptor	

*= names of specimens that are also included in the exhibition

Figure 4. Skull images used in the child knowledge assessment

Camarasaurus, Allosaurus, Diplodocus (each shown to participants as a full page image)

B.2 PARENT QUESTIONNAIRE

1- How interested is your child in dinosaurs? (Please circle)

1 2 3 4 5 6 7

Not interested in playing with dinosaurs or learning about them

Plays with dinosaurs & has other interests

Prefers playing with dinosaurs or learning about them more than most other subjects

2- How much does your child know about dinosaurs? (Please circle)

1 2 3 4 5 6 7

Knows one or fewer dinosaur names and facts

Knows 3 or more dinosaur names and facts

Knows many dinosaur names & facts

3- How interested are you in dinosaurs? (Please circle)

1 2 3 4 5 6 7

I rarely choose books & movies about dinosaurs

I sometimes choose books and movies about dinosaurs, but I have other interests

I choose movies and books about dinosaurs as often as I can

4- How much do you know about dinosaurs? (Please circle)

1 2 3 4 5 6 7

I can name 1 -2 dinosaur names & facts about them

I can name 3 or more dinosaurs & facts about them

I can name many dinosaurs & facts

5- If your child is interested in dinosaurs, what sparked that interest? **(Check all that apply)**

____ Friends ____ Siblings ____ A certain book ____ Web-site ____ Video

____Other

(please explain)____

6- Do you encourage your child to learn more about dinosaurs as opposed to other subjects?

___Yes ___No

7- How do you and your child like to learn about dinosaurs?

8- Which of the following do you have at home? **(Check all that apply)**

Dinosaur themed: ____Books____DVDs ____ Dino. figures ____ Dino. Games

9- What other interests does your child have? **(Check all that apply)**
_____ Trains _____Cars/ Trucks _____Animals _____ Princesses/ Fairytales _____ Arts & Crafts _____ Astronomy/ Space _____ Dolls_____ Sports _____Robots
_____Other:____

10- What are your child's favorite toys, books, and/ or games?

____

Please circle only one response to the remaining questions:

11- Have you visited the Carnegie Museum of Natural History with your child? Yes No

If Yes, how often do you visit each year? 1-2 times 3-5 times 6+ times

12- Are you members of the Carnegie Museum of Natural History? Yes No

13- How often do you take family visits to other museums each year?
0-1 2-3 4-5 6+ times

14- What is the highest level of education that you have completed?

Less than High School High School/ GED College Graduate school

APPENDIX C

DATA TABLES

C.1 SUMMARY OF EXPERT CHILDREN'S LEARNING TALK

Table 11. Raw means for learning talk during pre-test, museum, and post-test for expert children

Types of Learning Talk	**pre**	**museum**	**post**
Learning Talk (Totals)	23	109	19
Identification Talk	**10.27**	**65.86**	**7.92**
Feature Label	1.47	18.00	1.53
Diet Behavior	2.67	3.73	1.46
Scientific Name	6.13	44.13	4.93
Descriptive Talk	**2.47**	**22.13**	**2.14**
Form & Function Diet	0.67	2.20	0.20
Form & Function Other	0.27	5.13	0.40
Comparison: Dino-Dino	0.60	4.33	0.27
Comparison: Dino-Other	0.33	5.00	0.60
Affective	0.60	5.47	0.67
Disciplinary Talk	**10.73**	**21.40**	**9.06**
Ecology	5.60	10.40	3.33
Evolution			
Change over time	2.53	4.07	2.73
Common features	1.73	4.13	2.07
Common ancestors	0.87	2.80	0.93

C.2 SUMMARY OF NOVICE CHILDREN'S LEARNING TALK

Table 12. Raw means for learning talk during pre-test, museum, and post-test for novice children

Types of Learning Talk	pre	museum	post
Learning Talk (Totals)	**11.41**	**43.27**	**11.28**
Identification Talk	**5.60**	**23.14**	**5.87**
Feature Label	2.00	14.20	2.20
Diet Behavior	1.73	2.47	1.47
Scientific Name	1.87	6.47	2.20
Descriptive Talk	**1.81**	**13.33**	**1.20**
Form & Function Diet	0.27	1.33	0.27
Form & Function Other	0.67	0.73	0.00
Comparison: Dino-Dino	0.20	1.40	0.20
Comparison: Dino-Other	0.20	3.07	0.20
Affective	0.47	6.80	0.53
Disciplinary Talk	**4.00**	**6.80**	**4.21**
Ecology	2.73	3.20	2.27
Evolution			
Change over time	0.80	0.67	0.8
Common features	0.47	2.80	1.07
Common ancestors	0.00	0.13	0.07

C.3 SUMMARY OF LEARNING TALK OF PARENTS WITH EXPERT CHILDREN

Table 13. Raw means for learning talk during pre-test, museum, and post-test for parents with expert children

Types of Learning Talk	pre	museum	post
Learning Talk (Totals)	16.00	147.00	14.00
Identification Talk	**6.60**	**75.93**	**5.34**
Feature Label	2.00	28.73	1.47
Diet Behavior	1.73	8.87	1.40
Scientific Name	2.87	38.33	2.47
Descriptive Talk	**1.07**	**37.81**	**1.20**
Form & Function Diet	0.13	4.07	0.13
Form & Function Other	0.07	9.07	0.27
Comparison: Dino-Dino	0.27	5.47	0.00
Comparison: Dino-Other	0.27	8.73	0.13
Affective	0.33	10.47	0.67
Disciplinary Talk	**8.73**	**33.16**	**7.67**
Ecology	4.00	13.93	1.73
Evolution			
Change over time	2.80	11.29	3.27
Common features	1.40	6.27	2.40
Common ancestors	0.53	1.67	0.27

C.4 SUMMARY OF LEARNING TALK OF PARENTS WITH NOVICE CHILDREN

Table 14. Raw means for learning talk during pre-test, museum, and post-test for parents with novice children

Types of Learning Talk	pre	museum	post
Learning Talk (Totals)	13.60	92.59	13.53
Identification Talk	**5.67**	**45.00**	**4.46**
Feature Label	2.93	23	2.40
Diet Behavior	1.87	5.93	0.93
Scientific Name	0.87	16.07	1.13
Descriptive Talk	**2.26**	**25.05**	**1.40**
Form & Function Diet	0.53	2.53	0.33
Form & Function Other	0.20	4.53	0.20
Comparison: Dino-Dino	0.40	3.13	0.07
Comparison: Dino-Other	0.80	7.60	0.33
Affective	0.33	7.26	0.47
Disciplinary Talk	**5.67**	**22.54**	**7.67**
Ecology	2.60	7.87	2.93
Evolution			
Change over time	1.87	5.80	1.87
Common features	1.13	7.20	2.67
Common ancestors	0.07	1.67	0.20

C.5 SUMMARY OF COMMENTS PER HOUR (CPH) FOR EXPERT CHILDREN

Table 15. Comments per hour (CPH) means for learning talk during pre-test, museum, and post-test for expert children

Types of Learning Talk: Comments/Hour	pre	museum	post
Learning Talk (Total)	**63.48**	**102.76**	**55.49**
Identification Talk	10.14	25.69	11.03
Feature Label	17.34	5.80	9.68
Diet Behavior	36.00	71.27	34.78
Scientific Name	**12.09**	**32.90**	**14.30**
Descriptive Talk	0.48	3.13	0.97
Form & Function Diet	1.91	7.47	2.48
Form & Function Other	4.14	6.32	1.72
Comparison: Dino-Dino	2.27	7.58	4.48
Comparison: Dino-Other	3.29	8.40	4.65
Affective	**73.53**	**30.91**	**62.29**
Disciplinary Talk	38.75	15.94	22.77
Ecology	34.78	14.97	39.52
Evolution			
Change over time	11.13	6.05	14.38
Common features	5.73	3.28	6.27
Common ancestors	**63.48**	**102.76**	**55.49**

C.6 SUMMARY OF COMMENTS PER HOUR (CPH) FOR NOVICE CHLDREN

Table 16. Comments per hour (CPH) means for learning talk during pre-test, museum, and post-test for novice children

Types of Learning Talk: Comments/Hour	**pre**	**museum**	**post**
Learning Talk (Total)	84.08	103.85	93.44
Identification Talk	**44.50**	**54.24**	**48.45**
Feature Label	16.06	33.93	19.63
Diet Behavior	14.44	5.95	11.91
Scientific Names	14.00	14.36	16.91
Descriptive Talk	**9.16**	**34.66**	**10.41**
Form & Function Diet	1.43	3.16	2.23
Form & Function Other	0.62	1.95	0.00
Comparison: Dino-Dino	1.35	3.83	1.56
Comparison: Dino-Other	1.59	7.09	1.53
Affective	4.17	18.63	5.09
Disciplinary Talk	**30.42**	**14.95**	**34.58**
Ecology	20.45	7.92	18.69
Evolution			
Change over time	6.62	1.44	6.70
Common features	3.35	5.34	8.72
Common ancestors	0.00	0.25	0.47

C.7 SUMMARY OF COMMENTS PER HOUR (CPH) FOR PARENTS WITH EXPERT CHILDREN

Table 17. Comments per hour (CPH) means for learning talk during pre-test, museum, and post-test for parents with expert children

Types of Learning Talk: Comments/Hour	pre	museum	post
Learning Talk (Total)	106.15	214.46	96.20
Identification Talk	**41.52**	**110.57**	**36.36**
Feature Label	12.33	42.11	10.72
Diet Behavior	10.88	11.93	9.05
Scientific Names	18.31	56.53	16.59
Descriptive Talk	**6.87**	**56.15**	**8.19**
Form & Function Diet	0.92	5.66	0.76
Form & Function Other	0.56	11.94	1.65
Comparison: Dino-Dino	1.55	7.65	0.00
Comparison: Dino-Other	1.86	12.00	1.05
Affective	1.98	18.90	4.73
Disciplinary Talk	**57.76**	**47.74**	**51.65**
Ecology	25.89	18.97	11.57
Evolution			
Change over time	18.37	14.31	22.5
Common features	9.50	9.48	16.09
Common ancestors	4.00	4.98	1.49

C.8 SUMMARY OF COMMENTS PER HOUR FOR PARENTS WITH NOVICE CHILDREN

Table 18. Comments per hour (CPH) means for learning talk during pre-test, museum, and post-test for parents with novice children

Types of Learning Talk: Comments/Hour	pre	museum	post
Learning Talk (Total)	98.97	207.88	117.31
Identification Talk	**41.33**	**104.32**	**37.39**
Feature Labels	22.15	52.53	21.48
Diet Behavior	12.58	13.23	7.14
Scientific Names	6.60	38.56	8.77
Descriptive Talk	**15.71**	**54.94**	**12.47**
Form & Function Diet	2.96	5.80	2.87
Form & Function Other	1.65	9.64	1.76
Comparison: Dino-Dino	2.98	7.05	0.43
Comparison: Dino-Other	5.19	16.70	2.74
Affective	2.93	15.75	4.67
Disciplinary Talk	**41.93**	**48.62**	**67.45**
Ecology	19.29	18.23	25.42
Evolution			
Change over time	14.83	11.63	17.67
Common features	7.37	15.55	22.43
Common ancestors	0.44	3.21	1.93

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