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

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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. A total of 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 4 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

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variance in what children learned from the experience. An extended example illustrates how shared family noticing and conversation may support learning to observe nature.

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) and hypotheses are 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, which made it difficult to create accurate population counts. As expert observers, ornithologists know what features to notice when identifying kinds of birds and know 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 although 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 documented the roles of noticing, expectations, observation records, and productive dispositions in 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 speaking, 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 on 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 on during future scientific activity (Callanan & Jipson, 2001).

More often than not, this parent–child activity is collaborative in nature, which means 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). Evidence of these patterns is seen in museums where families typically operate as a "flexible learning system" (Hilke, 1989, p. 101), 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, which prompted 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 making 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 of drawing a child's attention to critical scientific features and processes as well as of 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). However, 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 that the child's understanding is similar to their own, particularly during shared scientific activity (Gleason & Schauble, 2000), or even because they assume that 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, 2010).

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, and 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, a 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, they asked some mothers to use their natural conversational strategies during the event and trained others to use an elaborated conversational strategy that 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 to pollination. 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, which makes the garden a good location for a study of families observing pollination.

Participants

A total of 79 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 ages 6 to 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 10 years old and a pilot study revealed that children ages 6 to 10 could more readily engage in the observational activities and science talk for the duration of the observation study, whereas children 5 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 because of 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 (see Appendix). 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 × 11" 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 covered 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 1 point for each correct response. Interrater reliability was 95%, and differences were resolved through discussion. Parent scores on the survey ranged from 5 to 28 points (M = 13.54, SD = 5.18). Parents were assigned to high-knowledge (n = 40) and low-knowledge (n = 39) conditions based on 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 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. . Parents in the treatment condition received training in the four elaborative conversational strategies (ECS): asking *wh-* questions, focusing talk on the child's interests, linking present to past experiences, and providing positive feedback. (These are defined in the "Parent ECS" section.) Approximately 1 week prior to the observation study parents received an 8-page illustrated pamphlet that described the four conversational strategies and included examples of parents using them 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-min 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 and 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: (a) to focus on children's observation and understanding of biological phenomena, (b) to feature authentic objects and disciplinary content within a natural history context, and (c) to include mothers and fathers as well as school-age children. So that we could compare parents' naturalistic style with that of the ECS 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, the researcher asked participants 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 min according to their interests, and responded to questions asked by either participant. The researcher also reminded the parent to talk with his or her child according to prior instruction. Finally, in order to frame their activity in the garden, the researcher instructed both parents and children, "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 parents and children appeared to observe. Observation studies lasted for an average of 14 min, 40 s (*SD* = 3.56), and ranged from about 6 min to 25 min.

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 1, children sorted eight 4 × 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 nonpollination pile and were assigned 1 point for each correct choice.

In Task 2, children compared two 4 × 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 1 point for each correct response.

To determine whether children could distinguish observation from inference, Task 3 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 were inferable (presence of nectar, making its own food, and flower’s origin). Children were assigned 1 point for each correct response.

In Task 4, 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 1 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 1 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 toward or appeared to be looking at during each task. On average, the pre- and postinterviews lasted a total of 12 min, 38 s, and ranged from approximately 7 min to 18 min.

CODING

In this section, we describe the coding developed for the ECS 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 testing using both transcripts and videotapes. One researcher coded all of the data. To assess reliability, another 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 ECS

The four ECS were coded from family talk that occurred during the observation study. In this coding scheme, *asking wh- questions* included questions that emphasized what, when, where, why, who, or how and that drew the child’s attention to specific aspects of objects and events, solicited information, or helped the child to make sense of the objects and events that he or she noticed:

"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 included talk in which parents guided or extended conversations toward pollination-related objects and activities in which the child expressed interest, particularly phenomena the child was already noticing, touching, or mentioning. In this example, the parent responds to the child's interest in a bee:

Child: Look at that! *(Points to a bee)*
Parent: It looks like it has a lot of pollen.
Child: That's a—
Parent: I think it's a baby bee. It's a teeny tiny bee.
Child: That's a bee all right.
Parent: These plants have a lot of pollen and it's easier for bees to get it.
Child: Why?
Parent: Well see how big and open that is? It's all fluffy with pollen?
Child: Yeah?
Parent: And then look at these. These are harder to get to.

Linking present to prior knowledge and experiences was talk in which parents made connections between what occurred during the observation study and what a child already knew or had already experienced about pollination and related phenomena. Linking could refer to experiences that occurred prior to the observation study or to experiences that occurred 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 was coded as *providing positive feedback* when parents explicitly acknowledged the child's content and observational contributions. For example, parents might have assessed the accuracy of their child's observations:

"That's right."

"That's happening just like you said."

However, parents might also have acknowledged the child's participation, as evidenced 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: (a) the unit of analysis was a parent's conversational turn, (b) a conversational turn could include more than one conversational strategy, (c) individual instances of an elaborative conversational strategy were counted each time they were uniquely used in a conversational turn, and (d) an individual statement could 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, and Pothier (2005), a central claim here is that this family talk can be identified as existing on a continuum from everyday, nondisciplinary talk to disciplinary science talk. How would one distinguish talk that was disciplinary from talk that was nondisciplinary 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 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) argued that full understanding of scientific mechanisms associated with scientific processes requires distinguishing between the ways entities interact within three states that they called 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 emphasized talk in which families either identified or located 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 included observations that elaborated on 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 focused on the connections between entities, properties, and activities as pollen is moved from one flower to another flower. Here disciplinary talk focused 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 focused 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 connected these changes to postpollination 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: (a) Coding reflected family pollination-related talk that occurred during the entire observation study; (b) each state could be distinctly identified and segregated; and (c) once counted in a particular state, an entity, feature, property, and/or activity was 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 (see Figure 1). A two-way analysis of variance (ANOVA) on parent use of

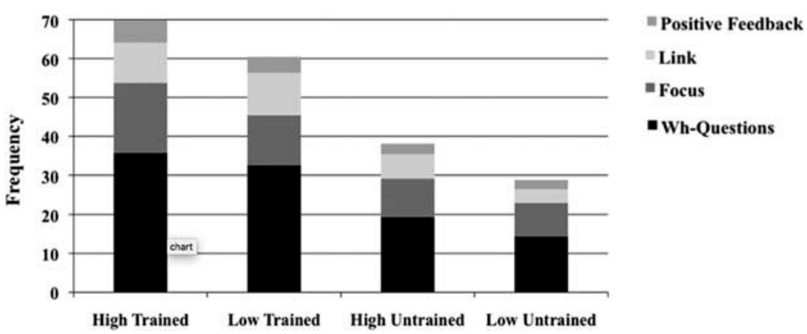

FIGURE 1 Mean number of parent elaborative conversational strategies.

ECS yielded a significant main effect for treatment and for parent knowledge: treatment, $F(1, 75) = 47.56$, $p < .001$, $d = 1.53$; parent knowledge, $F(1, 75) = 4.08$, $p < .05$, $d = 0.38$. 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 ($M = 38$, $SD = 24$).

To further understand the results of parent training, we examined elaborative strategies with the expectation that parents in the treatment groups would use each strategy more than parents in the control groups. As for strategies that made demands on 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—showed similar patterns of expected and unexpected results. A two-way ANOVA for child focus talk resulted in a significant main effect for treatment, as expected, $F(1, 75) = 10.61$, $p < .01$, $d = 0.64$. 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 but not for parent knowledge: training, $F(1, 75) = 18.55$, $p < .001$, $d = 0.71$; parent knowledge $F(1, 75) = 0.53$, $p > .05$.

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 on 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 elaborate on 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:

Child: Look over here. *(Looks at flowers using magnifying lens)*
Parent: Okay. What's different about these petals of these flowers? *(Looks at flowers using magnifying lens)*
Child: They're teeny.
Parent: Pardon?
Child:

They're teeny. They're tinier and they don't have the little stems coming out like that.
Parent: Yeah they're like ah—They're like a different shape aren't they?
Child: Umm hmm.
Parent: Yeah. The first ones were more of a what shape?
Child: A flower shape?
Parent: More like a big ball.
Child: Yeah.

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

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

These examples illustrate that parents may elaborate on 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 revealing that parents in the treatment groups generated more positive feedback ($M = 5$, $SD = 3.34$) than parents in the control groups ($M = 3$, $SD = 3.09$), $F(1, 75) = 11.12$, $p < .01$, $d = 0.75$. 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 *noncontent wh-* questions found only a significant main effect for treatment, $F(1, 75) = 15.06$, $p < .001$, $d = 0.86$. In contrast, parent use of the *wh- content* questions resulted in significant main effects for treatment as well as for parent knowledge: treatment, $F(1, 75) = 34.81$, $p < .001$, $d = 1.3$; parent knowledge, $F(1, 75) = 5.28$, $p < .05$, $d = 0.45$. 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 included 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

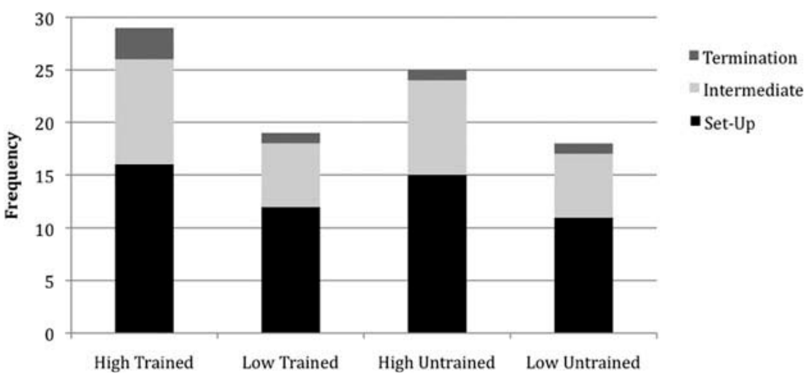

FIGURE 2 Parent–child disciplinary talk: Observations of pollination states.

knowledge but no effect for parent treatment: parent knowledge, $F(1, 75) = 24.40$, $p < .001$, $d = 1.13$; 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 ($M = 19$, $SD = 6.64$).

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, $F(1, 75) = 16.21$, $p < .001$, $d = 0.92$. 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, $F(1, 75) = 9.54$, $p < .01$, $d = 0.70$. Parents in the high-knowledge group generated more talk of postpollination 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 make up pollination. We began this analysis by asking whether differences in children's knowledge were associated with differences in parent knowledge. A two-way ANOVA for children's preinterview summary scores found a significant main effect for parent knowledge, $F(1, 74) = 13.08$, $p < .01$, $d = 0.78$. 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 analyses of covariance for postinterview scores were used in which preinterview 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 postinterview scores were not significantly different between conditions. (See Table 1 for unadjusted pre- and postinterview means.) A two-way analysis of covariance for summary scores yielded no significant effects for treatment or for parent knowledge: treatment, $F(1, 73) = 0.76$, $p > .05$; parent knowledge, $F(1, 73) = 0.09$, $p > .05$.

TABLE 1
Unadjusted Means of Child Pre- and Posttask Scores

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

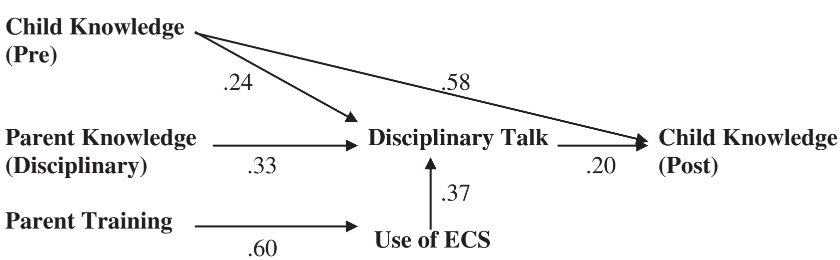

FIGURE 3 Model of parent–child observation with significant effects. ECS = elaborative conversational strategies.

A Model of Talk and Learning

We have shown that training and parent knowledge changed family talk. However, at the level of the 2 × 2 design of our study, we have so far not shown 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

TABLE 2
Correlations Between Variables in the Model (n = 79)

Variable	*1*	*2*	*3*	*4*	*5*	*6*
1. Parent disciplinary knowledge	—					
2. Parent training	.06	—				
3. Disciplinary talk	.50**	.12	—			
4. Parent use of ECS	.21	.60**	.45**	—		
5. Child preknowledge	.38**	−.16	.40**	.07	—	
6. Child postknowledge	.34**	−.02	.43**	.18	.70**	—

Note. ECS = elaborative conversational strategies.
**$p < 0.01$.

associated with greater learning. But a direct test of this model is difficult with the ANOVAs 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.

Three equations were generated to develop the model of parent–child observation. First, a stepwise multiple regression analysis was conducted to determine the variables that are significant predictors of total use of the ECS. Independent variables used in the equation were parent knowledge, parent training, and child preknowledge. 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 preknowledge as the independent variables. Parent knowledge was entered first and accounted for 25% of the variance. Use of ECS was entered next and accounted for an additional 13% of the variance. Child knowledge was 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 total child postobservation knowledge as the dependent variable and parent knowledge, parent training, use of ECS, child preknowledge, and disciplinary talk as the independent variables. In this case, child knowledge was entered first, accounting for 45% of the variance. Disciplinary talk was entered next and accounted for an additional 3% of the variance (child postobservation 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 9-year-old son. The mother was knowledgeable about pollination and also received training in the ECS. 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

		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.		

observation activity (talking, asking questions, returning to previously visited garden areas), and together they also pursued opportunistic connections to Otis's interests (e.g., inspecting a rain meter, hunting caterpillars). Their observation study lasted 23 min, about 10 min longer than average. Before presenting the example, we remind readers that coding was conducted with video and

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	

transcripts, which means that the assignment of codes was not done from the spoken word alone but from the temporal and physical context of the words.

Like many parents, the mother begins the observation study by asking her son where he wanted to start. He leads her to a tall structure that supports an exuberant passionflower vine with large exotic flowers, each of which could host many bees simultaneously. Otis reads an identification label and looks

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

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's attention to bees interacting with a flower.

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:

In this last comment, the mothers used 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 limit his choices and positively reinforce Otis’s assertions about pollen:

In this 3-min episode, several things occur that seem critical to understanding how families begin to observe more scientifically in informal contexts. First, Otis’s confusion about the properties of pollen and nectar emerges as a shared problem space and creates a focus that filters their observations of bees and flowers in the garden. This problem guides the mother’s attention, the questions she asks, and finding new opportunities to notice and reinforce what distinguishes pollen from nectar.

Second, the mother’s knowledge provides a critical lens for recognizing the significance of Otis’s 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’s mother rapidly shifts 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 be an attempt to address an immediate problem by verifying the top/bottom and solid/liquid rules that Otis articulates. What seems important to notice here, however, is that the rules are tenuous and rely on memorization rather than

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

meaningful understanding of their functions in pollination. In practice, the mother’s observations are substantially different from those of Otis: She observes floral structures and bee behaviors in relation to one another, whereas he sees floral structures and properties in isolation.

Third, the mother’s use of ECS invites 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 draw attention to the specific properties of pollen in ways that help Otis to encode pollen and bring to mind what he already understands 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:

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 noticed by directing attention to some aspect of the target phenomenon. Once their observation of the bees has run its course, the mother draws Otis's attention back to the different colors of the flowers she wanted 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 was 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 he then declares rather excitedly, "No, no,

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-upIntermediate
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

they're little bugs." His mother seems skeptical when Otis explains that the caterpillar ate 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

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

monarchs only ate milkweed") and Otis proclaims, "Wow. I really liked the caterpillar." They decide to return for another takes before leaving the garden.

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

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 head first)* 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

Here the mother not only redirects Otis's focus to the bee's interaction with the flower but also highlights 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:

Once the mother refocuses attention to pollinators in response to Otis's expressed interest in bugs, Otis seems 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.

It seems significant that Otis appears to intentionally search for nectar. Later he deliberately takes apart the model to see what is inside as well as to figure out where the stamen belongs. He expects the nectar to be located at the bottom of the petals, which suggests 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 set the foundation for more productive observations. Otis had 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 min 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 on 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 on 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. The 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 on 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 on 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 are 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 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 on (Kisiel, Rowe, Vartabedian, & Kopczak, 2012; Zimmerman & McClain, 2013) 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 (Gutwill & Allen, 2010; Knutson et al., 2016; Sobel & Jipson, 2015).

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 and 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 (Law & Lynch, 1990), 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 phenomenon itself (Ogilvie, 2006).

Consistent with Tharp and 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 the eyes of parents and children. 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 reconstructed 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. Although 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 to possibly think about building capacity in families to organize and optimize learning opportunities wherever they may arise.

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Appendix

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