From Seeing to Observing: How Parents and Children Learn to See Science in a Botanical Garden

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ABSTRACT

How do children begin to make the transition from *seeing* the natural world to *scientifically observing* the natural world? This study explored how differences in parent conversational strategies and disciplinary knowledge impact children's experience observing biological phenomena during shared informal learning. 79 parent-child pairs with children ages 6-10 participated in a controlled study in which half of the parents used their natural conversational style and the other half were trained to use four conversational strategies during family observations of pollination in a botanical garden. Parents were also assigned to high and low knowledge groups according to their knowledge of pollination biology. Findings suggest that parents who received training used the conversational strategies more than parents who used their natural conversational style. Parents and children who knew more about pollination at the start of the study exhibited higher levels of disciplinary talk in the garden. However, the use of the conversational strategies also increased the amount of disciplinary talk in the garden. The extent to which families engaged in disciplinary talk in the garden predicted significant variance in what children learned from the experience. An extended example illustrates how shared family noticing and conversation may support learning to observe nature.

INTRODUCTION

A fundamental goal of science is to find meaningful patterns wherever one looks in the natural world (Simon, 2001). This ability to organize phenomena into scientifically meaningful patterns is crucial to scientific activity (Daston, 2008; Norris, 1984) and is one characteristic that distinguishes expert observers from everyday observers (Ericsson, 1996; Patel, Kaufman, & Magder, 1996). In expert practice, systematic observation is the lens through which data are collected (Haila, 1992), hypotheses generated and refuted (Gould, 1986; Mayr, 1997; Moore, 1993), and is often the stimulus for discovery (Klahr & Simon, 1999). It would be difficult to imagine generating new scientific knowledge without skilled observation.

Despite the central role of observation, little attention has been given to the question of how people learn to be skilled observers in science. As many have noted, educators and researchers often underestimate systematic observation (Metz, 2000; Norris, 1985; Smith & Reiser, 2005; Tomkins & Tunnicliffe, 2001; Trumbull, Bonney, & Grudens-Schuck, 2005) and treat observation as an effortless, everyday practice that requires little more than noticing and describing surface features (Ault, 1998; Chinn & Malhotra, 2001; Metz, 1995). Consequently, novice observers use observation primarily in the service of collecting data (Eberbach & Crowley, 2009) and look at phenomena without also developing new knowledge (Ford, 2005).

Far more than simply seeing phenomena, systematic observation is a way of reasoning that engages both particular knowledge and particular habits of attention throughout the inquiry process (Ault, 1998; Finley & Pocovi, 2000; Mayr, 1982; Norris, 1984). For example, consider the formative development of the Cornell Ornithology Lab's Classroom FeederWatch program in which students observed living birds at feeders in order to learn about bird biology (Trumbull et al., 2005). Although the concept seemed simple, problems with identifying and counting birds soon emerged. For instance, students were not able to identify bird species in flight, nor were they able to discriminate between individual birds, making it difficult to create accurate population counts. As expert observers, ornithologists know what features to notice when identifying kinds of birds and to look for field marks to identify birds in flight. Without knowledge of the underlying theoretical concepts and of the complicated observational practices of ornithologists, students were unable to recognize scientifically meaningful patterns or to develop new knowledge about the biology of birds. What happened? Like so many, the program designers had assumed that it is easy to observe birds and underestimated the extensive knowledge, experience, and habits of perception that enable expert scientists to efficiently recognize meaningful forms and patterns (Daston, 2008; Goodwin, 1994). The expectation that untrained children should also observe scientifically meaningful patterns is a tall order.

So while it is true that children's everyday observations may help them to understand the natural world (Rogoff, 2003) and may share similarities with scientific observation (Carey, 1985; Gopnik, Meltzoff, & Kuhl, 1999; Vosniadou & Brewer, 1994), children still need support to become scientific observers (Krajcik et al., 1998). Learning to observe scientifically requires negotiating between disciplinary knowledge, theory, and practice (Ford, 2005; Lehrer & Schauble, 2004; Metz, 2000, 2004; Norris, 1985).

In a recent review (Eberbach & Crowley, 2009), we argued that although there is a considerable literature about the challenges of observing scientifically, very little is actually known about how scientific observation develops over time. We developed a conceptual framework that documents the roles of noticing, expectations, observation records, and productive dispositions on observation and proposes learning trajectories for children making the transition from everyday to scientific observation. This framework also identified the kinds of knowledge, tools, and experiences that could support such a learning trajectory. We concluded that designing transitional pathways is essential, whether these occur in formal or informal learning environments.

This current study explored two factors that may help children transition from *seeing* the natural world to *observing* the natural world. In particular, we explored the potential roles played by differences in parent knowledge about pollination biology and differences in parent conversational strategies. We asked whether these factors can help children to become more scientific in their observations of biological phenomena during a family visit to a botanical garden.

Parents and children in this study jointly observed episodes of pollination, which is a biological process that is critical to understanding biodiversity. Fundamentally, pollination involves moving pollen from stamen to stigma. At more complex levels, pollination reveals ecological and historical relationships between plants, animals, and environments (Estes, Amos, & Sullivan, 1983). Pollination provides fertile ground from which families can notice and elaborate upon the entities and activities of biological processes—from simply identifying floral parts and pollinators, to making conjectures about form and function, to talking about the fruit in the morning cereal. Given its availability in everyday and school environments, the topic of pollination can serve as a platform from which families can make observations that support deeper understanding about biological structures, behaviors, and functions.

Families as Learning Systems

Families provide one context in which children can come to observe and understand natural phenomena. During the course of everyday activities, such as preparing meals, reading together, or driving in the car, parent-child conversations provide a social context for making sense of what children see and experience. Many of these conversations occur when parents mediate a child's everyday noticing. For instance, parents often respond to children's spontaneous questions about natural phenomena—why is the sky blue—with explanations that help to establish causal connections (Callanan & Oakes, 1992). Likewise, parents may draw a child's attention to objects by naming, describing, and categorizing their features (Braswell & Callanan, 2003; Callanan, 1990). Some argue that such parent-child conversations and routines can establish a foundation for scientific thinking and practice (Ash, 2004a; Callanan & Oakes, 1992; Crowley & Jacobs, 2002) and can provide a common source of experience to draw upon during future scientific activity (Callanan & Jipson, 2001).

More often than not, this parent-child activity is collaborative in nature, meaning that the more experienced or knowledgeable member guides the learner's involvement (Rogoff, 1990; Wood, Bruner, & Ross, 1976), often by participating and learning themselves (Rogoff, Paradise, Mejia Arauz, Correa-Chavez, & Angelill, 2003). We see evidence of these patterns in museums where families typically operate as a "flexible learning system" (Hilke, 1989), in which all members spontaneously use strategies for acquiring and exchanging information, often revealing a preference for intergenerational information sharing (Diamond, 1986; Dierking & Falk, 1994). As fluid as these interactions may be, however, parents still manifest more "show and tell" behaviors than children, prompting Diamond (1986) to conclude that parents often assume the role of teacher. In this capacity, parents support the family's learning agenda by using both nonverbal behaviors such as pointing to objects of interest, and modeling attentive gestures, and verbal behaviors such as positive evaluations and reading signage aloud (Kim & Crowley, 2010). For a comprehensive review of families as learning systems in museums, see Haden (2010).

As in other everyday contexts, parents and children create meaning though conversation so that talk is both a process and an outcome of learning (Leinhardt & Crowley, 2002; Leinhardt & Knutson, 2004). This talk could be considered the primary outcome of family learning in museums (e.g., Crowley et al., 2001; Jipson & Callanan, 2003). Talk is a mechanism for scaffolding learning and denoting evidence of knowledge sharing and generation (Wickman & Östman, 2002). Of particular interest here, parents use talk as a general strategy for facilitating what children notice. For example, asking questions is a principal means for drawing a child's attention to critical scientific features and processes, as well as for eliciting what a child already understands (Ash, 2004b; Dierking, 1987). Other commonly used verbal strategies include highlighting and describing evidence that is important to notice at science exhibits (Crowley et al., 2001; Stevens & Hall, 1997; Szechter & Carey, 2009), making connections between an ongoing activity and a child's prior experience (Ash, 2004a; Crowley & Jacobs, 2002; Hilke, 1989), and reading interpretive text aloud (Diamond, 1986).

What roles do parents play in helping children move from everyday observational practices to scientific observational practices? Emerging evidence suggests that parents take on some aspects of scientific talk during shared activities in informal learning settings (e.g., Allen, 2002; Eberbach & Crowley, 2005; Zimmerman, Reeve, & Bell, 2010). On the other hand, evidence also shows that parents miss opportunities to scaffold children's observational practices in ways that support deeper engagement and learning. Even under optimal conditions, such as wandering around a dinosaur exhibition with an engaged and knowledgeable child, parents may disengage from their role as learning partner (Palmquist & Crowley, 2007). The literature offers many hypotheses about why parents might choose to disengage. Some parents may believe that science is simply a matter of looking and seeing (Driver, Leach, Millar, & Scott, 1996). Others may believe that interpreting evidence is unnecessary because they assume the child's understanding is similar to their own, particularly during shared scientific activity (Gleason & Schauble, 2000), or even because they assume the child knows more about a particular topic (such as dinosaurs) than they do (Palmquist & Crowley, 2007). Parents may consider a child to be too young or too inexperienced to reason about complex information and problems (Schauble et al., 2002), or may judge the designed museum environment to do the explanatory work, particularly when children use interactive exhibits (Melber, 2007). Alternatively, parents may want to engage in observation and learning, but the environment presents obstacles to collaborative engagement or does not provide sufficient support for the content knowledge that could enrich family conversations (Knutson & Crowley, 2014).

Supporting Parents' Role as Mediators of Children's Observations

How might parents be encouraged to further support children's observational practices in ways that extend opportunities for engagement and learning? A first step in answering this question might be found in joint attention studies from the memory development literature. Investigators have been interested in the role of parent-child talk during shared activity and how this talk impacts what children notice, encode, and recall (e.g., Fivush, Haden, & Reese, 2006; McGuigan & Salmon, 2004; Ornstein, Haden, & Hedrick, 2004).

In a two-part study, for example, pairs of mothers and preschool children either looked at dioramas at a natural history museum or walked together through an unfamiliar neighborhood (Tessler & Nelson, 1994). When asked to recall these events, children only mentioned events and objects that *both* the mother and child had observed and talked about together. No child recalled events or objects that were talked about by the mother only or the child only. Furthermore, children whose mothers connected the ongoing event with prior experience remembered more than children whose mothers made no such connections. The authors concluded that parent talk essentially trains a child's habits of attention and scaffolds how and what to notice, represent, and remember.

Following up on these findings, Boland, Haden, & Ornstein (2003) presented pairs of mothers and preschool children with activities (e.g., loading a backpack for camping) that used an array of relevant toy objects (e.g., hot dogs, fishing pole). They hypothesized that a parent's strategies for talking as an event unfolds draw the child's attention to the salient features of a shared event in such a way as to enhance the child's encoding and memory of the event. To test this hypothesis, some mothers were asked to use their natural conversational strategies during the event and others were trained to use an elaborated conversational strategy, which consisted of asking open-ended questions, linking current activity to prior experience, focusing talk on the child's interests, and praising the child's contributions. Results indicated that training was successful, however the effect of the elaborative strategy on children's memory was mixed. Training yielded only a marginal difference in the overall number of event features that children recalled. However, children whose mothers used an elaborative strategy described significantly more details and provided more information about the event features than children whose mothers simply used their natural conversational strategies. Taken together, these two studies offer evidence that parent talk strategies shape children's everyday habits of attention.

In this study, we ask how differences in parent conversational strategies and parent disciplinary knowledge may support a child's observation of pollination during shared family activity in an informal learning environment. We also ask the question of how different patterns of family observation are or are not related to differences in what children learn from informal activity. Our study connects learning sciences research on informal environments with the memory literature on joint attention. In informal learning environments, parents sometimes highlight evidence, engage in scientific talk, and build shared knowledge with their children, but sustaining joint attention and talking about observations can be challenging. Parents may need additional support to scaffold their children's transition from everyday to scientific observation, particularly when a parent's prior knowledge may not support deep engagement with the demands of scientific disciplines or when parents simply do not use conversational strategies that support a child's scientific reasoning.

METHODS

Study Context and Setting

The study occurred in a 9,000 square foot section of the outdoor Discovery Garden of Phipps Conservatory and Botanical Garden (Pittsburgh, PA) during summer when environmental conditions were conducive for pollination to occur. Designed to actively engage children with hands-on discovery of plant environments, the Discovery Garden features a variety of themed areas (e.g. Bog Garden, Butterfly Garden) connected by a winding pathway along which visitors can brush up against plants with an array of floral structures and patterns. The specific plants selected for the garden are particularly attractive to pollinators, making the garden a good location for a study of families observing pollination.

Participants

Seventy-nine parent-child pairs participated in this study, including 68 mothers and 11 fathers, of whom 90% were Caucasian, 6% Asian, and 4% African American. A brief background survey revealed that 92% of parents held a college degree. Most parents (71%) visited museums with their family at least four times each year.

Our sample also included 49 girls and 30 boys aged 6-10 years old (*M* = 8 years, 3 months, *SD* = 1 year, 3 months). These ages were targeted because the Discovery Garden was designed for children up to ten years old and a pilot study revealed that children aged six to ten could more readily engage in the observational activities and science talk for the duration of the observation study, whereas children five and younger could not do so consistently as a group.

Parents and children were recruited while visiting the Discovery Garden and a city park summer camp program where families interested in nature activities might gather. During recruitment 105 families agreed to participate in the study, of which 92 completed all recruitment activities (i.e., receiving verbal information about the study, discussing questions raised by potential participants, and obtaining parental written consent). Of those, 11 families chose not to begin the study and two additional families completed the study but were later eliminated due to equipment failure. Families received free museum passes for their participation.

Parent Knowledge Assessment

During recruitment, all parents completed a knowledge survey that was used to assess disciplinary knowledge of pollination biology and to assign parents to high and low knowledge conditions. Researchers read the survey questions aloud and recorded parents' responses. In the first part of the survey, parents were asked to observe a single 8.5"x11" digital image of a bee pollinating a flower, to explain what appeared to be happening in the image, and to identify features that were important to their explanation. Then parents responded true, false, or unsure to seven statements related to pollination biology. Finally, parents were asked to describe and explain observable form and function relationships that appeared in three sets of floral images. The range of questions covers core components of scientific observation, including habits of attention, disciplinary knowledge, and theory. The survey items were refined through several pilot studies with adult visitors to a botanical garden, and reflected the kinds of images, facts, and explanations that are common in adult interpretive programs in this setting.

Two researchers coded all of the surveys, assigning one point for each correct response. Interrater reliability was 95% and differences were resolved through discussion. Parent scores on the survey ranged from 5-28 points (*M* = 13.54, *SD* = 5.18). Parents were assigned to high knowledge (n = 40) and low knowledge (n = 39) conditions based upon a median split of these scores. Once assigned to a knowledge condition, parents were then randomly assigned to either the treatment condition (n = 39) or to the control condition (n = 40). This design resulted in four study groups: High Knowledge-Treatment (n = 20); High Knowledge-Control (n = 20); Low Knowledge-Treatment (n = 19); and Low Knowledge-Control (n = 20).

Parent Treatment Conditions

One clear, but somewhat surprising, finding from Boland et al (2003) was that a relatively simple parent training on conversational strategies could directly impact family conversations, at least for the duration of the study. The duration and intensity of our parent training closely followed that of Boland, et al (2003). Parents in the treatment condition received training in the four elaborative conversational strategies: asking *Wh*-questions, focusing talk on the child's interests, linking present to past experiences, and providing positive feedback. (These are defined in the following section.) Approximately one week prior to the observation study parents received an eight-page illustrated pamphlet that described the four conversational strategies and included examples of parents using these with their children. Parents were instructed to read the pamphlet twice prior to the scheduled study date and to reflect on how they might incorporate these strategies into everyday conversations with their child.

Immediately prior to the start of the observation study, parents in the treatment condition watched a 12-minute DVD that featured parents applying each of the conversational strategies with their children during a visit to a natural history museum. A researcher interviewed parents to ensure that each parent had read the pamphlet, understood each conversational strategy, and discussed any questions a parent might ask about the strategies. The training materials were modified from the Boland, et al (2003) study in several ways: (1) to focus on children's observation and understanding of biological phenomena; (2) to feature authentic objects and disciplinary content within a natural history context; and (3) to include mothers and fathers as well as school-age children. In order to compare parents' naturalistic style with that of the elaborative conversational strategies of the treatment condition, parents in the control condition received no training and were instructed to talk with their child using their natural ways of talking with their child.

Observation Study

Each parent-child pair participated in an observation study, during which time they observed living plants and pollinators. In order to increase the opportunities for noticing pollination, participants were asked to visit four adjacent garden areas. To allow for the vagaries of pollinator activity and to be consistent with how people learn in informal environments (Bell, Lewenstein, Shouse, & Feder, 2009), families could visit these areas in any sequence, could engage deeply or casually according to their interests, and could return to any area as desired so long as they visited each area. After completing this sequence, participants visited a fifth area, which featured a large-scale flower model (a median section of a typical angiosperm flower, 18 inches long by 14 inches wide by 21 inches high) and one butterfly puppet and one bee puppet.

At the start of the observation study, the researcher described the study's protocol, identified the garden areas, suggested that participants take about 10 minutes according to their interests, and responded to questions asked by either participant. The researcher also reminded the parent to talk with their child according to prior instruction. Finally, in order to frame their activity in the garden, both parents and children were instructed, "You can learn a lot about bugs and plants by looking for and talking about pollination together."

Each observation study was videotaped and each participant wore a dual-channel, wireless microphone. Video data focused on parent-child interactions and on the features of objects that they appeared to observe. Each observation study lasted for an average of 14 minutes, 40 seconds (*SD* = 3.56) and ranged from about 6 minutes to 25 minutes.

Child Materials and Activities

Prior to and after the observation study, one researcher interviewed each child at a table in the garden, independent of the parent. All children completed all five tasks that provided multiple opportunities to explore what they noticed and understood about pollination.

The first two tasks used photo sorts in order to elicit what children noticed about plants and pollinators. In task one, children sorted eight 4" x 6" photographs, half of which depicted scenes related to pollination (i.e., a butterfly with its proboscis inserted into a flower, a bee on the center of a flower, a bee with pollen on its body flying near a flower, and a bee perched on the stamen of a flower) and half of which did not (i.e., bees on a peach, a butterfly resting on a leaf, a bee on a closed flower bud, and a bee on a leaf but with a flower nearby). Children organized the photographs into a pollination pile and a non-pollination pile and were assigned one point for each correct choice.

In task two, children compared two 4" x 6" photographs that appeared to be the same image of a bee flying near the pistil of a flower. However, one image included the flower with its stamen intact, whereas the other image had been modified to remove the stamen's anthers. Children were asked whether a bee could pollinate these flowers and were assigned one point for each correct response.

To determine whether children could distinguish observation from inference, task three involved asking children to observe a living flower and to respond to five yes/no questions that began with, "Can you tell just by looking at this flower if it (fill in blank—such as "has pollen"). Some aspects were observable (presence of pollen, specific floral color) and some inferable (presence of nectar, making its own food, and the flower's origin). Children were assigned one point for each correct response.

In task four, children observed the same living flower and were asked to indicate how a bee would look for something to eat in this flower. Children's responses were scored one point for each reference to specific features and form/function relationships.

To investigate children's understanding of pollination as a biological process, the final task involved children using the flower model and pollinator puppets to explain something about bees visiting flowers. Children received one point for each relevant feature, function, and relationship that they identified.

All children wore a wireless microphone and were videotaped during the interview. Video data focused on children's activities and on the features of objects that children gestured towards or appeared to be looking at during each task. On average, the pre and post interviews lasted a total of 12 minutes, 38 seconds and ranged from approximately 7 minutes to 18 minutes.

CODING

In this section, we describe the coding developed for the Elaborative Conversational Strategies and Disciplinary Talk. For each coding plan data were transcribed and verified from videotapes of parent-child interactions during the observation study. Individual coders conducted reliability using both transcripts and videotapes. One researcher coded all of the data. To assess reliability, a second researcher coded a random 20% of the data. Interrater agreement was at or above 87% for all coding categories and all differences were resolved through discussion.

Parent Elaborative Conversational Strategies

The four elaborative conversational strategies (ECS) were coded from family talk that occurred during the observation study. In this coding scheme, *asking Wh-questions* includes questions that emphasize what, when, where, why, who, or how and that draw the child's attention to specific aspects of objects and events, solicit information, or help the child to make sense of the objects and events that they notice:

> "So what's it doing?"
> "How do you know it's a moth?"
> "Where's the yellow stuff?"
> "Why do you like this one more than that one?"

Focusing the conversation on the child's interests includes talk in which parents guide or extend conversations towards pollination-related objects and activities in which the child has expressed interest, particularly phenomena the child is already noticing, touching, or mentioning. In this example, the parent responds to the child's interest in a bee:

> C: Look at that! (*Points to a bee*)
> P: It looks like it has a lot of pollen.
> C: That's a—
> P: I think it's a baby bee. It's a teeny tiny bee.
> C: That's a bee all right.

P: These plants have a lot of pollen and it's easier for bees to get it.
C: Why?
P: Well see how big and open that is? It's all fluffy with pollen?
C: Yeah?
P: And then look at these. These are harder to get to.

Linking present to prior knowledge and experiences are those in which parents make connections between what occurs during the observation study and what a child already knows or has already experienced about pollination and related phenomena. Linking may refer to experiences that occur prior to the observation study or to experiences that occur earlier in the observation study:

"Didn't you learn that in school?"
"That's like the plant in Grandma's garden."
"Have you seen the bee do this before?"
"The proboscis is like a straw."
"That's like the one I showed you over there."

Finally, talk is coded as *providing positive feedback* when parents explicitly acknowledge the child's content and observational contributions. For example, parents might assess the accuracy of their child's observations:

"That's right."
"That's happening just like you said."

However, parents might also acknowledge the child's participation, as evident here:

"That's a really cool thing to notice."
"You seem to be getting used to being around the bees."

The ECS coding scheme followed these general assumptions: (1) the unit of analysis is a parent's conversational turn; (2) a conversational turn may include more than one conversational strategy; (3) individual instances of an elaborative conversational strategy are counted each time they are uniquely used in a conversational turn; and (4) an individual statement may be coded for multiple strategies. For instance, the question "What about the moth we just saw?" would be coded both as a *Wh*-question and as an example of linking present and past activity.

Disciplinary Talk

Family observations in the garden will be accompanied by talk. Consistent with Warren, Ogonowski, & Pothier (2005), a central claim here is that this family talk can be identified as existing on a continuum from everyday, non-disciplinary talk to disciplinary science talk. How would one distinguish talk that was disciplinary from talk that was non-disciplinary in a botanical garden? Certainly disciplinary talk would be talk that refers to the specific entities that comprise insect-driven pollination, such as plants and pollinators. But environment is also an entity when considered as the temporal, spatial, and ecological conditions in which the process of pollination occurs. Thus, we counted talk that referred to time (e.g., seasons, temperature, duration and repetitiveness of pollinator behavior), orientation (e.g., floral position before and after pollination, alignment of pollinator to flower), and specific entity relations (e.g., floral structures and properties that attract pollinators, pollinator structures that enable access to floral rewards, foraging and landing behaviors of pollinators in relation to floral structures).

However, entities are not necessarily the whole story. Machamer, Darden, and Craver (2000) argue that full understanding of scientific mechanisms associated with scientific processes requires distinguishing between the ways entities interact within three states that they call Set-Up Conditions, Intermediate Activities, and Termination Conditions. Following from this, we coded all references to entities with respect to one of these states, all which are temporally bound.

For pollination to occur, entities must have particular structural features and/or properties that can support particular activities. Thus, Set-Up Conditions emphasize talk in which families either identify or locate the entities:

> "That's a bee"
> "Is that a monarch?"
> "I think the pollen is the yellow stuff."
> "The nectar's in there."
> "Wow! There's a big chunk of pollen on his back leg."

Set-Up talk also includes observations that elaborate upon specific properties of entities:

> "This flower sure has a lot of pollen."
> "That butterfly has a long tongue!"
> "Look he's got little hairs on his leg."

Finally, Set-Up talk included references to ecological and entity relations necessary for pollination to occur:

> "The butterflies can only fly when it's warm enough."
> "Doesn't the flower have to be open?"
> "They come to get the nectar."
> "So butterflies have really long tongues to get the nectar out of those flowers."

Intermediate Activities focus on the connections between entities, properties, and activities as pollen is moved from one flower to another flower. Here disciplinary talk focuses on *how* pollen is transferred, specifically the activities and behaviors of pollinators:

> "He's sipping the nectar!"
> "See how that bee is crawling inside that flower and getting pollen on his legs."

> "See he gets the pollen on his tummy."
> "And he takes it from here and then puts it on another flower."

Intermediate Activities also focus on concurrent relationships between plant, pollinator, and environment entities, such as repetitiveness, orientation, and form and function relationships:

> "Look at how fast that bee is getting pollen. It doesn't stop."
> "Look how he [*sic* bee] is sticking his head right in there!"
> "See? Butterflies land on these flat flowers with their long legs and get the nectar with their long tongues."

Once pollen is transferred, the floral entities may be altered and the later stages of floral and pollinator life cycles are possible. Disciplinary talk in the Termination Condition explicitly connects these changes to post-pollination differences:

> "Looks like the bees have already been here. The pollen looks all dried up."
> "It looks like these have already been pollinated."
> "This one is already made into seeds."
> "The bees don't seem to come to the ones that are all dried up."
> "And then they go back to the hive and make honey."

The coding scheme for disciplinary talk applied these general guidelines: (1) Coding reflects family pollination-related talk that occurred during the entire observation study; (2) Each state can be distinctly identified and segregated; and (3) Once counted in a particular state, an entity, feature, property, and/or activity is not counted again.

RESULTS

We first present quantitative findings around the experimental design. These findings are then followed by an in-depth extended example in which we unpack one family's experience in the garden and highlight how their talk and observations activated the transition from seeing to observing.

Parent Use of Conversational Strategies

Did the training protocol modify parent use of the strategies in the treatment groups? We constructed an overall ECS measure by summing each of the four constituent strategies (Figure 1). A two-way Analysis of Variance on parent use of ECS yielded a significant main effect for treatment, F (1, 75) = 47.56, $p < .001$, d = 1.53, and for parent knowledge, F (1, 75) = 4.08, $p < .05$, d = .38. Looking at Figure 1, we see that both treatment groups (M = 58, SD = 23) generated more ECS strategies than the two control groups (M = 29, SD = 15). Likewise, high knowledge groups (M = 49, SD = 23) typically generated more ECS strategies than parents in groups with less pollination knowledge (M = 38, SD = 24).

Insert Figure 1 about here

To further understand the results of parent training, elaborative strategies were examined with the expectation that parents in the treatment groups would use each strategy more than parents in the control groups. For strategies that made demands upon parent knowledge—asking *Wh*-questions, focusing talk on children's interests, and linking to prior experiences—we anticipated that parents with higher levels of pollination knowledge would use these strategies more frequently.

A two-way ANOVA for *Wh*-questions resulted in a significant main effect for treatment, F (1, 75) = 40.64, $p < .001$, $d = 1.43$. As expected, parents in the treatment groups used *Wh*-questions more frequently than those in the control groups. However, we were surprised to find no significant effect for parent knowledge, F (1, 75) = 2.28, $p > .05$.

The next two strategies—child focus talk and linking to children's prior experiences—show similar patterns of expected and unexpected results. A two-way ANOVA for child focus talk resulted in a significant main effect for treatment, F (1, 75) = 10.61, $p < .01$, $d = .64$, as expected. However, there was no effect for parent knowledge, F (1, 75) = 2.93, $p > .05$. Similarly, a two-way ANOVA for use of the linking strategy also revealed a significant effect for training, F (1, 75) = 18.55, $p < .001$, $d = .71$, but not for parent knowledge F (1, 75) = .53, $p > .05$.

The finding that there were no significant differences between high and low knowledge parents' use of these two strategies was unexpected, particularly as coding for each strategy necessitated that parent activity elaborate upon or make connections to pollination-related content. Why then did parent knowledge not significantly affect implementation? As it turns out, each strategy could be executed with relatively simple or complex understanding of pollination. Consider the following exchanges in which parents elaborated upon phenomena in which the child has expressed interest. In the first exchange, a 10-year-old girl directs her father's attention to flowers and together they observe the surface features of the petals:

> C: Look over here. (*Looks at flowers using magnifying lens*)
> P: Ok. What's different about these petals of these flowers? (*Looks at flowers using magnifying lens*)
> C: They're teeny.
> P: Pardon?
> C: They're teeny. They're tinier and they don't have the little stems coming out like that.
> P: Yeah they're like ah- They're like a different shape aren't they?
> C: Umm hmm.
> P: Yeah. The first ones were more of a what shape?
> C: A flower shape?
> P: More like a big ball.
> C: Yeah.

Here a mother and her 8-year-old daughter focus on how a bee's structure supports the transfer of pollen:

C: Yeah, oh look- that- oh it has a tongue and it has a little sucky thing. (*Looks at bee*)
P: Oh you see that on the bee?
C: Yeah I saw it. And yeah.
P: You saw it going onto that?
C: It like lands on the pollen things and the pollen gets on their feets. See?
P: Yeah. See he's sucking. Where is he sucking? Is he sucking down there where the pollen is?
C: Yeah. [pause 10 seconds]
P: His feet are kind of down where the pollen is but he's kind of sucking the nectar out of the very, very (unintelligible).
C: Yeah, uh-huh. So that's how it gets the pollen on his feet.

These examples illustrate that parents may elaborate upon surface features such as size and shape as well as structural and behavioral relationships during child focus talk. Likewise, when linking to a child's prior experience, parents could do so in ways that did or did not demand complex knowledge of pollination. For instance, parents might refer to the child's prior experiences learning about pollination in school or they might compare the surface features of plants in the botanical garden with plants grown at home. Seen in this light, neither strategy *necessarily* demands that parents tap into more complex levels of pollination knowledge for successful implementation.

The last strategy to be reported is positive feedback. A two-way ANOVA for positive feedback found one significant effect, *F* (1, 75) = 11.12, *p* < .01, *d* = .75, revealing that parents in the treatment groups generated more positive feedback (*M* = 5, *SD* = 3.34) than parents in the control groups (*M* = 3, *SD* = 3.09). This is generally consistent with use of the elaborative strategies, as they emphasize feedback that acknowledges the child's interest and participation.

Taken together, these findings suggest that a relatively simple training protocol can be used to modify how parents interact with their children during shared activity in an informal learning environment. Training successfully resulted in parents in the treatment groups using the four conversational strategies more frequently than parents in the control groups, regardless of how much parents knew about pollination.

At the same time that training increases the attentive behaviors of parents, manipulating the content of their observations appears to be more challenging. This was made evident in their use of *Wh*-questions. We were surprised that parent knowledge appeared to play no significant role in the use of this strategy, particularly as research has shown that parent use of *Wh*-questions bears strong connections to content during parent-child talk (Ornstein et al., 2004). Closer inspection revealed that *Wh*-questions—unlike the other strategies—could support operational purposes (e.g., "Where should we go next?") as well as content purposes (e.g., "How's that bee getting that yellow stuff on him?"). Viewed in this light, it was not surprising that a two-way ANOVA for *non-content Wh*-questions found only a significant main effect for treatment, *F* (1, 75) = 15.06, *p* < .001, *d* = .86. In contrast, parent use of the *Wh-content* questions resulted in significant main effects for treatment, *F* (1, 75) = 34.81, *p* < .001, *d* = 1.3, as well as for parent knowledge, *F* (1, 75) = 5.28, *p* < .05, *d* = .45. Thus, parents in the treatment groups (*M* = 27, *SD* = 13) typically generated more *Wh*-content questions than parents in the control groups (*M* = 13, *SD* = 8). Likewise, parents with higher pollination knowledge (*M* = 22, *SD* = 12) generated more *Wh*-content questions than parents with less pollination knowledge (*M* = 17, *SD* = 12).

Disciplinary Talk

We now turn to an analysis of what we have termed disciplinary talk in the garden, which includes set-up, intermediate activities, and termination states (Machamer et al., 2000). We first analyzed all family talk about pollination as shown in Figure 2. A two-way ANOVA for disciplinary talk resulted in a significant main effect for parent knowledge, *F* (1, 75) = 24.40, *p* < .001, *d* = 1.13, but no effect for parent treatment, *F* (1, 75) = 1.25, *p* > .05. Overall, families that included parents with higher pollination knowledge talked about observing significantly more pollination states (*M* = 27, *SD* = 8.35) than families that included parents with less pollination knowledge (*M* = 19, *SD* = 6.64).

Insert Figure 2 about here

We then examined each pollination state separately and found similar patterns. First, a two-way ANOVA for Set-Up Conditions talk revealed a significant main effect only for parent knowledge, *F* (1, 75) = 16.21, *p* < .001, *d* = .92. Families with parents in the high knowledge groups generated more talk of entity features and properties (*M* = 16, *SD* = 4.50) than families with parents in the low knowledge groups (*M* = 12, *SD* = 3.58). Second, there was a significant main effect for parent knowledge in the Intermediate Activities, *F* (1, 75) = 26.89, *p* < .001, *d* = 1.18. Families in which parents had higher knowledge of pollination generated more talk related to pollen transfer (*M* = 9, *SD* = 3.23) than families with less knowledge of pollination (*M* = 6, *SD* = 2.87). Finally, there was a significant main effect for parent knowledge in the Termination Conditions, *F* (1, 75) = 9.54, *p* < .01, *d* = .70. Parents in the high knowledge group generated more talk of post-pollination conditions (*M* = 2, *SD* = 1.95) than parents in the low knowledge group (*M* = 1, *SD* = 1.19).

Children’s Learning

Children completed a knowledge assessment prior to and immediately following the observation study. Their responses were scored for evidence of what children noticed and understood about the entities and activities that comprise pollination. We begin this analysis by asking whether differences in children’s knowledge were associated with differences in parent knowledge. A two-way ANOVA for children’s pre interview summary scores found a significant main effect for parent knowledge, *F* (1, 74) = 13.08, *p* < .01, *d* = .78. Because children with parents in the high knowledge group scored higher (*M* = 17, *SD* = 4.52) on average than children with parents in the low knowledge group (*M* = 14, *SD* = 3.02), a series of two-way ANCOVA analyses for post interview scores were used, in which pre interview scores functioned as the covariate to adjust for these differences.

We then asked whether children’s knowledge scores changed in response to any of the study’s conditions and activities. Overall, the post interview scores were not significantly different between conditions. (See Table 1 for unadjusted pre and post interview means.) A two-way ANCOVA for summary scores yielded no significant effects for treatment, $F(1, 73) = .76$, $p > .05$, nor for parent knowledge, $F(1, 73) = .09$, $p > .05$.

Insert Table 1 about here

A Model of Talk and Learning

We have shown that training and parent knowledge changed family talk. However, at the level of the two-by-two design of our study, we have failed thus far to show any significant impact of that talk on children's learning. Our hypothesis is that training and parent knowledge can lead to more disciplinary talk and that more disciplinary talk would be associated with greater learning. But a direct test of this model is difficult with the ANOVA's because they test only for the impact of the conditions and do not directly detect the impact of disciplinary talk itself on learning. To make the most direct test of our hypothesis, we conducted a series of multiple stepwise regressions to construct the model in Figure 3. This model assumes that children's knowledge at the conclusion of the garden experience is influenced by their own prior knowledge and by disciplinary talk in the garden, which is a function of child knowledge, parent knowledge, and parent use of ECS. Finally, parent training influences the use of ECS. For descriptive purposes, the correlation matrix is included in Table 2.

Insert Figure 3 About here

Insert Table 2 About here

Three equations were generated to develop the model of parent-child observation. First, a step-wise multiple regression analysis was conducted to determine the variables that are significant predictors for total use of the elaborative conversational strategies (ECS). Independent variables used in the equation were parent knowledge, parent training, and child pre-knowledge. Results revealed that only parent training accounted for significant variance, use of ECS = 29.23 + .60 Parent Training, $R^2 = .35$.

A second regression analysis was conducted with disciplinary talk as the dependent variable and parent knowledge, parent training, parent use of ECS, and child pre-knowledge as the independent variables. Parent knowledge entered first and accounted for 25% of the variance. Use of ECS entered next and accounted for an additional 13% of the variance. Child knowledge entered last and accounted for an additional 5% of the variance, Disciplinary Talk = 1.86 + .33 Parent Knowledge + .37 Use of ECS + .24 Child Knowledge, $R^2 = .43$.

The final regression was conducted with the total child post observation knowledge as the dependent variable and parent knowledge, parent training, use of ECS, child pre-knowledge, and disciplinary talk as the independent variables. In this case, child knowledge entered first, accounting for 45% of the variance. Disciplinary talk entered next and accounted for an additional 3% of the variance, Child Post Observation Knowledge = 6.53 + .58 Child Knowledge + .20 Disciplinary Talk, $R^2 = .48$.

Thus, what children learn from the observation study appears to be a function, at least in part, of how much family disciplinary talk is generated. The finding that disciplinary talk is a function of how much parents know about pollination is not surprising, but interestingly, it is also a function of how much parents use ECS. Hence, parent training did result in differences in children's learning but only through the mediating influence of disciplinary talk in the garden.

Unpacking One Family's Interaction in the Garden

To better understand how parent conversational strategies and disciplinary knowledge interact while families observe in the garden, we focus on an exemplary example involving a mother and her nine-year-old son. The mother is knowledgeable about pollination and also received training in the elaborative conversational strategies. She rated her knowledge of pollination as high and identified college, professional interest, and media as knowledge sources. She reported that the ECS were easy to implement.

Otis (a pseudonym) described himself as liking sports and bugs. During the interview he reported learning about pollination "long ago in kindergarten" and described pollination as "getting pollen so the bees can make honey." In this way, Otis was typical of many children in our study: school was cited as an early but incomplete source of knowledge and the topics of bees and honey dominated his conceptualization of pollination.

Interactions between mother and son included a lot of humor. Either one could initiate topics and extend or curtail observations. Both appeared engaged with the observation activity (talking, asking questions, returning to previously visited garden areas) and together they also pursued opportunistic connections to Otis' interests (e.g., inspecting a rain meter, hunting caterpillars). Their observation study lasted 23 minutes, about 10 minutes longer than average. Before presenting the example, we remind readers that coding was conducted with video and transcripts, meaning that the assignment of codes was not done by the spoken word alone, but by the temporal and physical context of the words.

Like many parents, the mother begins the observation study by asking her son where he wants to start. He leads her to a tall structure that supports an exuberant passionflower vine with large exotic flowers, each of which can host many bees simultaneously. Otis reads an identification label and looks toward the top of the vine while the mother looks intently at a flower. She asks a question that initiates the first pollination observation and redirects Otis' attention to bees interacting with a flower.

		ECS	Disciplinary Talk
Mother	Hey look at that Otis. Do you see what those bees are doing in there?	Wh-question	Intermediate
Otis	Yeah. They're going down deep and sucking I think the nectar out of it.		Intermediate
Mother	Sucking the nectar out of it?		Intermediate
Otis	Either that or the pollen. I got confused.		Set-Up
Mother	Yeah?		
Otis	I think the nectar is on top.		Set-Up

Mother	You think the nectar is on top?		Set Up
Otis	Yeah. Don't. They might get hot and sting you.		

Here and throughout the observation study, the mother used questions as a primary strategy for inviting participation, clarification, and focusing attention. This strategy included adopting a pattern of reframing Otis's comments as questions. These questions typically evoked elaborative responses from Otis and, as evident in the following interaction, encouraged close noticing of phenomena:

Mother	Oh here. Why don't you use your lens and see? Tell me what you see.	Wh-question	
Otis	They're clambering around. (*Looks with magnifying lens*)		Intermediate
Mother	They're clambering around?		Intermediate
Otis	There are little tiny yellow dots on it. (*Looks at flower with magnifying lens*)		Set-Up
Mother	Where do you see the yellow dots?	Wh-question	Set Up
Otis	On the - those. (*Points to flower*)		Set Up
Mother	On that part of the flower right there? (*Points to flower*)		Set Up
Otis	Yeah.		
Mother	Why do you think that's pollen?	Wh-question	Set Up
Otis	Um, cause I think I remember now –um, no, no no - that's nectar (*laughs*). The nectar is on the top and then the pollen is on the bottom.		Set-Up
Mother	What do you remember that from honey? You said you think you remember.	Wh-question, Linking	

In this last comment, the mother uses the linking strategy. In response, Otis recalls seeing some diagram and haltingly describes nectar as “sort of like water” before concluding, “It's a liquid and then the pollen is the – is sort of a solid.” The mother then asks simple yes/no questions that both narrow his choices and positively reinforce Otis' assertions about pollen:

Mother	So, can we talk about this just one more time? The yellow dots that you noticed? I mean do those look like a solid? (*Looks through magnifying glass*)		Set Up
Otis	Yes.		
Mother	So do you think that might be the pollen?		Set Up
Otis	Yes. (*Looks at flower*)		

Mother	I think you're right. I think that top part is the pollen.	Positive Feedback	Set Up

In this three-minute episode, several things occurred that seem critical to understanding how families begin to observe more scientifically in informal contexts. First, Otis' confusion about the properties of pollen and nectar emerged as a shared problem space and created a focus that filtered their observations of bees and flowers in the garden. This problem guided the mother's attention, the questions she asked, and finding new opportunities to notice and reinforce what distinguishes pollen from nectar.

Second, the mother's knowledge provided a critical lens for recognizing the significance of Otis' uncertainty about pollen and nectar. Failing to understand such differences makes it challenging to infer form and function relations and less knowledgeable parents often overlooked their child's confusion about pollen and nectar. Here Otis' mother rapidly shifted her questions from noticing bee behaviors in relation to the flowers (*Do you see what those bees are doing in there?)* to noticing the properties of pollen and nectar that make pollination possible (*You think the nectar is on top*?). This shift may have been an attempt to address an immediate problem by verifying the top/bottom and solid/liquid rules that Otis articulated. What seems important to notice here, however, is that the rules are tenuous and rely upon memorization rather than meaningful understanding of their functions in pollination. In practice, the mother's observations were substantially different from those of Otis: She observed floral structures and bee behaviors in relation to one another whereas he saw floral structures and properties in isolation.

Finally, the mother's use of ECS invited Otis to actively notice phenomena and to share his prior knowledge of floral structure. The mother could simply have identified pollen and nectar; instead, her questions and positive reinforcement drew attention to the specific properties of pollen in ways that helped Otis to encode pollen and bring to mind what he already understood about pollination.

Continuing to another garden area, the mother leads Otis to flowers that she wants to look at. Otis appears engaged—he spontaneously uses his magnifying lens to look closely at the flowers—but he is also easily distracted:

Mother	So why does this plant make flowers?	Wh-question	Termination
Otis	Well I think the bee helps it. Cause – hmmm. I don't know - but I think um - oh what are those?		Set-Up

He points to a bee whizzing by. This prompts his mother to shift focus to the bee, which leads to a brief shared effort to identify bees by size ("that's huge!") and temperament ("those look like the mean ones"). Like other parents who use the focus strategy, his mother seizes the opportunity to elaborate on phenomena that the child notices by directing attention to some aspect of the target phenomenon. Once their observation of the bees has run its course, the mother draws Otis' attention back to the different colors of the flowers she wants to look at. But Otis, who seems willing to make simple comparisons ("this one grows into that one"), seems less interested in exploring abstract ideas about the function of flowers, a point his mother is pressing.

A turning point in their negotiation of attention occurs when Otis notices a caterpillar ("Whoa! Look at that caterpillar!") and together they peer through a magnifying glass. They initially observe its feet before noticing something on the leaf that Otis identifies as pollen but then declares rather excitedly, "No, no, they're little bugs." His mother seems skeptical when Otis explains that the caterpillar eats the bugs. This prompts a joint search for the caterpillar's mouth, which when located, confirms that the caterpillar is, in fact, eating bugs. As they head to another garden area, the mother expresses her surprise ("I thought monarchs only ate milkweed") and Otis proclaims, "Wow. I really liked the caterpillar." They decide to return for another look before leaving the garden.

From this point forward, the mother actively takes on management of attention by applying the focus talk strategy to connect Otis' interest in bugs with her own interests in plants. She frames their observations through the lens of pollinators rather than plants (which she has done prior to observing the caterpillar). Her management can be subtle, such as asking questions and directing Otis to notice relations between bees and flowers:

Mother	Oh there's a bee. Should we take a look at - Oh look at that. Are you still looking at pollen?	Focus Talk	Set Up
Otis	No I'm trying to burn it.		
Mother	Don't do that! (*laughs*) Look at what the bee's doing.	Focus Talk	Intermediate
Otis	They're sucking the - pollen out of it.		Intermediate
Mother	Sucking the pollen? Wow, look at its proboscis. Do you see how long the proboscis is? It sticks it in each one of those little flowers.	Focus Talk	Intermediate / Set-Up Intermediate
Otis	It takes no time at all.		Intermediate
Mother	I think it's going after the nectar. That must be on the very inside - the nectar part.	Focus Talk	Intermediate / Set-Up

Here the mother not only redirected Otis' focus to the bee's interaction with the flower, she also highlighted the bee's proboscis (a mouthpart that enables bees to suck nectar) to make a gentle correction about the real target of the bee's activity (nectar). In another example, Otis initiates an observation:

Otis	Oh look I found another one.		Set-Up
Mother	Another what?	Wh-question, Focus Talk	Set Up
Otis	Tiny, tiny, tiny bee.		Set Up
Mother	Where?	Wh-question, Focus Talk	Set Up
Otis	It just flew away.		

Mother	Oh. Was it inside like it was over there?	Linking	Intermediate
Otis	No, but I think it was sort of like, trying to get in.		Intermediate

Once the mother refocused attention to pollinators in response to Otis' expressed interest in bugs, Otis seemed more willing to observe intermediate relations between pollinators and plants as well as the structural features of the set-up conditions that dominated his initial observations.

Near the end of their time in the garden, Otis and his mother turn their attention to the flower model and pollinator puppets. The model can be taken apart and reassembled and its parts are numbered but are otherwise unidentified. Otis picks up a stamen that is lying on the table and intently inspects the flower model.

Otis	Oooh look number 6. I think that's nectar. (*Points to flower model*)		Set-Up
Mother	You think what's nectar? (*Looks at flower model where son points*)	Wh-question, Focus Talk	Set Up
Otis	The 6.		
Mother	The number 6? Hmm. Why do you think that?	Wh-question, Focus Talk	
Otis	Oooh and that's pollen I think. (*Points to stamen*) Because well - I saw the little bugs crawling down deep and I think it's supposed to be looking for nectar.		Set-Up Intermediate
Mother	They have to get all the way down there? (*Points to deep inside flower center*)		Intermediate
Otis	Yeah.		
Mother	So if they go, if they have to get all the way down there (*Picks up bee puppet)* – here I'm going to shove the bee all the way down there. (*Positions bee headfirst*) Then what – are some of the things that happen to the bee on the way down – and on the way back up? (*Lifts bee out of flower)*	Focus Talk, Wh-question	Intermediate
Otis	It gets pollen on it.		Intermediate
Mother	Yeah.		
Otis	I found where it goes. (*Inserts stamen into flower model*)		Set-Up

It seems significant that Otis appeared to intentionally search for nectar. Later, he deliberately took apart the model to see what was inside, as well as to figure out where the stamen belonged. He expected the nectar to be located at the bottom of the petals, suggesting that he has begun grasping some functional relationship between the behavior of bees and the structure of flowers. This is more complex than his original explanation of “making honey” and sets the foundation for more productive observations. Otis has begun transitioning from everyday to more scientific ways of observing in the garden.

DISCUSSION

At its core, this study is about the practice of observation, how families learn to notice natural phenomena, and the role of conversation in the development of scientific practices in designed settings. We found that when families observed and engaged in more frequent disciplinary talk during visits to a garden, children were more likely to learn about pollination from the experience. The frequency of disciplinary talk during observation was a function of what families knew about pollination before the study and the extent to which parents were successful in using ECS. We demonstrated that a relatively simple parent training was sufficient to improve parent use of ECS during shared family observation in a botanical garden.

With this in mind, we begin this discussion by considering the implications of this study for the design of informal learning interventions. Our findings clearly demonstrate the impact of a relatively simple, convenient, and brief parent training protocol that can be implemented in typical informal learning environments. Preparation on the part of parents required about 30 minutes and involved reading a short pamphlet and viewing a video that featured parents using the strategies in a similar learning context. The strategies in the training were those that many parents are familiar with and already use in the course of everyday family activity. In fact, all parents—in both treatment and control groups—used all four strategies during the observation study. The effect of training was to make the use of these familiar strategies more common in the garden.

Although there have been many prior studies of family learning in informal settings, very few controlled experiments have directly tested interventions that could potentially guide and support family learning in those settings. It may be worth reflecting upon the very notion of “intervention” in informal settings where learning is by free choice and shaped in an ongoing way by the settings, participants, and cultural contexts (Bell et al., 2009). Informal learning interventions should be flexible, so that families can choose how and when to draw upon a resource to support their ongoing—and emergent—goals and activity. The simple intervention that we tested prompted parents to use familiar strategies in the garden and was enough to nudge family activity in ways that impacted observational practices and learning conversations. Impact might have been stronger had we also installed signage or tools throughout the garden that reinforced ECS or provided just-in-time content knowledge that parents could pick up and incorporate into explanatory talk.

The model of ECS used in our intervention was drawn from work on children’s memory development (Boland et al., 2003). Our extension to an informal science learning context raises additional issues about the features of ECS that are particularly important for learning rather than remembering. For example, the use of *Wh*-questions and child focus talk seems especially relevant to the broader goal of supporting children as they transition from seeing to observing the natural world. Asking *Wh*-questions is an important practice of expert scientists (e.g., Haila, 1992; Mayr, 1997) and is consistent with effective pedagogical practices used in science classrooms (Smith & Reiser, 2005). When parents ask *Wh*-questions, they filter complex environments, and consequently children may be better equipped to closely notice and elaborate upon particular entities, features, and activities.

Likewise, child focus talk is another strategy that filters complexity, albeit from the perspective of a child's interests. Building upon an individual's motivations for learning and engagement is a valued practice in informal learning environments (Bell et al., 2009). But we also see this strategy successfully used by teachers who have adopted a science-as-practice perspective (Lehrer & Schauble, 2006) and who strive to balance the interests of students with the demands of the discipline. For example, teachers in Lehrer, Schauble, and Petrosino (2001) and Metz (2000) used children's expressed interest in familiar organisms (i.e., fruit flies, crickets) as a springboard for engaging children in such observational practices as feature analysis, repeated observations of the same phenomena, and the transformation of direct observations into new forms (i.e., population maps, animal behavior taxonomies).

In contrast, the ECS component strategy of linking to prior experience may have done less to support scientific habits of attention. Consider that parents typically compared features of various phenomena without regard to disciplinary merit: "These look like the red flowers we have by the front door." This is a common reduction of observation that Metz (1995) has criticized for failing to support the development of scientific reasoning.

Our overall interpretation of the findings, as shown by the model in Figure 3, is that the intervention had an impact on child learning through the mediating variables of use of the ECS strategy and the subsequent increase in disciplinary talk. However, the model also makes clear that prior parent and child knowledge of pollination had direct effects on the frequency of disciplinary talk. It is perhaps to be expected that parents who know more about pollination might have more opportunities to engage in disciplinary talk in the garden, and we created a contrast between relatively higher and lower parent knowledge specifically because we wanted to explore potential interactions between prior knowledge and the more general use of ECS. Our findings confirmed that parent knowledge plays a key role in levels of both ECS and disciplinary talk, and should motivate future research that untangles the role of parent knowledge in learning conversations. Specifically, we wonder whether interventions targeted at increasing parent knowledge would successfully impact family learning. The kinds of knowledge we tested in our population of parents is not particularly difficult to teach—we think it could be accomplished in a training program similar to the one we developed for ECS, or made available directly in the learning environment through signage or facilitation.

Our current findings pose a hypothesized sequence—from intervention, through conversation, to learning—that can be generalized to a wide range of informal settings. However, the particulars of making any intervention successful will depend on the background, resources, and goals of families. In our study, participating families were mostly white, frequent museum visitors, and with college educated adults. Clearly, further research is needed before implications can be drawn to a broader population of families. All families bring valuable resources to informal learning environments, although these environments sometimes fail to support the deployment of those resources in a learning interaction (Dawson, 2014). Our advice for those interested in developing family learning interventions would be to closely observe existing activity in a specific learning setting to identify potential resources that families draw upon (Zimmerman & McClain, 2013; Kisiel, Rowe, Vartabedian, & Kopczak, 2012), and then engage in deep research/practice collaborations focusing on how those resources might impact learning and learning environments, leading to iterative design interventions that reflect the localized context (Knutson, et al., 2016; Sobel & Jipson, 2015; Gutwill & Allen, 2010).

These findings also have implications for broader theoretical questions about the transition from everyday to scientific observational practice. A central challenge of observational practice is to reach agreements about what an individual sees with what others see (Daston, 2008). To address this challenge, scientists have created cultural tools—equipment, language, and disciplinary systems of knowledge and practice—that enable the collaborative construction of shared vision (Daston & Galison, 2007; Goodwin, 1994). One way to frame our findings is to think about family knowledge and the use of ECS as transportable tools that can be applied across learning contexts to support joint attention and talk in ways that literally help parents and children to see the same things during observations.

From this perspective, the families in this study were learning a form of disciplined noticing (Daston, 2008; Eberbach & Crowley, 2009; Lobato, Rhodehamel, & Hohensee, 2012). In the observation framework described earlier, noticing is a critical dimension of observational practice and involves learning to detect the signal from the noise. Persisting in seeing the “objects of science” in new ways builds perception, memory, experience, skill, and understanding (Daston, 2008). Through guided experience with the “descriptive organization of seeing”, learners synthesize, grasp, and highlight meaningful relationships and develop a trained eye. To become proficient in disciplined noticing learners need more than book knowledge—they need guided experiences of observing the phenomena itself (Ogilvie, 2006).

Consistent with Tharp & Gallimore (1988), we have argued that the process of transitioning from everyday to more scientific observation is facilitated by joint attention and participation (family conversation in this case). It was through conversation during shared focus that the process of pollination unfolded before their eyes. Verbal acts of describing aspects of pollination enabled parents and children to begin to organize what they noticed—sometimes revealing patterns of form and behavior. Through persistent, repeated noticing of pollinators, flowers, and environmental conditions, families constructed and re-constructed knowledge. Talk provided opportunities to mark the observations, to compare behaviors, to focus and explain the features and stuff of pollination phenomena. In this way, family talk functioned as a mechanism for “the fusion of perception, memory, and experience” (Daston & Lunbeck, 2011, p. 5).

In the end, these findings contribute to the ongoing conversation about how people learn about science over place and time. Whether learning occurs in a classroom, in the home, or as in our case, while visiting a designed informal science learning environment, a key question is how best to think about how general everyday learning practices develop into discipline-specific learning practices such as observing. Although there may be serendipitous examples of how everyday science learning connects with classroom-based science learning, we believe that the informal learning infrastructure can play a key role in increasing the number and quality of these otherwise serendipitous events. While our findings are about the ways in which observation can be conceptualized and supported in rich authentic learning environments—perhaps more significantly—our findings are also about how we could think about building capacity in families to organize and optimize learning opportunities wherever they may arise.

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Table 1. Unadjusted Means of Child Pre and Post Task Scores

		Treatment Group				Control Group			
	Knowledge Group	**Pre**		**Post**		**Pre**		**Post**	
		M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
	High	6.1	*0.9*	6.2	*1.1*	6.3	*1.3*	6.4	*1.2*
Task 1	**Low**	5.4	*1.6*	6.0	*1.3*	5.8	*1.2*	6.0	*1.5*
	High	1.2	*0.6*	1.3	*0.6*	1.1	*0.6*	1.4	*0.6*
Task 2	**Low**	1.1	*0.6*	1.3	*0.7*	1.1	*0.6*	1.4	*0.5*
	High	2.2	*0.8*	2.3	*0.6*	2.0	*0.7*	2.1	*0.8*
Task 3	**Low**	1.8	*0.8*	2.2	*0.8*	2.1	*0.7*	2.0	*0.7*
	High	1.1	*0.6*	1.4	*0.6*	1.4	*1.0*	1.4	*0.9*
Task 4	**Low**	1.0	*0.6*	1.4	*0.7*	1.1	*0.7*	1.1	*0.7*
	High	5.6	*3.3*	6.3	*2.9*	7.0	*3.7*	7.3	*3.6*
Task 5	**Low**	3.9	*1.9*	5.3	*2.9*	4.5	*1.7*	5.5	*2.5*
	High	16.2	*4.4*	17.5	*4.0*	17.8	*4.7*	18.6	*4.6*
Total	**Low**	13.2	*2.9*	16.2	*3.3*	14.6	*2.8*	16.0	*3.4*

Table 2. Correlations for Variables in the Model (n = 79)

	Parent Knowledge	**Parent Training**	**Disciplinary Talk**	**Use of ECS**	**Child Pre Knowledge**	**Child Post Knowledge**
Parent Disciplinary Knowledge	1					
Parent Training	.06	1				
Disciplinary Talk	.50**	.12	1			
Parent Use of ECS	.21	.60**	.45**	1		
Child Pre Knowledge	.38**	-.16	.40**	.07	1	
Child Post Knowledge	.34**	-.02	.43**	.18	.70**	1

**Correlation is significant at the 0.01 level (2-tailed)

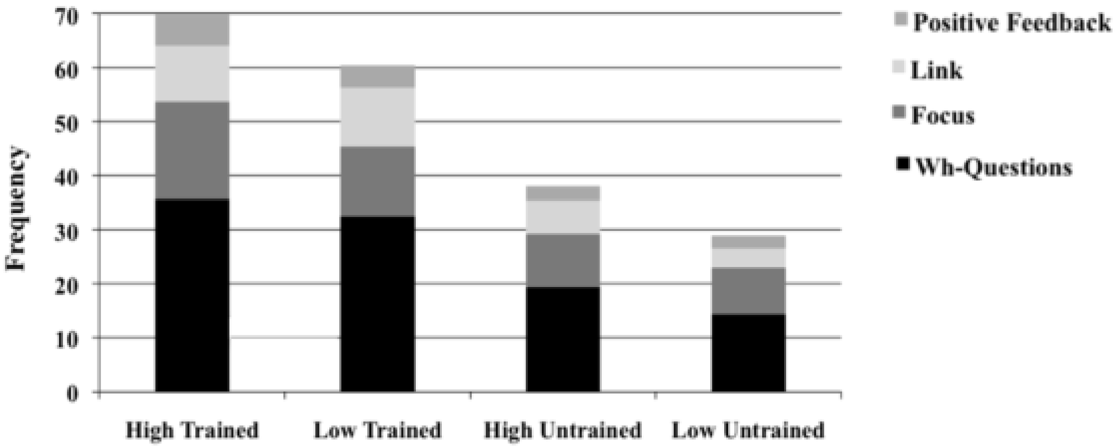

Figure 1. Mean Number of Parent Elaborative Conversational Strategies

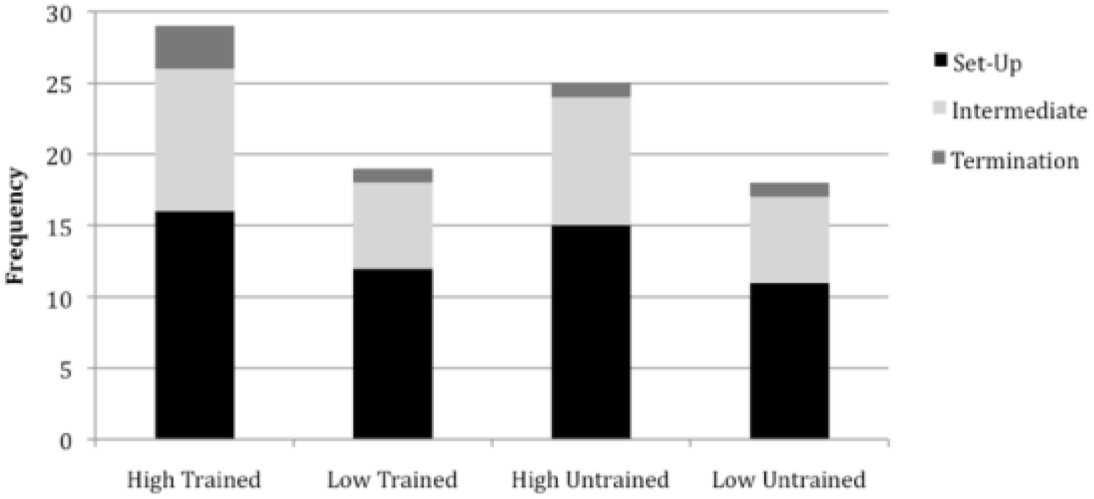

Figure 2. Parent-Child Disciplinary Talk: Observations of Pollination States

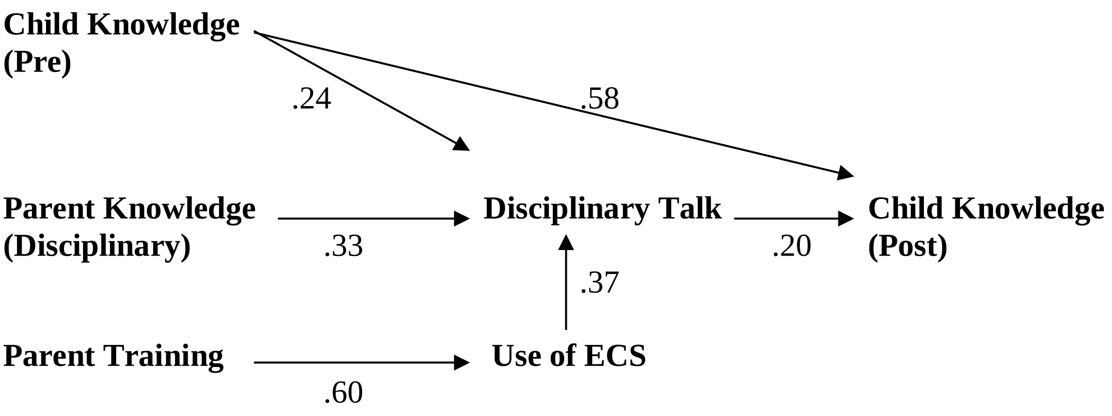

Figure 3. Model of Parent-Child Observation with Significant Effects

EYES OF SCIENCE PARENT SURVEY

1. Here is a photograph of a flower and a bee. How would you explain what is happening in this photograph?

2. Having said that, which features in this photograph do you think are important to notice in order to support your explanation? Probe: Is there anything else?

Anther
Bee
Color (floral)
Filament
Flower
Nectar guides
Pistil
Pollen
Pollen Pocket
Sunny
Proboscis
Shape (floral)
Stamen
Stigma
Style

Concept….(up to 6 points)
Pollen on bee's body
Bee getting nectar
Color attracts
Proximity of bee to flower
Pollen on flower
Sex organ of plant

3. What are the parts of the flower that you can see in this photograph? Probe: Is there anything else?

4. What are the parts of the insect that you can see in this photograph? Probe: Is there anything else?

Decide if each statement is true or false. Check *don't know* when you are unsure.

	Statements	**True**	**False**	**Don't Know**
5	Plants and insects depend upon one another.			
6	Butterflies move pollen on purpose.			
7	Honeybees visit flowers to eat nectar and pollen.			
8	Photosynthesis is how plants make food.			
9	A flower has ovaries to make pollen.			
10	Pollination is moving pollen from one flower to another flower.			
11	Butterflies visit flowers to eat pollen.			

12. In a few words, explain your response to, "A flower has ovaries to make pollen."

13. These flowers have something in common that you can see. What is it? What is its purpose?

A

B

C

14. Which flower is *most* likely to attract BUTTERFLIES? (*Circle only one*.) Why?

A

B

C

15. Which flower is *most* likely to attract BEES? (*Circle only one*.) Why?

A

B

C