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Building Islands of Expertise in Everyday Family Activity

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How do young children first learn about academic disciplines? Long before they encounter science, history, or social studies in grade school, children begin developing a wealth of informal knowledge about each topic. In science, for example, young children are actively developing nascent scientific reasoning skills, naïve theories for scientific domains, knowledge of interesting science factoids, knowledge about famous scientific narratives, and even some early ideas about what different kinds of scientists do in their professional work. As this everyday academic literacy develops, children are simultaneously developing a sense of identity as individuals who are more or less interested and motivated to seek out opportunities to engage in activities that are related to various academic disciplines. As one focus of our museum learning research, we continue to explore how parents mediate children's experiences in and out of museums to help weave multiple moments of learning into broader informal knowledge about academic disciplines.

In this chapter we introduce the notion of islands of expertise, explore links between related socio-cultural and information processing theory, and overview a study of family conversations while parents and children look at authentic and replica fossils in a museum.

Building an Island of Expertise in Everyday Activity

An island of expertise is a topic in which children happen to become interested and in which they develop relatively deep and rich knowledge. A typical island emerges over weeks, months, or years and is woven throughout multiple family activities. Because of this, developing islands of expertise is a fundamentally social process. They are co-constructed through the ongoing negotiation of children and parents' interests, children and parents' choices about family activities, and children and parents' cognitive processes, including memory, inferencing, problem solving, and explanation. As children develop deeper knowledge, islands of expertise support conversations and learning that can be more advanced than would be possible in domains in which the child's knowledge is of a more typically sketchy nature. Thus, islands of expertise become platforms for families to practice learning habits and to develop, often for the first time, conversations about abstract and general ideas, concepts, or mechanisms. Even when a child loses interest and an island of expertise begins to fade, the abstract and general themes that used the islands rich knowledge as a launching pad, will remain connected to children's other knowledge.

To illustrate what we mean, consider a child who, on his second birthday, is given a Thomas the Tank Engine picture book. In turns out that he likes the book, which is about the adventures of a small steam locomotive on an island railway. In fact, in turns out that he likes the book a lot and asks his parents to read it to him over and over. While waiting for a flight a few weeks later, perhaps the boy's father buys a Thomas the Tank Engine toy at the airport store. Maybe his parents pickup a few Thomas the Tank Engine videos next time they are at the video store. Maybe the mother decides that the boy could be Thomas for Halloween. When planning a Sunday outing, the parents might decide the boy would enjoy visiting a nearby train museum. As the boys' knowledge about trains deepens, the family checks out more advanced train books from the library. The family starts planning side-trips to other train museums when they travel. If they visit Steamtown National Historic Site in Scranton, Pennsylvania, maybe the boy spends a lot of time looking at "Big Boy"—a gargantuan 4-8-8-4 Union Pacific steam locomotive—and maybe, having noticed his interest, the parents stop at the gift shop to buy the boy a T-shirt with a picture of Big Boy on the front and a list of its vital statistics on the back. When he wears the shirt later, it serves as a conversational prompt for the boy, his parents, and others.

If the boy's position on the repeated reading of the same books and the repeated watching of the same videos is anything like that of a typical 2-year old, the boy (and his parents) would have soon memorized lots of domain-specific knowledge. They would have learned labels such as firebox, tender, boiler, drive wheels, sanding gear, and steam dome. They would have acquired at least some general knowledge about mechanisms of locomotion—for example, that steam, coal, and water are sometimes involved and that diesel or electricity are sometimes involved. They would have learned schemas for a variety of train scenarios, such as firemen shoveling coal, drive wheels slipping on wet tracks, conductors shouting "All Aboard!", passengers eating in the dining car, and (particularly in the case of the Thomas stories) derailments, crashes, and breakdowns of all sorts.

Although the visits to museums have been relatively infrequent, they have provided unique opportunities to attach the well-learned domain-specific knowledge to actual trains. The boy may be able to make some of these connections himself. The parents would probably make many more through explanations, descriptions, and questions intended to help the boy interpret the visit through the lens of their shared prior knowledge about trains. The museum visits may have also opened up aspects of trains that were unavailable from other sources. For example, if the museum has an operating steam locomotive (as many do), the boy may have been surprised to find out that they are much louder, larger, dirtier, and scarier than he might have imagined. Because their previous shared experiences have contributed to a shared knowledge base about trains, family conversations during the museum visit would have been richer and more focused. Similarly, the experience of the visit provides subsequent opportunities to extended and deepen the on-going family conversation about trains as the boy and his parents wait later at a railroad crossing for a freight train to pass, look at snapshots from the museum visit, or read a new book about trains.

By the time the boy turns 3-years old, he has developed an island of expertise around trains. His vocabulary, declarative knowledge, conceptual knowledge, schemas, and personal memories related to trains are numerous, well-organized, and flexible. Perhaps more importantly, the boy and his parents have developed a relatively sophisticated conversational space for trains. Their shared knowledge and experience allow their talk to move to deeper levels than is typically possible in a domain where the boy is a relative novice. For example, as the mother is making tea one afternoon, the boy notices the steam rushing out of the kettle and says: “That’s just like a train!” The mother might laugh and then unpack the similarity to hammer the point home: “Yes it is like a train! When you boil water it turns into steam. That’s why they have boilers in locomotives. They heat up the water, turn it into steam, and then use the steam to push the drive wheels. Remember? We saw that at the museum.”

In contrast, when the family was watching football—a domain the boy does not yet know much about—he asked “Why did they knock that guy down?” The mother’s answer was short, simple, stripped of domain-specific vocabulary, and sketchy with respect to causal mechanisms—“Because that’s what you do when you play football.” Parents have a fairly good sense of what their children know and, often, they gear their answers to an appropriate level. When talking about one of the child’s islands of expertise, parents can draw on their shared knowledge base to construct a more elaborate, accurate, and meaningful explanations. This is a common characteristic of conversation in general: When we share domain-relevant experience with our audience we can use accurate terminology, construct better analogies, and rely on mutually held domain-appropriate schema as a template through which we can scribe new causal connections.

As this chapter is being written, the boy in this story is now well on his way to 4-years old. Although he still likes trains and still knows a lot about them, he is developing other islands of expertise as well. As his interests expand, the boy may engage less and less often in activities and conversations centered around trains and some of his current domain-specific knowledge will atrophy and eventually be lost. But as that occurs, the domain-general knowledge that connected the train domain to broader principles, mechanisms, and schemas will probably remain. For example, when responding to the boy’s comment about the tea kettle, the mother used the train domain as a platform to talk about the more general phenomenon of steam.

Trains were platforms for other concepts as well, in science and in other domains. Conversations about mechanisms of locomotion have served as a platform for a more general understanding of mechanical causality. Conversations about the motivation of characters in the <u>Thomas the Tank Engine</u> stories have served as platforms for learning about interpersonal relationships and, for that matter, about the structure of narratives. Conversations about the time when downtown Pittsburgh was threaded with train tracks and heavy-duty railroad bridges served as a platform for learning about historical time and historical change. These broader themes emerged for the boy for the first time in the context of train conversations with his parents. Even as the boy loses interest in trains and moves on to other things, these broader themes remain and expand outward to connect with other domains he encounters as he moves through his everyday life.

What kind of learning is this? First, it is fundamentally collaborative. Everything the boy knows about trains was learned in social contexts co-constructed with his parents. The book reading has obviously been collaborative: The parents read the text, answer the child's questions, ask questions of their own, and point out interesting parts of the pictures that are not reflected in the text. The museum visits have obviously been collaborative: The family goes together to the museum and talks about trains before, during, and after the visit. Watching train videos and playing with train toys may appear less collaborative on the surface because, although he sometimes engages in these activities with his parents, he often does them more or less by himself. However, even this solitary activity is collaborative in the sense that the videos and toys reflect parent choices about what would be appropriate and interesting for the boy.

Second, although some of the learning may be highly planned and intentional, much of it is probably driven by opportunistic "noticing" on the part of both the parent and the child. Recent efforts to consider parent input into children's categorization decisions, for example, have predominately been directed at developing an account for how parents structure a fixed interpretation for children. As Keil (1998) pointed out, casting parents as simple socializers who provide fixed didactic interpretations for children is unlikely to be the right model. There is nothing more annoying then someone who provides you with pedantic explanations that you do not want or that you could not make use of. In reality, however, everyday parent-child activity hinges on a dual interpretation problem. The parent needs to decide what is worth noting, based on their own knowledge and interests, their understanding of their child's knowledge and interests, and their current goals for the interaction. Children are making the same calculation, simultaneously. Over time, the family interprets and re-interprets activity, bringing out different facets: Sometimes they highlight the science, sometimes the history, sometimes the emotion, sometimes the beauty, and so on. Thus, the family conversation changes to become more complex and nuanced as it traces the learning history of the family and extends through multiple activities.

Finally, and perhaps most importantly, this kind of learning cumulates from many relatively unremarkable moments. As they develop islands of expertise, children may experience a few deep personal insights and powerful moments of discovery. They may receive occasional detailed direct instruction from a parent, teacher, or television show. But most of what they know about a topic they probably learned in smaller moments of practicing, remembering, and exploring. In studies of expertise in adult learners, an often-cited estimate is that it requires about 10,000 hours or about 10 years of practice in a domain before becoming expert (Hayes, 1985). A child's island of expertise around, for example, dinosaurs, is a modest accomplishment compared to what the average paleontologist knows, but the overall point about practice is probably the same: The expertise of both the interested child and adult scientist reflect repeated exposure to domain-specific declarative knowledge, repeated practice in interpreting new content, making inferences to connect new knowledge to existing knowledge, repeated conversations with others who share or want to support the same interest, and so on.

Do Islands of Expertise Exist?

Although we do not know much about how children develop scientific literacy and expertise in everyday settings, we do know something about the consequences of such development. Chi and Koeske (1983) described a 5-year old dinosaur expert who, through repeated reading of dinosaur books with his mother, had developed a well-organized semantic network of dinosaur knowledge that enabled him to categorize and recall novel dinosaurs more accurately when they were related in meaningful ways to his prior knowledge. Similarly, Chi's (1978) earlier work demonstrated that children skilled in chess were better able to recall configurations of chess pieces than a group of college students who were chess novices. Chi's work focused primarily on exploring the role of content knowledge in the development of memory, and findings were interpreted to support the conclusion that the content and organization of children's knowledge played a much larger role in the development of memory than any age-related changes in architectural parameters such as working memory capacity or processing speed.

Despite the fact that Chi's work has now become a familiar staple of textbook chapters on memory development, the field lost interest in what seems to us to be the obvious next set of questions: How did these children become experts? How did they get interested in these domains? What kinds of activities did they engage in? What role did their parents play? Is there anything we could do to facilitate the development of early expertise more generally?

Current approaches to children's development of early theories have often described children as intuitive scientists who instinctively collect evidence and construct theories as they learn about the world (Wellman & Gelman, 1998). A great deal of research has focused on describing the contents and structure of children's theories at different ages. One of the common ways that researchers have assessed children's theories is to present children with a novel instance and to describe the way that children come to identify, understand, and connect that knowledge to their existing theories. Less attention has been paid to the ways that this process occurs in everyday environments and the ways parents might assist children in developing theories.

However, the studies that do exist suggest that spontaneous dialogue between parents and children might provide useful information for building theories, among other things (e.g., Callanan & Oakes, 1992; Crowley, Callanan, Jipson, Galco et al, 2001; Ochs, Taylor, Rudulph, & Smith, 1992). For example, Callanan and Oakes (1992) asked parents to write summaries of parent-child conversations that occurred in response to children's quesitions about "why things happen" and "how things work." They found that preschool children asked meaningful questions to get information about phenomena they were curious about. Parents provided frequent causal explanations in response to children's questions accounting for a large part of the conversational turns between children and parents (32% with 3 year olds, 61% with 4 year olds, 54% with 5 year olds). These parent child conversations took place mostly at home during everyday, mundane activities such as bathtime, meals, reading, or watching television. They also occurred while riding in the car and to a smaller degree in other activities outside the home.

Children's questions encompassed a wide variety of topics including: natural phenomena, biological phenomena, physcial mechanisms, motiviation/behavior, and cultural conventions.

Similarly, Ochs, et al. (1992) recorded dinnertime conversation of families with a 5-year-old child and at least one older sibling. They found family conversation to contain the elements and structure of scholarly discourse—a place to posit and challenge theories about everyday phenomena. Families were engaged in conversation in which family members stated evidence for their theories, challenged interpretations of that evidence, and challenged methods used by actors in everyday activities.

In our work we have been interested in exploring the hypothesis that parent conversation, and parent explanation in particular, contributes to building islands of expertise in informal learning.

Our interest in explanations as a mechanism is based on research that focuses on the facilitative effect of explanations on adult and children's problem-solving and conceptual change. Among adults, the presence of spontaneous self-explanation has been associated with greater transfer across domains that range from learning how to program LISP (Pirolli, 1991), to learning statistics (Lovett, 1992), to developing accurate mental models from undergraduate physics textbooks (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). Similarly, the construction of collaborative explanations has been linked with problem solving success among dyads working on scientific reasoning microworlds (Okada & Simon 1997) and practicing scientists conducting cutting-edge molecular biology research (Dunbar, 1995; 2001). A number of particular mechanisms have been proposed to account for the facilitative effect of explanations, including proposals that the act of constructing and understanding explanation allows problem solvers to identify impasses in their knowledge, generate new hypotheses, construct new inferences or generalizations, or restructure existing knowledge bases (Crowley, Shrager, & Sielger, 1997; Van Lehn, Jones, & Chi, 1992).

The facilitative effect of explanations also holds for children, although they are less likely than adults to spontaneously generate explanations in the course of exploration, categorization, or problem solving. Laboratory studies of children's thinking suggest that when adults offer explanations as they demonstrate new problem-solving strategies, children are better able to transfer strategies to novel problems (Brown & Kane, 1988; Crowley & Siegler, 1999). Similarly, when adults provide causal explanations as children construct family-resemblance categories from novel instances, children are more accurate in categorizing subsequent instances (Krascum & Andrews, 1998). If adults do not provide such explanations or at least explicitly prompt the child to generate their own explanations, it is unlikely that children will decide to do so on their own (Goncu & Rogoff, 1998; Siegler, 1995). In each of these studies, the adults were experimenters following a script; however, the findings are consistent with the notion that parents giving spontaneous explanations may help shape what children learn from everyday activity.

What does parent explanation look like in the context of everyday scientific thinking? Consider, for example, the kinds of parent explanation identified in a recent observational study of families using an interactive science exhibit during visits to a children's museum (Crowley et al., 2001). Families were videotaped during spontaneous, undirected use of a zoetrope—a simple animation device with a series of animation frames inside a cylinder that spins. When children spun the cylinder and looked at the animation through the slots on the side of the cylinder, they saw animation due to the stroboscopic presentation of the individual frames.

In more than one third of parent-child interactions, parents were observed to explain to their children. Examples included talk about causal links within the local context ("The horse looks like it's running backwards because you spun this thing the wrong way"), talk that made a connection between the exhibit and prior knowledge or experience ("This is how cartoons work"), and talk about unobservable principles underlying, for example, the illusion of motion ("Because your mind… your eye… sees each little picture and each one's different from the other one, but your mind puts it all in a big row").

Notice that none of these examples rises to a level that would be considered sufficient to meet formal philosophical or pedagogical definitions of what it means to offer a sufficient explanation of a phenomena or a device. Furthermore, the parent explanations observed were also more simple and incomplete than other forms of situated, informal explanation that have been described in studies of scientific activity in classrooms and professional settings (e.g., Dunbar, 1995; Glynn, Dult, & Thiele, 1995; Lehrer, Schauble, & Petrisino, 2001; Saner & Schunn, 1999).

Although it is undoubtedly true that parents sometimes offer complete and accurate explanations when engaged in everyday family activity, it may be far more common for parent-child conversation to include what might be considered components of a formal explanation: suggestions of how to encode evidence; highlighting individual causal links; offering simple analogies; and perhaps introducing relevant principles and terminology (Callanan & Jipson, 2001; Callanan & Oakes, 1992; Gelman et al., 1998).

To distinguish them from normative definitions of explanation and richer forms of explanation that are sometimes encountered in studies of on-going classroom or workplace discourse, these fragments of explanatory talk have been called explanatoids (Crowley & Galco, 2001). Although brief and incomplete, parent explanatoids are well targeted to a moment of authentic collaborative parent-child activity. We hypothesize that parent explanatoids are powerful because they are offered when relevant evidence is the focus of joint parent-child attention and thus they serve the function of providing children an online structure for parsing, storing, and making inferences about evidence as it is encountered. Although each individual explanatoid might be unlikely to catalyze a fully realized moment of strategy shift, conceptual change, or theory development, the cumulative effect of parent explanatoids over time could be one of the direct mechanisms through which parents and children co-construct scientific thinking in everyday settings.

In a second study of everyday scientific thinking in museums, several hundred families with children from 1 to 8 years-old were videotaped while using 18 interactive science exhibits representing a broad range of scientific and technical content, including biology, physics, geology, psychology, engineering, robotics, and computers (Crowley, Callanan, Tenenbaum, & Allen, 2001). Replicating the findings of the Crowley, Callanan, Jipson, et al. (2001) study, parents were observed to use explanatoids in about one third of interactions. However, this broader study also revealed a gender difference: Parents were about three times more likely to offer explanations when using exhibits with boys than when using exhibits with girls. This finding suggested that, if parent explanation has any effect on children's learning, boys and girls may be learning different things from at least some kinds of everyday scientific thinking and thus may be developing different knowledge or attitudes about science before they encounter science instruction in elementary school. This possibility in part motivated the rationale for the current study's focus on how parent explanation changes what children learn from everyday scientific thinking, although gender differences are not a focus of the current study.

Examining A Moment of Learning: Family Conversations About Fossils

We now present a study of parent-child conversation while families examined dinosaur fossils together in the Pittsburgh Children's Museum. The study was designed with two goals. First, we wanted to describe family learning conversations while parents and children examined objects that belong to a common domain of early interest and expertise—dinosaurs. Second, we wanted to test whether different patterns of parent-child conversation were associated with different outcomes in terms of what children could remember about the objects they had just seen. As with the other chapters in this section of the volume, this study examines a learning moment in great detail. But we do not do so because we think anything fundamental will be learned about dinosaurs in the few minutes we happen to get on tape. We do so from the theoretical perspective of such common moments being the raw materials through which grander developments such as islands of expertise are built.

Parents and children were asked to interact with both authentic and replicated fossils as they might normally do during a museum visit. Two researchers set up a table with two sets of dinosaur fossils—a set of five authentic fossils and a set of four fossil replicas. The authentic fossils were an eggshell fragment from the Saltasaurus dinosaur, a toe bone, a rib bone fragment, a piece of coprolite (fossilized feces), and a gastrolith (stones thought to aid digestion). The replicas included the hind claw of a Velociraptor, a footprint of an unknown dinosaur, an Oviraptor egg, and a 7-inch tooth from Giganotosaurus. Along side of each object, researchers put an index card containing information on the identity and age of the fossil and the location where it was discovered.

Twenty-eight families with children from 4 to 12 years old were recruited into the study when they approached the table during a visit to the Pittsburgh Children's Museum. The researchers explained the study to the families and, if the parents and children were interested in participating, obtained informed written consent from the parents. Families then examined both sets of fossils (order of the sets was counterbalanced), taking as much time as the liked. After they had finished with both sets, parents filled out a questionnaire while the experimenter asked children to identify each of the fossils. Sessions lasted approximately 15 minutes for each family and were videotaped.

What One Family Said

We begin with an example interaction to illustrate the kinds of conversational support that parents provided. The following interaction took place between a 4-year-old boy and his mother. On the parent questionnaire the mother rated her son's interest in dinosaurs as 7 on a 7-point scale and rated his current knowledge as 3. She rated her own interest as 6 and knowledge as 4. The mother reported that the family had visited the local natural history museum more than 5 times in the last year and had also visited the local children's museum, the science center, and the zoo 2 to 5 times each. She reported that the family engaged several times a week in watching science-oriented TV, reading books about science, and using computer programs or websites focused on science. Clearly, they were well-practiced in informal science settings.

As the session begins, the pair are sitting at the table; the boy on the left and the mother on the right. In front of them are the replicas; randomly laid out from right are the egg, footprint, tooth, claw, and coprolite. The boy (B) reaches across his mother (M) to pick up the Oviraptor egg at the far end of the table:

B: This looks like this is a egg. [He turns it over a few times in his hands.]

M: Ok well this… [M picks up the card and glances at the label. She is using a "teachy" tone that suggests that the boys is probably wrong and she is going to correct him and inform him what the object actually is.][1]

M: That's exactly what it is! [She appears surprised, speaking quickly in a more natural and rising tone of voice while turning to the child and patting him on the arm] How did you know?

B: Because it looks like it. [He is smiling and appears pleased.]

M: That's what it says, see look *egg, egg…* [pointing to the word "egg" on the card each time she says it and annunciating the way parents do when they are teaching children to read] …Replica of a dinosaur *egg*. From the oviraptor.

M: [Turns gaze away from the card towards her child, putting her hand on his shoulder and dipping her head so their faces are closer.] Do you have a . . . You have an oviraptor on your game! You know the egg game on your computer? [M makes several gestures similar to the hunt-and-peck typing that a child might do on a computer keyboard.] That's what it is, an oviraptor.

M: [Turns back to the card and points to text on the card. She again starts speaking in her "teacher" voice.] And that's from the Cretaceous period. [pause] And that was a really, really long time ago.

[1] [1]For the purposes of this chapter, we have added our interpretive comments into the transcript that were not part of the original transcripts used for coding in the larger study.

M: And this is . . . all the way from Mongolia which is way, way, way far away. [Her intonation drops on "away" and she puts the card back to its place on the table, signaling that they are done examining the egg.]

M: [Turning away from the table and looks her other, younger child who has been playing nearby.] Noah, come back! [She begins getting up to chase the sibling while B puts the egg back in its place on the table.]

M: [Pats the footprint, which is next to the egg, while she stands] And this one, see if you can tell . . . [She pats the footprint again] Look at that one, and tell me what you think. [She runs off camera after the sibling.]

B: [Picks up the footprint, turns himself half-way away from the table, and starts examining it with a puzzled expression.]

The first thing to notice about the interaction is how the family oscillates between more formal to less formal learning talk. The boy established the agenda by choosing the egg as the first object to examine. It was the fossil farthest away from him, and he had to lean over past his mother to pick it up. He may have been interested in looking at it first because he already thought he knew that it was an egg. His mother's response suggested that she thought he was probably wrong and she began reading to correct him. When she discovered that the boy had been correct, she changes immediately from her "teacher" voice into a more excited and proud-sounding parent voice, implicitly praising the boy and asking how he knew what the object was.

Three more times in this segment, and throughout the subsequent interaction, the mother goes back and forth between these formal and informal voices. She often marked the transition to formal by turning her face and body toward the table and gesturing toward the fossils and information cards. She marked the transition to informal by turning toward the child, touching him, and hunching over a bit so that their eyes are on a more equal plane. As she asked the boy about his computer game at home, her gestured tapping of an imaginary keyboard occurred away from the table and in the space between her and the boy—offering a physical reinforcement of the connection she was trying to establish between this moment and their prior family learning history.

Another thing to notice is that the mother makes choices about what she highlights for the child. Here is the text that appeared on the information card that accompanied the fossil:

- Replica of a Dinosaur Egg
- From the Oviraptor
- Cretaceous Preriod
- Approximately 65 to 135 million years ago
- The actual fossil, of which this is a replica, was found in the Gobi desert of Mongolia

The mother voiced the words "oviraptor," "egg," and "cretaceous," but paused when she came to "65 to 135 million years ago" and substituted the text "long, long time ago."

Similarly, she mentioned "Mongolia," but not "Gobi desert." We are in no position to interpret why she decided to mention some but not all of the card information, however it does serve as a reminder of how parent participation mediates the child's experience—in this case the mother is acting as an online filter for the information available from the exhibit.

Finally, and most importantly with respect to the idea of islands of expertise, the mother makes an explicit connection between the exhibit and the boy's prior learning experience with his computer game which is apparently about different dinosaurs and their eggs.

When the mother returns from chasing the younger sibling, the boy looks up at her:

B: Know what this is? Looks like a footprint.

M: That's exactly what that is! This is a footprint from a dinosaur—we don't know what kind of dinosaur—from the early Jurassic period. Just like, what dinosaur is from Jurassic period? From your game? Was it the T. Rex? (pause) I think so. Remember I told you there's a movie called Jurassic Park and that's from 200 million years ago. And it comes from. a dinosaur . . . that can be found where we live in North America. There used to be dinosaurs here. I know! And in Europe and in Africa. Okay? And that's the footprint. Okay?

Once again, the mother mixes references to their prior learning conversations—in this case a reference to the movie Jurassic Park. This reference is actually something of a stretch with the only connection being that the footprint came from a Jurassic-era dinosaur, with the mother spinning that association back again into one of the child's games. The mother also filters the card information into the statement that dinosaurs used to live where "we live in North America" and then extends that into a list that includes Europe and Africa. And so it goes through several more replica fossils:

M: And this is . . . the hind claw. What's a hind claw? (pause) A claw from the back leg from a velociraptor. And you know what . . .

B: Hey! Hey! A velociraptor!! I had that one my [inaudible] dinosaur.

M: I know, I know and that was the little one. And remember they have those, remember in your book, it said something about the claws . . .

B No, I know, they, they…

M: Your dinosaur book, what they use them…

B: have so great claws so they can eat and kill…

M: they use their claws to cut open their prey, right.

B: Yeah.

M: So that's what that is. And that's from the Cretaceous period. That's a really hard word.

B: Cretaceous period.

M: Good. And that's 80 million (emphasis) years ago which is a really very long time and . . . The real one—this is a copy—but the real one comes from this country which means this dinosaur was in our country.

B: I'm not even afraid of dinosaurs.

M: You shouldn't be because there aren't any.

M: This was . . . we talked about. Aha—this is funny. The dinosaur's name was giganotosaurus . . . Do you think he was really big? Giganotosaurus.

After finishing the replicas, the mother and boy turn to the set of authentic fossils. This time the mother takes the lead, picking up the rib bone fragment:

M: This is a real dinosaur rib bone. Where are your ribs? Where are your ribs? No that's your wrist. Very close.

B: Oh, yeah, right here.

M: Yeah, that's right. Here. Protecting your heart . . . and your lungs. And this was one from a dinosaur from the Jurassic period, also found from our country. In a place called Utah.

M: And this one . . . [M picks up the coprolite] Oh! Your not . . . guess what that is. Look at it and guess what that is.

B: Um, what?

M: Guess. What's it look like?

B: His gum? What? Mom!

M: It's dinosaur poop.

B: Ooooo (laughs)

M: That's real dinosaur poop.

B: I touched it! (laughs)

M: It's so old that it doesn't smell anymore. It turned to rock. It's not mushy like poop. It's like a rock. And that's from the Cretaceous period but we don't know what dinosaur made it. And this was also found in our country in Colorado. I think that's pretty funny.

B: What's this?

M: So this one . . . Oh, that's called . . . that's a stone that dinosaurs. . .remember in your animal book it says something about how sometimes chickens eat stones to help them digest—it helps them mush up their food in their tummy?

B: Yeah.

M: Well, dinosaurs ate stones to mush up their food in their tummy and this was one of the stones that they ate. They're so big, that to them this was a little stone. Right? And that also comes from Colorado.

By now the Boy and his Mother have established a rhythm—he points to a fossil, she tells him what it is, he comments on it, she establishes a link between some aspect of the fossil and the boy's experience, and she provides some information about the geologic time period and where the fossil comes from. The connections for these three fossils have been to the boys own anatomy, to joking references to the smell and texture of feces (the coprolite never failed to delight children and their parents in this way because, except for the fact that it was fossilized, it looked just like what it was), and to a book the boy has that apparently describes chickens and gastrolithes. They finish up with the toe and egg shell fragment:

B: How about this?

M: This one, that's his toe.

B: Toe? (in disbelief)

M: Also from the United States. Utah. And that was one of his toes. Imagine there were probably . . . you know . . . 3 of them, maybe.

B: That looks like it not [inaudible]and that was like this. (pause) And that was up like this (makes silly noises)

M: That's from the Jurassic period.

B: Oh! (yelling and silly) another Jurassic period.

M: They're all from Jurassic and Cretaceous, right?

M: Oh, here's another one we missed. Oh. This is . . . a piece of an egg of a dinosaur from a Saltosaurus dinosaur. I wonder why he was called Saltosaurus. Maybe he was salty.

B: (laughs)

M: This was part of the egg.

B: Well maybe when, where he lived . . . [inaudible]

M: Maybe, maybe. And this is also from South America.

The conversation about the last two fossils is the first place where the mother and boy reveal uncertainty about the fossils. They wonder about the toes ("there were probably . . . you know . . . three of them, maybe) and they pose half-serious hypotheses about why one dinosaur was named Saltosaurus. As they finish this set of fossils, the interviewer moves in to administer the posttest to the boy while the mother fills out the parent questionnaire.

What Parents Said and Children Learned

We now present a quantitative descriptions of what parents in general talked about and what children remembered from the experience. To describe what parents talked about, family conversations while examining the fossils were transcribed from videotape and coded with a line-by-line scheme intended to identify the function of utterances. As shown in Table 10.1, we coded eight different categories of mediation. The first two codes (object label and other ID card information) were for talk where parents provided children details available from the index cards that accompanied each fossil. The next two codes, observable properties and value and authenticity, were for descriptions of the objects' perceptual properties or value. The final group of codes were for four different types of explanations that we encountered in this data set. All coding was conducted by a single rater. Reliabilty, assessed by a second independent rater who re-coded 20% of the transcripts, ranged from 87% to 99% agreement for each category in the coding scheme.

As shown in 10.1, the most frequent kind of mediating parent talk was labeling the objects, followed by parents mentioning other information from the identification card that accompanied each fossil. (Families saw a total of nine objects, so the average of 18.2 instances of parents labeling objects works out to parents labeling each object an average of two times.) Explanations were quite common, with an average of almost one explanation per object. Among the four kinds of explanation, inferences about function were the most common, followed by inferences about scale and connection to experience and anatomy. Finally, parents described physical properties for about half of the objects and made a few comments about value and authenticity.

What effect did these different kinds of parent mediation have on children's learning? Recall that, at the end of the session, children were asked by the experimenter to identify each of the nine fossils. To determine whether success in identifying fossils was associated with different levels of each kind of mediation, we conducted a four ANOVAs on children's recall scores with level of mediation (high vs. low) and child's age group (older [7 to 12 yrs. old] vs. younger [4 to 6 yrs. old]) as between subject factors. The four ANOVAs explored the effect of talk related to the identification cards (labeling and other card information combined); the effect of explanatory talk; the effect of talk about fossil properties; and the effect of talk about value and authenticity. For each analysis children were grouped into high or low mediation categories through a median split on the number of coded instances of each kind of parent mediation. Table 10.2 shows the mean number of fossils children could correctly identify, broken down by age of child and whether parents provided high or low levels of mediation. The table also shows the F and p values for the two main effects and the interaction in each test.

TABLE 10.1: Coding Categories and Mean Frequencies for Parent Fossil Talk

Coding Category	Definition	Mean Number of Utterances Coded
Object label	Parent identifies the object, either with a technical term (e.g., "This is coprolite.") or with an everyday equivalent (e.g., "This is fossilized dino poop.")	18.2
Other Identification card information	Parent reads information other than the label of the fossil from the fossil's data sheet concerning where the fossil was found, how old the fossils is thought to be, etc.	7.8
Observable properties	Parent talks about physical properties of the object (e.g., "See these little bumps?"; "It's heavy, isn't it?"; "See this long, pointy thing?").	5.5
Value and authenticity	Parent talks about whether the object is real or replicated or talks about how rare, special, or valuable the object is.	2.4
Explanation Compare anatomy	Parent compares the fossil to an analog in human anatomy, most often the child's own (e.g., "See, dinosaurs had ribs just like you do.")	1.5
Connect experience	Parent connects the experience to a previous family experience or to shared prior knowledge (e.g., "Remember when we saw one of these in your book?" or "We went there last year for vacation!", after the parent had read to the child that a fossil was dug up in Colorado.)	1.5
Infer scale	Parent makes an inference about the size of dinosaurs based on the size of the object (e.g., "This dinosaur was probably only as big as a dog.")	2.3
Infer function	Parent makes an inference about the function of the object, based on its properties (e.g., "This was probably used to kill its prey.")	3.1
Total Explanation		8.4
Total Mediation		42.3

The first thing to notice about Table 10.2 are the significant main effects for age on identification scores in each of the four ANOVAs. Thus, unlike younger children, older children found the task of correctly identifying the nine fossils fairly easy regardless of whether their parents provided higher levels of mediation. The one exception to this was for whether parents provided explanations, where older children who heard more explanatory talk had perfect identification scores vs. the 85% for children who heard less.

The second thing to notice is that younger children generally could identify only half of the objects if their parents provided lower levels of mediation while with higher levels they could identify objects at rates comparable to the older children. This difference is picked up by the interactions for age and mediation level for card information and fossil properties and the main effect of mediation for explanation. Although the difference was in the same direction for value and authenticity, the effect was not significant.

TABLE 10.2

Percent Correct Fossil Identification by High or Low Parent Mediation and Age Group

	Younger (4- to 6-yrs. old)		Older (7- to 12-years old)		F (1,24)	F (1,24)	F (1,24)
	Low mediation	High mediation	Low mediation	High mediation	Parent mediation	Age group	interaction
Identification card information	49	86	94	89	3.57	8.16**	6.04*
Explanations	51	84	85	100	8.57**	9.10**	1.29
Observable propoerties	57	90	93	91	3.39	4.47*	4.60*
Value and authenticity	58	85	91	93	2.62	5.22*	1.78

* $p < .05$, ** $p < .01$.

The findings so far support the idea that higher levels of mediating talk by parents was associated with children learning to identify more fossils, particularly for the younger children who jumped from about half correct to more than 84% correct when parents provided more mediation. However, as one can see by reading through the example of the mother and son we presented earlier, different kinds of mediation often occur within the same conversation. We might expect, for example, that a parent who talks often about information from the card might also be a parent who explains often. If that were the case, which kind of mediation might be most directly associated with greater identification scores?

To answer this question we used a step-wise regression, allowing us to identify the variables that accounted for the largest amount of variance in the identification scores. Because the older children's scores were close to ceiling, and thus had little variance, we ran the analysis only on the younger group.

The step-wise regression included 10 variables as potential predictors of children's fossil identification scores. Among the potential predictors were the numbers of coded instances of each of the eight types of mediation that appeared in Table 10.1.

We also included two additional variables as potential predictors. Under the logic that parents might offer more elaborate forms of mediation if dinosaurs were already a developing islands of expertise for the family, we also included parents ratings of their children's knowledge about and interest in dinosaurs, and parents' ratings of their own knowledge about and interest in dinosaurs. Both of these measures were computed from items on the questionnaire that parents completed while their children participated in the post-test with the experimenter. The first-order correlations among all variables in the regression are presented in Table 10.3.

TABLE 10.3

Correlations Between Variables in the Regression Analysis for Families with 4- to 6-year olds

	Fossil Identification Score	Object Label	Other Identification Card information	Observable properties	Compare anatomy	Connect experience	Infer scale	Infer function	Value and authenticity	Child Knowledge/ Interest	Parent Knowledge/ Interest
Fossil Identification Score	1.00										
Object Label	.56*	1.00									
Other Identification Card informatio	.44*	.10	1.00								
Observable properties	.54*	.67**	-.05	1.00							
Compare anatomy	.38	.50*	.53*	.20	1.00						
Connect experience	.50*	.09	.66**	.16	.42*	1.00					
Infer scale	.22	.05	.54*	-.10	.21	.50*	1.00				
Infer function	.35	.69**	.08	.43*	.69**	.38	-.00	1.00			
Value and authenticity	.36	.19	.48*	.39	.43*	.41*	-.06	.17	1.00		
Child knowledge/interest	-.01	.03	.29	-.30	.33	.18	.29	.27	-.26	1.00	
Parent knowledge/interest	.14	.28	.10	.04	.46*	.18	.34	.56**	-.37	.58**	1.00

• $p < .05$, ** $p < .01$.

The step-wise regression revealed that object label and connections to prior knowledge were the only significant predictors of the younger children's identification scores. Object label entered in the first step of the regression, accounting for 31% of the variance. This makes sense since children would have been more likely to be able to identify fossils correctly if their parents had labeled them correctly in the first place. What was more interesting was that the next and last variable to enter was the extent to which parents made connections to prior knowledge, brining the final R^2 up to .51 Thus, even after accounting for effect of whether parents had provided children with labels for the fossils, the extent to which parents offered explanations that linked back to prior experience with dinosaurs was associated with higher levels of fossil identification during the post-test. After the effects of labeling and connections to prior knowledge had been accounted for, no other variables accounted for significant variance. The final regression equation was: Correct fossil identification = 2.97 + .56 Identify fossil + .45 Connections to prior knowledge, $F(2,14) = 7.35$, $p < .01$.

Conclusion

Does the mediation parents provide to children in the course of spontaneous conversation make a difference in children's learning? Our findings suggest that it might, particularly when the task is difficult for children. Among the 4- to 6-year olds in our study, higher levels of parent mediation while examining dinosaur fossils were associated with children identifying more of the fossils on the post-test. The regression suggests that the most important forms of mediation were offering labels and providing explanations that connect back to shared family learning history. Although the older children's responses were close to ceiling and there were no significant effects for most categories of mediation, the one effect significant effect we did observe was consistent with the idea that explanations are associated with greater learning during family museum activity. However, it is important to note that, as with many studies that examine correlations between spontaneous behavior in naturalistic settings, the current findings are consistent with a causal link between parent mediation and children's learning, but they do not, in and of themselves, conclusively support one.

Take a moment to consider the patterns illustrated by the quantitative analyses in relation to the example interaction of the mother and the boy. Among the most frequent kind of parent mediation we coded in the larger study were labeling the fossils and talking about other information from the index cards that accompanied the fossils. As the example of the mother and boy illustrated, these kinds of mediation were important parts of the rhythm the family established as they worked their way through the sets of objects. The mother often used questions about identity of the object as a signal that the pair was moving on to the next object. After the child guessed or the mother told what the object was, she often moved next to provide a few supporting details from the index card while the child continued to handle the object. While she provides such information, the boy can be observed on the videotape turning the objects slowly, sometimes moving them up and down to feel their heft, and, in the case of the velociraptor claw, slashing at imaginary beasts.

Many times we observed that parents stopped with this kind of information and moved on to the next object. However, the boy and his mother often went the next step to engaging in explanatory talk, including talk that connected objects to previous learning experiences—books, movies, and computer games that they had already played. We do not have any good objective measure of exactly how much this pair knew about dinosaurs, but both the content of their interaction and the mother's self-report on the questionnaire suggest that they were already well into building an island of expertise around the topic. Their interaction and the quantitative analyses are consistent with our original claim that much of a child's early domain-specific expertise may be forged from relatively mundane moments where parents and children label, link, and learn through collaborative activity and conversation.

The current study also suggests something about the unique role of museums in building islands of expertise. Although the child and parent may have spent many hours reading about dinosaurs in a book, it is only in the museum that they can attach this knowledge to the authentic objects. Thus, conversations in museums are infrequent events compared to other learning opportunities. We propose that the learning conversation in the museum, precisely because it is rare and thus fairly memorable, may become a particularly powerful example on which further learning can be built. Not in the sense that the child or parent would recall the experience more or less exactly and operate on it to extract new information, but that the general gloss of the situation could be recalled and connected in much the way that the mother did in the story about trains that opened this chapter. It would be much harder to identify an experience that was more common, because there have been many that may need to be distinguished. In other words, the location of the museum "marks" the conversation. Conversations that occur in unmarked spaces, such as around the dinner table, may often be harder to index and recall in joint ways in conversations. A bit of talk that struck someone as particularly meaningful may not strike the other participants that way. When an opportunity to extend children's interest presents itself, and a parent tries to locate an example to build a connective link, it strikes us as somewhat hard to do so by saying, "Remember that one time at dinner when we talked about the T-Rex?" compared to saying "Remember that time at the museum when we talked about the T-Rex?"

Young children are sometimes described as intuitive scientific thinkers with an instinct for seeking out evidence, noticing patterns, drawing conclusions, and building theories. Yet, although children may engage naturally in collecting and organizing evidence in everyday settings, they do so in ways that are not necessarily consistent with formal definitions of good scientific thinking (Kuhn, 1989). As Klahr (2000) pointed out, there is something of developmental paradox here: Despite the fact young children are not systematic, exhaustive, or focused when collecting evidence, they nonetheless appear to do a good job building theories about everyday domains. In this chapter we have advanced the hypothesis that, through joint activity, guided by a combination of children's and parents' interests, families can build deep, shared domain-specific knowledge bases, which we refer to as islands of expertise. As families move across contexts, between the backyard and the museum, between car rides and book reading, between the dinner table and the computer, they trace these interests, looking for opportunities to collect and connect new experiences. These islands can become platforms on which to build advanced conversations about disciplines such as science. In this chapter we have provided an example of how one family in particular, and other families more generally talk about dinosaur fossils in the context of a museum visit. Future research should pursue how these conversations are connected across context and the specifics of whether these well-marked domains support advanced reasoning.

References

Brown, A. L. & Kane, M. J. (1988). Preschool children can learn to transfer: Learning to learn and learning from example. Cognitive Psychology, 20, 493-523.

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

Callanan, M. A., & Oakes, L. M (1992). Preschoolers' questions and parents' explanations: Causal thinking in everyday activity. Cognitive Development, 7, 213-233.

Chi, M. T. H. (1978). Knowledge structures and memory development. In R. S. Siegler (Ed.), Children's thinking: What develops? Hillsdale, NJ: Erlbaum.

Chi, M. T. H., Bassok, M., Lewis, M. L., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. Cognitive Science, 13, 145-182.

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

Crowley, K. & Galco, J. (2001). Everyday activity and the development of scientific thinking. In K. Crowley, C. D. Schunn, & T. Okada (Eds.), Designing for science: Implications from everyday, classroom, and professional science. Mahwah, NJ: Erlbaum.

Crowley, K., Callanan, M.A., Jipson, J., Galco, J., Topping, K., & Shrager, J. (2001). Shared scientific thinking in everyday parent-child activity. Science Education, 85 (6), 712-732.

Crowley, K., Callanan, M.A., Tenenbaum, H.R., & Allen, E. (2001). Parents explain more often to boys than to girls during shared scientific thinking. Psychological Science, 12 (3), 258-261.

Crowley, K., Shrager, J., & Siegler, R.S. (1997). Strategy discovery as a competitive negotiation between metacognitive and associative knowledge. Developmental Review, 17, 462-489.

Crowley, K. & Siegler, R.S. (1999). Explanation and generalization in young children's strategy learning. Child Development, 70, 304-316.

Dunbar, K. (1995). How scientists really reason: Scientific reasoning in real-world laboratories. In R. J. Sternberg & J. E. Davidson (Eds.), The nature of insight. Cambridge: MIT Press.

Dunbar, K. (2001). What scientific thinking reveals about the nature of cognition. In K. Crowley, C. D. Schunn, & T. Okada (Eds.), Designing for science: Implications from everyday, classroom, and professional science. Mahwah, NJ: Erlbaum.

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

Glynn, S. M., Dult, R., & Thiele, R. B. (1995). Teaching science with analogies: A strategy for constructing knowledge. In S.M. Glynn & R. Dult (Eds.), Learning science in the schools: Research reforming practice, (pp.247-273). Mahwah, NJ: Erlbaum.

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

Hayes, J. R. (1985). Three problems in teaching general skills. In S. Chipman, J. W. Segal, & R. Glaser (Eds.), *Thinking and learning skills, Vol. 2* (pp. 391-406). Hillsdale, NJ: Lawrence Erlbaum Associates.

Keil, F. C. (1998). Words, moms, and things: Language as a road map to reality. Monographs of the Society for Research in Child Development, 63(1), 149-157.

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

Krascum, R. M., & Andrews, S. (1998). The effects of theories on children's acquisition of family-resemblance categories. Child Development, 69 (2), 333-346.

Lehrer, R., Schauble, L., & Petrisino, T. A. (2001). Reconsider the role of experiment in science education. In K. Crowley, C. D. Schunn, & T. Okada (Eds.), Designing for science: Implications from everyday, classroom, and professional settings. Mahwah, NJ: Lawrence Erlbaum Associates.

Lovett, M. C. (1992). Learning by problem solving versus by examples: The benefits of generating and receiving information. Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society. (pp. 956-961). Hillsdale, NJ: Lawrence Erlbaum Associates.

Ni, Y. Cognitive structure, content knowledge, and classificatory reasoning. Journal of Genetic Psychology, 159, 280-296.

Ochs, E., Taylor, C., Rudolph, D., & Smith, R. (1992). Storytelling as a theory-building activity. Discourse Processes, 15, 37-72.

Okada, T. & Simon, H.A. (1997). Collaborative discovery in a scientific domain. Cognitive Science, 21, (2), 109-146.

Pirolli, P. (1991). Effects of examples and their explanations in a lesson on recursion: A production system analysis. Cognition and Instruction, 8(3), 207-259.

Saner, L., & Schunn, C. D. (1999). Analogies out of the blue: When history seems to retell itself. In the Proceedings of the 21st Annual Conference of the Cognitive Science Society. Mahwah, NJ: Erlbaum.

Siegler, R. S. (1995). How does cognitive change occur: A microgenetic study of number conservation. Cognitive Psychology, 25, 225-273.

VanLehn, K., Jones, R.M., Chi, M. T. H. (1992). A model of the self-explanation effect. Journal of the Learning Sciences, 2, 1-59.

Wellman, H.M. & Gelman, S.A. (1998). Knowledge acquisition in foundational domains. In: D. Kuhn & R.S. Siegler (Eds.), Handbook of Child Psychology: Cognition, Perception, & Language. New York: Wiley.