THE EFFECT OF PARENTS' CONVERSATIONAL STYLE AND DISCIPLINARY KNOWLEDGE ON CHILDREN'S OBSERVATION OF BIOLOGICAL PHENOMENA

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This study was designed to better understand how children begin to make the transition from *seeing* the natural world to *scientifically observing* the natural world during shared family activity in an informal learning environment. Specifically, this study addressed research questions: 1) What is the effect of differences in parent conversational style and disciplinary knowledge on children's observations of biological phenomena? 2) What is the relationship between parent disciplinary knowledge and conversational style to children's observations of biological phenomena? and 3) Can parents, regardless of knowledge, be trained to use a teaching strategy with their children that can be implemented in informal learning contexts?

To address these questions, 79 parent-child dyads with children 6-10 years old participated in a controlled study in which half of the parents used their natural conversational style and the other half were trained to use particular conversational strategies during family observations of pollination in a botanical garden. Parents were also assigned to high and low knowledge groups according to their disciplinary knowledge of pollination. Data sources included video recordings of parent-child observations in a garden, pre-post child tasks, and parent surveys.

Findings revealed 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, which is to be expected. However, the use of the conversational strategies also increased the amount of disciplinary talk in the garden, independent of what families knew about pollination. The extent to which families engaged in disciplinary talk in the garden predicted significant variance in children's post-test scores. In addition to these findings, an Observation Framework (Eberbach & Crowley, 2009) that hypothesizes how everyday observers become scientific observers is proposed.

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PREFACE

And so, life *is* for learning. I am grateful to all of those who have supported my pursuit of the questions explored in this investigation. I am indebted to the patience and intellect of the members of my dissertation committee—Kevin Crowley, Michael Ford, Gaea Leinhardt, and Christian Schunn—and to the generous support of the School of Education Alumni Fund. Phipps Conservatory and Botanical Garden generously welcomed the research team and every family into the garden. Of course, no study would have been possible without the parents and children who enthusiastically contributed their experiences to this endeavor. And finally, I am so very appreciative of the ample confidence and support from so many friends and family, of whom my father has been chief cheerleader.

1.0 INTRODUCTION

"You see, but you do not observe."

Sherlock Holmes, A Scandal in Bohemia

Scientists make observations to learn about the natural world. Observation is fundamental to all scientific activity and to all scientific disciplines (Daston & Vidal, n.d.; Norris, 1984): It is the foundation on which hypotheses and data are based, the lens by which hypotheses are strengthened or refuted (Mayr, 1997; Moore, 1993); and often the stimulus for scientific discovery (Klahr & Simon, 1999; Mayr, 1997; Simon, 2001). Reliable data—whether collected in the field or laboratory—depend upon skilled observation to ensure the collection and accurate documentation of critical evidence, and to build explanations and theories.

On the surface, scientific observation is deceptively simple: Phenomena happen, phenomena are observed, and phenomena are recorded. How difficult can it be to observe scientifically? After all, children everywhere make observations in order to learn about their everyday world (Rogoff, Paradise, Mejia Arauz, Correa-Chavez, & Angelill, 2003). But, as Sherlock Holmes astutely remarked, seeing is not observing.

This dissertation explores how children begin the transition from "seeing" the natural world to "observing" the natural world during a family visit to a botanical garden. In particular, we consider how parent knowledge about pollination biology and parent training in the use of an elaborated conversational style enables children to be more scientific in their observations of biological phenomena.

1.1 THE COMPLEXITY OF OBSERVING SCIENTIFICALLY

To observe scientifically requires much more than sensory perception and using one's senses. Although highly tangible, sensing is only one aspect of observation. True scientific observation requires the coordination of disciplinary knowledge, theory, practice, and habits of attention (Daston & Vidal, n.d.). To illustrate what we mean we turn to lessons learned from the early development of Cornell Ornithology Lab's Classroom FeederWatch curriculum (Trumbull, Bonney, & Grudens-Schuck, 2005). In this program, middle school students were expected to observe living birds as a means of engaging in authentic scientific inquiry. The premise seemed simple: Strategically locate birdfeeders around school grounds, systematically observe living birds, engage in authentic inquiry, and learn about the biology of birds. Yet, evaluation of the curriculum revealed little or no change in students' disciplinary knowledge or in their understanding of scientific inquiry. Moreover, most students failed to see how their observations might help ornithologists. What went wrong?

Evaluation suggested that the developers—who included educators and expert ornithologists—had underestimated the complexity of observational practice, its interrelationship with disciplinary knowledge, and the degree to which teachers and students needed scaffolding to support systematic observation. Like so many, they had assumed it is easy to observe birds. Yet, problems with identifying and counting birds soon emerged: Students could not identify birds in flight, nor could they distinguish between individual birds, making it impossible to generate accurate population counts. As trained observers, ornithologists know what features to observe when identifying kinds of birds and to look for field marks to distinguish individual birds in flight. Lacking this specialized knowledge and practice, students were unable to make scientifically meaningful observations.

Attracting adequate numbers and kinds of birds is essential to systematic observation of birds, but to everyone's surprise, birds did not flock to the classroom feeders. The team had underestimated how their knowledge of bird biology informs identification of environmental conditions that attract birds and, as a result, provided too little guidance for placing the feeders. Without this knowledge, teachers and students may have placed feeders where it was convenient to observe the feeders without also considering the ecological conditions necessary to attract birds. Trumbull et al (2005) concluded that "[to] learn a sophisticated form of observation particular to a discipline … careful observation is structured by knowledge about birds and by knowing the kinds of questions to ask about the birds one may see" (p. 13). This was easy for the scientists—they had amply rehearsed these activities—but unfamiliar territory for students and teachers.

This example illustrates several concepts important to the development of scientific observation. First, systematic observation is a challenging enterprise, yet one that is often underestimated by educators and researchers (Chinn & Malhotra, 2002a; Metz, 2000; Norris, 1985; Smith & Reiser, 2005). Too often, observation is cast as a general everyday skill that requires little more than noticing and describing surface features (Ault, 1998; Chinn & Malhotra, 2001; Metz, 1995). Consequently, students look at phenomena without developing new knowledge or associating their observations with scientific reasoning and explanations (Ford, 2005). The student observations in this example were more characteristic of everyday observation.

This leads to the second point: Scientific observation is not a domain general practice, but one that goes hand in hand with disciplinary knowledge, theory, and practice (Ault, 1998; Daston & Vidal, n.d.; Finley & Pocovi, 2000; Ford, 2005; Mayr, 1982; Norris, 1984). When observations are disconnected from disciplinary contexts, we see but we do not observe. Without sufficient understanding of the underlying theoretical concepts of ornithology, and without awareness that ornithologists have sophisticated observational habits, students failed to learn about the biology of birds and authentic scientific inquiry.

Third, learning to observe scientifically necessitates bootstrapping between specific disciplinary knowledge, theory, and practice (Ford, 2005; Lehrer & Schauble, 2004; Metz, 2000, 2004; Norris, 1985). Although children are intent observers whose everyday observations help them to understand and negotiate the world (Rogoff, 2003), and their observations may share similarities with scientific observers (Carey, 1985; Gopnik, Meltzoff, & Kuhl, 1999; Vosniadou & Brewer, 1994), children still need support to be scientific observers. Perhaps, with more knowledge of bird biology, the feeders might have been located in places that would have attracted more birds as well as meeting the students' observational requirements.

Finally, this example illustrates some fundamental differences between expert and novice observers. Expert ornithologists appeared to effortlessly detect field marks to distinguish individual birds, whereas students had difficulty even identifying kinds of birds. This perceptual acuity is evident in other experts, such as chess masters who can perceive meaningful patterns and accurately reproduce the locations of chess pieces on a game board from memory (Chase & Simon, 1973; Chi, 1978). Like other experts, the ornithologists have hierarchal, highly organized structures (within their discipline) that enable them to effectively encode and organize the world differently from novices, and to efficiently notice and recall meaningful patterns (Ericsson, 1996; Hecht & Proffitt, 1995; Patel, Kaufman, & Magder, 1996). In short, without the disciplinary context necessary for systematically observing birds, students in this example had limited opportunity for building new knowledge about birds or becoming proficient observers.

1.2 WHY STUDY THE DEVELOPMENT OF SCIENTIFIC OBSERVATION IN EVERYDAY CONTEXTS?

We are interested in how "seeing" biological phenomena may transition into "observing" biological phenomena in informal learning environments, how families use observation to learn in informal learning settings, and how parents might be supported as mediators of children's disciplinary habits of attention.

1.2.1 Opportunities for Observing Scientifically in Everyday Contexts

Although scientific observation is a complex practice, there are many reasons why everyday contexts may support the development of powerful observations of the natural world. To begin, the natural world offers rich environments and countless opportunities for becoming a practiced observer. Whether picnicking in the park, gardening in the backyard, or walking along a city sidewalk, children can freely notice and experience biological organisms up close time and again.

The everyday world also includes built environments where families can engage deeply with authentic biological phenomena in settings designed to mediate disciplinary knowledge and practice. In this way, a long tradition of environmental education programs in botanical gardens have supported first-hand observation of diverse living plants in dynamic ecological settings and have sown the seeds of awareness, curiosity, and knowledge of botanical content (Sanders, 2007).

1.2.2 Families as Learning Systems

Families provide yet another context in which children come to observe and understand natural phenomena. During the course of mundane, 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 try to mediate a child's everyday observations. 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 features of objects by naming, describing, and categorizing objects (Callanan, 1990) or by pointing out particular features of objects (Braswell & Callanan, 2003). Some argue that everyday parent-child conversations and routines such as these establish the foundation for scientific thinking and practice (Ash, 2004a; Callanan & Oakes, 1992; Crowley & Jacobs, 2002) and provide a common source of experiences to draw upon during future shared 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, often by participating and learning themselves (Rogoff et al., 2003). We see evidence of this pattern 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; Hilke, 1989). As fluid as these parent-child 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 non-verbal behaviors (e.g., pointing to objects of interest, modeling attentive gestures) and verbal behaviors (e.g., positive evaluations, reading signage aloud).

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, & Knutson, 2002; Leinhardt & Knutson, 2004). Of particular interest here, parents appear to 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 describing features and evidence that are critical to notice at science exhibits (Crowley et al., 2001), extending a child's existing knowledge by connecting current activity to prior experience (Ash, 2003; Hilke, 1989), and reading interpretive text aloud (Diamond, 1986).

General strategies such as these may help children to notice specific features and processes, but do not necessarily support the development of scientific observation. In order for that to be plausible, parent talk should show some sensitivity to differences between scientific domains and scientific disciplines. And, in fact, there is some evidence to suggest that parents do engage in talk that is characteristic of different scientific domains. For example, at biology-themed exhibits, parent explanations and questions to their children convey themes consistent with the big ideas of biology such as growth, adaptation, form and function, classification, and evolutionary theory (Allen, 2002; Ash, 2003, 2004a; Palmquist & Crowley, 2007). In everyday contexts, parents' explanations about the change in size of biological objects are more likely to reflect organic causes, whereas they are more likely to ascribe changes in size of physical phenomena to chemical causes (Jipson & Callanan, 2003). Nevertheless, their language is often imprecise or ambiguous, using what Ash et al (2007) label as "everyday science talk".

Although parents appear to adjust their talk to reflect differences between scientific domains, informal learning settings research says little about how parents and children talk at the level of scientific disciplines (Ellenbogen & Stevens, 2005). The few studies that explicitly focus on scientific disciplines occur in the context of school field trips and focus on content gains without also considering disciplinary habits of mind (e.g., Anderson, Lucas, & Ginns, 2000; Falk & Dierking, 1997).

Further research is needed to understand whether parent talk occurs at the level of discipline, and if so, how parent disciplinary talk conveys both disciplinary knowledge and practice, and the effect of disciplinary talk on family conversations. Albeit tacitly, a few museum-based studies suggest that families do engage in disciplinary talk and habits of attention. For example, when families observed pollination occurrences in a botanical garden, some parent talk echoed aspects of the disciplinary discourse of field biologists as they generated play-by-play narrative accounts of pollinator behavior and highlighted functional relationships between plant and pollinator structures (Eberbach & Crowley, 2005).

Similarly, during a visit to a dinosaur exhibition, families observed and compared features across specimen, and they also made explicit references to paleontology concepts such as the age and distribution of dinosaurs (Palmquist & Crowley, 2007). However, in a surprising twist, family behavior changed dramatically with the emergence of disciplinary talk. In particular, when children were relative novices, talk was equally distributed between parents and children, and parents used the exhibit's interpretive features to mediate the learning experience. In contrast, when children were relative experts, parents talked significantly less than their children and also failed to use the exhibition to build upon their child's understanding. Instead, parents seemed to remove themselves from the family learning system, prompting the researchers to conclude that informal learning environments may need to provide parents with ways to extend learning trajectories.

1.2.3 Supporting Parents' Role as Mediators of Children's Observations

Even when families have specialized knowledge or the environment is adequately supportive, parents may miss opportunities to develop children's observational practices in ways that support deeper engagement and learning. There are many possible reasons for this pattern: Some parents may believe that science is simply a matter of looking and seeing (Driver, Leach, Millar, & Scott, 1996). Other parents may believe that interpreting evidence is unnecessary because they assume the child's understanding is the same as their own, particularly during shared scientific activity (Gleason & Schauble, 2000), or because the child is already highly knowledgeable about the topic (Palmquist & Crowley, 2007). On the other hand, parents may consider a child to be too young or too inexperienced to reason about complex information and problems (Schauble et al., 2002). Finally, parents may judge the designed museum environment to be doing the explanatory work, particularly when children are using interactive exhibits (Melber, 2007).

So how might parents be encouraged to further children's observational practices in ways that support deeper engagement and learning? To address this question, we turn to research that investigates children's memory development and which provides insight into how parent-child talk during shared activity affects what children notice, encode, and recall (e.g., Fivush, Haden, & Reese, 2006; McGuigan & Salmon, 2004; Ornstein, Haden, & Hedrick, 2004).

We focus on two studies here. The first study demonstrates the significance of joint attention in conjunction with collaborative talk on what children notice and subsequently recall (Tessler & Nelson, 1994). In this two-part study, pairs of mothers and preschool children either looked at dioramas at a natural history museum or walked together through an unfamiliar neighborhood. 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 in either study 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 about the walk than did children whose mothers made no such connections. The authors concluded that parent talk essentially trains a child's habits of attention and is instructional in how and what to notice, represent, and remember.

In contrast to Tessler & Nelson's naturalistic context, the second study involved a staged camping event during which pairs of mothers and preschool children participated in shared activities (e.g., loading a backpack) and used an array of fabricated objects (e.g., hot dogs, fishing pole). Boland, Haden, & Ornstein (2003) argued that a parent's style of talk as an event unfolds would draw the child's attention to the salient features of a shared event and support the child's contributions to the conversation 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 style during the camping event and others were trained to use an elaborated conversational style, 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 the manipulation worked: Trained mothers used the four conversational strategies more frequently than untrained mothers and the manipulation did not generalize to other aspects of the mother's conversational style. The effect of conversational style on children's memory, however, was mixed. In particular, the manipulation yielded only a marginal difference in the overall number of event features that children recalled during open-ended questioning. However, children whose mothers used an elaborative style were able to describe significantly more details and provide more information about the event's features than children whose mothers simply used their natural conversational style.

Taken together, these studies present evidence that parent talk and the style of that talk have an effect on children's habits of attention. However, they shed little light on changes in children's knowledge or understanding of those events and objects. Neither study used conceptual change as a dependent measure, so it remains an open question whether parents' conversational style also impacts children's cognitive development or disciplinary learning. This may be beside the point during staged events that afford little opportunity for extending and deepening knowledge. However, it is of great importance in authentic, content-rich everyday and informal learning environments. Is it possible that elaborative conversation, in concert with parent knowledge, could enhance what children notice and understand about biological phenomena in informal learning environments?

1.3 PURPOSE OF THE STUDY

The purpose of this study is to understand how parental interventions and parental disciplinary knowledge influence children's observations of biological phenomena during shared activity in an everyday learning context. In particular, we explore how differences in parent conversational style and knowledge of pollination biology could support a child's transition from that of an everyday observer to a scientific observer.

In doing so, this study presents an opportunity to extend both developmental and informal learning research about how parents scaffold children's emerging everyday and scientific knowledge during shared activity. Although parents may successfully highlight evidence (e.g., features, behaviors, processes), engage in thematic talk, and build shared knowledge, they also miss opportunities to support the development of more powerful observations and deeper understanding of biological phenomena. Frequently left to their own resources in informal science education contexts, parents may need additional support to fulfill their role as primary teacher to their children, particularly when a parent's prior knowledge does not support deep engagement with the demands of scientific disciplines or when parents simply do not use strategies that support a child's scientific reasoning.

1.3.1 Research Questions

More specifically, this study addresses the following research questions:

1. What is the effect of parent differences on children's observation of biological phenomena?

a. What is the effect of parent disciplinary knowledge on children's observation of biological phenomena?

b. What is the effect of parent conversational style on children's observation of biological phenomena?

c. What is the relationship between parent disciplinary knowledge and parent conversational style to children's observations of biological phenomena?

2. Can parents, regardless of disciplinary knowledge, be trained to use a teaching strategy (i.e., elaborative conversational style) that can be implemented in informal learning contexts?

2.0 REVIEW OF THE LITERATURE

The purpose for this review is to understand what it means to observe scientifically. Specifically, we examine what distinguishes scientific observers from everyday observers and consider the kinds of activities that support observations that are increasingly scientific. To do so, we pursue four major strands of inquiry: (1) What does it mean to observe within a disciplinary framework?; (2) What do children's everyday observations look like?; and (3) What knowledge, tools, and practices do children need in order to observe within a disciplinary framework? We do this by bringing together several literatures: developmental psychology, science education, and the studies of science. Although we include examples within school contexts, our primary interest is the out-of-school informal and everyday contexts where children encounter biological phenomena.

2.1 OBSERVING LIKE EXPERT BIOLOGISTS

> In a profession more observational and comparative than experimental, the ordering of diverse objects into sensible categories becomes the sine qua non of causal interpretation. A taxonomy is not a mindless allocation of objective entities into self-evident pigeon-holes, but a theory of causal ordering. Proper taxonomy requires two separate insights: the identification and segregation of the basic

phenomenon itself, and the division of its diverse manifestations into subcategories that reflect process and cause. (Gould, 1986, p. 63)

What does scientific observation look like when practiced by expert biologists? We suspect that many readers may think of observation solely in terms of controlled experimentation in which scientists observe the results of manipulated variables. But biologists also use many non-experimental methodologies to observe and understand phenomena. Our focus here is on observational biologists who primarily use the comparative method and who systematically contrast the features of organisms and classify variations among organisms (Futuyma, 2001; Mayr, 1982). Although such observations are sometimes misconstrued as being merely descriptive, when biologists observe the morphological features of organisms, they are simultaneously inferring evolutionary relationships and testing hypotheses about the causal order of organisms (Futuyma, 2001; Gould, 1986, 2002; Mayr, 1982).

Our interest in the practices of observational biology is twofold. Systematic observation and comparison is a complex method used by biologists, yet one that is often misunderstood and treated as a simple skill by educators and others. Consequently, children may be directed to observe, compare, and describe phenomena without meaningful disciplinary context and without gaining deeper scientific understanding. Second, observational biologists typically engage scientifically at the level of organisms, which are tremendously fascinating to children and which children can easily access and observe during the course of their daily activities.

2.1.1 Expert Noticing and Reasoning

It would be impossible to navigate an enormously complex and diverse nature without some interrelated system of observation. It would be similarly impossible to make scientifically meaningful observations and comparisons without taxonomy (Mayr, 1982). Biological taxonomies are comprised of highly detailed morphological descriptions of organisms and hypothetical arrangements of groups of organisms. The underlying principle for these groupings is that members of taxon (i.e., a distinct group of organisms) share a common descent and have more characteristics in common than those that do not (Futuyma, 2001; Mayr, 1982, 1997). For this reason, biologists arrange organisms into hierarchal levels of increasingly broader categories—species to genus to family and so on—as a means of interpreting evolutionary process and cause.

Based upon a study of expert systematic botanists, Alberdi, Sleeman, & Korpi (2000) concluded that taxonomies enable scientists to look beyond the surface morphological features of organisms to extract information and to infer relationships that are not readily apparent. For instance, upon first seeing an individual plant, close observation of its many parts roused prior knowledge about the plant’s life cycle, habitat, geographical nativity, and taxonomic family.

The study also suggested that the ways botanists systematically compare plants depend upon the extent to which morphological features correspond to taxonomic expectations. When observing two or more plants that conformed to taxonomic expectations, botanists activated a systematic comparison in which information from one plant triggered a point-by-point comparison of another plant (e.g., pistil to pistil). In this way, botanists identified similarities and differences between plants, frequently comparing similarities between negative and positive instances (i.e., “It’s not like that, it’s like that…”) or comparing differences between negative instances (i.e., “It’s not like that, nor like that…”).

In contrast, when faced with unexpected observations, botanists compared a botanical feature of one plant (e.g., pistil) with the categorical features (e.g., floral structures) of another: “This is in the category? This really does puzzle me…because…it’s got the branched flower stem, but totally different flower head…unless it’s something to do with the fruits…It’s nothing to do with pollination, really…they’re not all wind dispersed” (p.74). By shifting attention to the whole floral structure—the primary feature for grouping plant families—botanists were able to make theoretically driven comparisons and to speculate about alternative taxonomic groupings. In effect, to resolve moments of uncertainty, botanists looked beyond the morphological aspects of individual flowers and inferred evolutionary relationships based upon a hypothetical organization of organisms.

This study illustrates several points about the nature of expert scientific observation. First, perception is foundational to learning across the continuum of knowledge acquisition (Jones & Smith, 1993; Mervis, Johnson, & Scott, 1993). Expert botanical observers are extremely adept at coordinating their perceptions of phenomena (e.g., floral structure) with abstract, theoretical entities (e.g., plant families). This seamless coordination is also evident in how biologists in other contexts use existing knowledge to notice and organize key features that support inferences about deep principles and relationships within biological systems (Hmelo-Silver & Pfeffer, 2004; Medin, Lynch, Coley, & Atran, 1997).

Second, systematic observation and comparison can be a powerful method for supporting complex hypothesis testing without experimental manipulation (Mayr, 1982). In this study, botanists implicitly used taxonomic theory to select diagnostic features (e.g., pistil, stamen) that supported point-by-point comparisons. In this way, taxonomies—like other theories—draw the observer's attention to theoretically meaningful features (Ault, 1998; Gould, 1986). When surprised by anomalous observations, however, botanists explicitly referred to theoretical expectations (i.e., "This is in the category?") and indirectly tested taxonomic expectations by comparing plants at higher levels of categorization. Taken together, these points reveal how perception and observation are integral to scientific practice.

2.1.2 Asking the Right Questions

In addition, the Alberdi et al (2000) study also reveals that asking the right questions at the right time is a powerful heuristic. Doing so enables biologists to bring order to a vast and complex nature by drawing attention to specific aspects of organisms and biological environments that have disciplinary meaning. Doing so also ensures that data is collected and analyzed to answer questions and solve problems (Moore, 1993).

Mayr (1997) asserts that three fundamental questions drive biological observations: What?; How?; and Why? Accordingly, what-questions are the foundation of any scientific discipline and are key to establishing the facts of science and "fueling speculation" (Haila, 1992, p. 247). The resulting catalogue of biological descriptions is fundamental to the comparative activities of observational biologists (Mayr, 1997). Recall that botanists initiated their observations by noticing a plant's features and activating prior biological knowledge, which in turn, supported theoretically driven comparisons (Alberdi et al., 2000). What-questions also filter complex environments and focus a biologist's attention as data is collected in the field. For expert biologists generating many what-questions during data collection is a productive strategy for extracting information from observed phenomena. As it is, biologists with more expertise tend to ask many more what-questions than less experienced biologists, who generate many hypotheses but few questions (Larreamendy-Joerns, Sandino, & Tascon, in press). Similar to everyday observers, less experienced biologists may generate explanations before collecting all of the available data.

Both how- and why-questions are necessary to questions of biological causation that occur within the time scale of the observational activity as well as the evolutionary history of the organisms (Gould, 1986, 2002; Haila, 1992). Whereas how-questions focus on current conditions and concern immediate causations (e.g., how does an organism function?), why-questions focus on the evolutionary factors that account for all aspects of living organisms over time and concern ultimate causation (e.g., why are some organisms comparatively similar and others so dissimilar?).

Each type of question is critical to Gould's argument that proper taxonomy requires that the phenomenon must be identified and segregated, and that taxonomic ordering must reflect process and cause. Two of these questions are evident in the Alberdi et al (2000) study. For example, when botanists initiated observations by noticing a plant's features, they essentially sought to answer the question, "What is this?" It is also possible to infer that when plants did not meet taxonomic expectations, botanists activated a why-question as they made comparisons and searched for characteristics of common ancestry. Had the botanists been concerned about the distribution of these species, they may have generated questions about how floral structure affects seed dispersal. In this way, each type of question responds to the problem at hand and draws attention to critical aspects of the phenomenon.

2.1.3 Documenting Observations

The questions that biologists ask guide their observations and ultimately the data they record and collect. Many of these records are eventually transformed into inscriptions—written representations of phenomena—that allow scientists to ask different questions of phenomena. These may assume relatively identifiable forms (e.g., line drawings, models) as well as more abstract forms (e.g., diagrams, graphs, taxonomic trees, written descriptions). However stylized, inscriptions serve two primary purposes: to document phenomena and to support scientific understanding and discourse (Janovy, 2004; Latour, 1990). As stylized annotations, inscriptions both reduce and enhance information in order to highlight theoretically important features and relations, such as the field marks of birds or the distribution of populations that are not easily discerned when phenomena are observed in complex settings (Haila, 1992; Lehrer, Schauble, & Petrosino, 2001; Lynch, 1990; Myers, 1990).

Inscriptions necessarily reflect the theories, questions, and practices of each scientific discipline (Daston & Vidal, n.d.; Kitcher, 1984; Metz, 1995). For example, the stylized written descriptions used to support botanists who study relationships among kinds of plants, would be of limited use to ecologists concerned with the distribution of common species. Over time, inscriptions are refined and standardized, which is essential to the collective scientific enterprise but also to the comparative work of observational biologists. Imagine how challenging it would be to test and revise taxonomic hypotheses without strict disciplinary practices of representation.

Latour (1990) argues that inscriptions ultimately benefit scientific argumentation because they can be reduced to elegant geometrical equations. However, observational biologists interested in the emerging characteristics of organisms at different levels of natural systems may argue that there are points beyond which phenomena cannot be meaningfully reduced

(Dobzhansky, 1966; Gould, 2002; Kitcher, 1984; Mayr, 1997). It seems worth noting that biologists also document their observations by collecting the stuff of nature: fossils, preserved specimen, and living collections. Similar to inscriptions, the purpose of these collections is to preserve change and to support scientific communication and reasoning. Biological collections can serve these purposes because they include theoretically important specimen, which are representative of populations rather than attempts to include all of nature. The specimen in these collections are often reduced and enhanced in order to highlight critical features. For example, the pressed plant specimen in herbaria include only those features, such as floral structures, which support disciplinary knowledge and comparative reasoning. According to Latour, a collection's primary disadvantage is that it cannot be easily manipulated. However, certain biologists might count this fact among their principle advantages.

2.1.4 Productive Dispositions

Until now we have considered how the demands of the biological discipline affect observation. Here we consider how the interests and identity of individual biologists may also drive observations. For those biologists who are also self-described naturalists, the quest for knowing more about biology is often in response to a profound fascination with particular organisms (Futuyma, 1998; Gould, 2002; Greene, 2005; Janovy, 2004; Wilson, 1995). Dobzhansky, for example, was known to rearrange plans and travel far distances for the chance of seeing new species of fruit flies (Ayala, 1985). Whether described in terms of love, admiration, or raison d'être, the desire to understand particular organisms appears to be a motivating influence for sustained interest. Consider, for example, Gould's (2002) perceptive estimation of the habits of practicing scientists: "…[There is] hardly a natural historian, dead or alive, that has ever failed to locate his chief delight in the lovely puzzles, the enchanting beauty, and the excruciating complexity and intractability of actual organisms in real places" (p.1338).

Gould's insight alludes to the role that real organisms in real places may play in the development of a biologist's interests and identity. For some the sense of being a biologist can only be fully realized in the field (Janovy, 2004). But is it just raw nature at work here? Evidence suggests that informal interactions among biologists, in and out of the field, significantly contribute to forming and sustaining habits of attention (Bowen & Roth, 2007; Kohler, 2002; Larreamendy-Joerns & Sandino, 2002). Wherever these biologists gather, informal conversations soon focus on the observation of organisms: They talk about the organisms they are looking at now—often in excruciating detail—about the organisms looked for but not found, and about their plans for future looking. It should be no surprise that such deeply embedded observational habits—cultivated across settings and during years of profound curiosity—spill into a biologist's everyday activities (Janovy, 2004). This habit of observing cannot be simply switched on and off, so that everyday experiences like walking in a park or across a city become new opportunities for further looking and observation of the biological complexity all around.

To summarize, observational systems use specific practices and tools to address specific questions and problems (Haila, 1992). These systems are made up of components that are necessarily interrelated: The nature of the phenomena and the disciplinary framework inform the biologist's questions, which in turn, affect how data is collected and represented. In addition, these habits of practice may interact with a biologist's identity and observation of the everyday natural world. The components making up any observational system necessarily reflect specific disciplinary problems, questions, and habits, so that the actual combination of components may be different from those highlighted here. Nevertheless, the practice of scientific observation may be described to include: noticing, theoretical expectations, observational records, and productive dispositions.

2.2 CHILDREN'S EVERYDAY OBSERVATIONS

Having explored what it means to observe like an expert biologist, we now consider what it means for children to observe like everyday observers. What do we mean by everyday observation? Typically, everyday has been positioned as being qualitatively different from scientific, whether it is knowledge (Driver, 1994; Gopnik, 1996), explanation (Brewer, Chinn, & Samarpungavan, 2000; Keil & Wilson, 2000), argumentation (Bell, Bricker, Lee, Reeve, & Zimmerman, 2006; Smith & Reiser, 2005), or observation (Daston & Vidal, n.d.; Park & Kim, 1998; Vosniadou & Brewer, 1994). From this perspective, everyday observations are practical and possibly intuitive experiences that both derive from and inform daily life—understanding that "sweaters keep us warm even though a sweater sitting on a table is not warmer than the surrounding room" (Chinn & Malhotra, 2002a, p. 339), or awareness that some objects sink and others float (Penner & Klahr, 1996). Others have argued that positioning everyday in contrast to scientific is potentially pejorative and negates the generative nature of everyday cognition, which is an entity in its own right and which occurs in the normal cycles of life (Lave, 1988; Warren, Ogonowski, & Pothier, 2005). Adhering to a scientific concept of everyday observation, we might adopt Mayr's (1997) use of simple observation to identify those that are largely descriptive and non-causal in nature. For the purpose of this paper, we define everyday observations as those that occur with little or no knowledge of the constraints and practices of scientific disciplines.

Our distinction is not intended to diminish observations that occur in everyday contexts for everyday observation can be a powerful mechanism for learning.

Cross-cultural research reveals that children everywhere make observations in order to learn about their everyday world (Goncu & Rogoff, 1998; Rogoff, 2003; Rogoff et al., 2003; Scribner & Cole, 1973). Consider that, from children's earliest development, active observation and emulation of others—with little or no explanation—is key to learning cultural norms and practices, including early language development, human behavior, and the manipulation of tools and objects (Falk & Dierking, 2000; Gopnik et al., 1999; Rogoff et al., 2003; Tomasello, 1999).

Yet, however universal observation is to children's learning it is also influenced by and practiced within cultural contexts. For some children, observation, in concert with participation in shared endeavors, is the primary means for learning the skills, values, and mannerisms of their culture (Philips, 1972; Rogoff, 2003). Rogoff (2003) notes that in cultures where children participate in community activities, they are expected to be simultaneously alert to many things and to learn activities through keen observation and emulation. In comparison, in cultures where observation is not the primary source of learning, such as that of U.S. middle class families, children are encouraged to observe one thing at a time and to rely on explanations more than observation to learn everyday activities. For example, U.S. parents routinely assume responsibility for explaining their children's observations during shared activity in everyday settings (Ash, 2003; Callanan & Oakes, 1992; Crowley et al., 2001).

Although considered powerful in everyday cultural contexts, when considered within scientific contexts, children's observational skills are portrayed as unsystematic, unfocused, and unsustained (e.g., Chen & Klahr, 1999; Keys, 1999; Klahr, 2000; Kuhn, 1989; Kuhn, Amsel, & O'Loughlin, 1988; Kuhn, Garcia-Mila, & Anderson, 1995; Roth, Campbell, Lucas, & Boutonne, 1997; Schauble, 1990, 1996). In such contexts, children might be described as classic "dust-bowl empiricists" who make lots of observations but have trouble encoding evidence, making valid inferences, and connecting observation to theory. Accordingly, children's everyday observations have been shown to do little work towards building complex scientific understanding of natural phenomena (Ford, 2005).

To better understand what kind of everyday observers children are in scientific contexts, we examined the scientific reasoning and science education literatures in which observation was either the focus of the research or at least played a key role in the research task. The following is organized across three of the dimensions identified as components of expert scientific observation: noticing, expectations, and observational records. The fourth component, productive dispositions will be explored in the next section.

2.2.1 What Children Notice

Perception is a fundamental aspect of scientific observation, whether the observer is an expert or novice. Whereas scientists notice multiple dimensions of phenomena—meaning microscopic and telescopic, novel and familiar, surface and abstract—children typically notice "middle-sized, close, perceptible, and familiar objects" (Gopnik, 1996, p.492). We see evidence of this in observation tracking tasks in which infants notice and imitate facial expressions or attend longer to anticipated behaviors of nearby people and objects (Gopnik et al., 1999; Meltzoff, 1988, 2005). This pattern of perception is also consistent with findings from environmental psychology and cultural geography in which young children are more apt to notice separate objects in familiar landscapes—a tree stump, bubbling water in a section of a stream—rather than complex systems or distant landscapes (Hart, 1979; Tuan, 1974).

Even as children mature, they tend to notice phenomenological features and events narrowly and do not spontaneously notice aggregates such as populations, distributions, hierarchical orders, or complex systems. Consider that seventh graders typically mentioned only one morphological feature when comparing differences between two fish (Hmelo-Silver & Pfeffer, 2004), or that fifth graders spontaneously focused on individual plants rather than populations when tracking plant growth (Lehrer & Schauble, 2004), or that sixth graders had difficulty connecting their observation of termite behavior occurring at the microlevel with events at the macrolevel (Penner, 2001). These examples are not exceptional: The scientific reasoning and education literatures provide ample evidence that children are more likely to notice isolated instances of evidence than they are to consider all of the available evidence, prompting Klahr (2000) to conclude that what children consider to be sufficient evidence to support a hypothesis is frequently inadequate. Similarly, in studies using an experimental model, children typically consider only a portion of the possible variables to manipulate (Klahr, Fay, & Dunbar, 1993; Penner & Klahr, 1996; Schauble, 1990) or the possible experimental results to observe (Karmiloff-Smith & Inhelder, 1975; Schauble, 1990). For instance, children often notice final experimental results without attending to causal interactions that occur along the way (Schauble, Glaser, Raghavan, & Reiner, 1991; Smith & Reiser, 2005; White, 1993). These examples represent just the tip of a much larger iceberg: Across settings and ages children seem predisposed to arbitrarily noticing phenomena.

Why do they do this? Some might argue that young children are concrete thinkers who focus on the salient features of phenomena because they cannot reason about abstract, underlying causal connections (Flavell, 1985; Tversky, 1985). If this were true we might expect that, with increasing age, a child’s attention would be more evenly distributed between noticing surface features and recognizing underlying relationships. Evidence suggests otherwise. Consider, for example, that children's explanations typically stress observable biological processes such as behavior and growth with little mention of underlying causal principles, whether the children are in grades 2, 5, 8, or 12 (Abrams, Southerland, & Cummins, 2001). Likewise, both novice middle school students and novice teachers focused on an aquarium's structural elements (e.g., sand, fish, plants) but failed to recognize how these components also simultaneously functioned as parts of a complex and dynamic system (Hmelo-Silver, Marathe, & Liu, 2007; Hmelo-Silver & Pfeffer, 2004). Thus, difference in age alone is insufficient to account for this observational pattern.

A more satisfactory explanation is that children tend to focus on the surface features of phenomena because they lack domain knowledge (Chi, Hutchinson, & Robin, 1989; Johnson & Mervis, 1994, 1997) and because many phenomena are too complex to explain without discipline-specific knowledge (Driver, 1983; Woods-Robinson, 1995). The degree to which children notice surface or deep features is related to the extent of their associated knowledge. For example, Johnson & Mervis (1994) found that 5-year-olds with little knowledge of shorebirds compared different birds by referring exclusively to morphological features such as size, color, and shape. As their knowledge about shorebirds developed, so did their ability to notice and coordinate multiple physical and behavioral attributes into patterns that supported grouping shorebirds around abstract concepts of form and function and natural order. In particular, more knowledgeable 5-year-olds developed the ability to notice and compare multiple occurrences of features such as bill and toe structures, which in turn, supported inferences about functional behavior and categorical relationships among shorebirds that distinguish them from other kinds of birds.

So what can everyday observers learn from simple observation in the absence of prior knowledge? A study in which 12-year-old novices conducted self-directed observations of brine shrimp suggests that, while this activity may stimulate children's curiosity and interest, the potential for learning is limited (Tomkins & Tunnicliffe, 2001). As might be expected, children primarily noticed the most salient features and behaviors of the shrimp. They generated lists of features, such as noticing differences in color and shape, but missed opportunities to make connections, such as failing to associate color and shape with differences in the sex of the shrimp. Their observations also reinforced misconceptions (i.e., students misinterpreted mating behavior for child rearing practice) and a tendency to infer meaning from only a portion of the evidence. When children have little or no knowledge of biological phenomena, they are reduced to compiling lists of isolated instances. Such lists are poor measures of learning, particularly as children indiscriminately include both relevant and irrelevant features (Driver, 1983; Ford, 2005; Keys, 1999). When children are cast into an activity with inadequate knowledge and instructional support, observation becomes a weak method for collecting data rather than a powerful method for reasoning scientifically.

In short, everyday observers fail to notice the right things. Instead, they notice many irrelevant features and behaviors that fail to forge connections or to support deeper understanding of complex phenomena. Disciplinary knowledge, however, can filter, focus, and foster understanding.

2.2.2 Expectations and Evidence

It should come as no surprise that children's everyday expectations are closely associated with what they notice. Children's everyday expectations arise from their empirical observations of everyday life (Vosniadou & Brewer, 1992, 1994), often coinciding with periods of intense observation and experimentation (Driver, 1983; Gopnik, 1996). Through repeated exposure children begin to expect objects and phenomena to behave in ways that conform to their direct observations. For example, a child plays with rubber ducks and soap in the bathtub and comes to expect that heavier objects will sink and lighter objects will float. Although observations like these are experimental in nature, children also form expectations about phenomena they cannot manipulate. For example, night after night a child looks at the sky and comes to expect to see the moon and stars when night falls. And while it may be true that perception plays a proportionally larger role for younger children (Gopnik, 1996), observation of phenomena and the inferences drawn from observation continue to play a critical role in the development of children's everyday expectations, even as other sources are incorporated (Duschl, Schweingruber, & Shouse, 2007).

The relationship between observation and expectations is not unidirectional, however. Children's expectations also influence what they do and do not notice. Expecting to see the moon only in the night sky, children often fail to see the moon in the morning sky (Vosniadou & Brewer, 1994). So it would seem that children see the world through their own "conceptual spectacles" (Driver, 1993, p.5). This tendency of seeing what one expects to see, which Klayman & Ha (1987) refer to as confirmation bias, suggests that children actively seek evidence that supports their expectations and ignore evidence that is contradictory. This tendency is apparent in a classic study in which Karmiloff & Inhelder (1975) asked young children to balance blocks, some of which could be balanced on geometric center and some of which had hidden weights and could not be balanced on geometric center. Expecting that "things balance in the middle" children tried to balancing each block at its geometric center, even though multiple attempts failed. Furthermore, they ignored observations made during an earlier exploration of the blocks' properties in which they had successfully balanced the blocks. Why could they balance the same blocks in one instance but not in another? It is possible that when children had only weak expectations about the blocks' properties they could explore the blocks, observe their behavior, and balance the blocks. However, once children formed the expectation that "things balance in the middle," they excluded contradictory observational evidence from consideration and persisted in attempting to balance all blocks at their geometric center.

In addition to affecting what they notice, everyday expectations also influence how children initially structure a problem and decide which features may be important to observe (Schauble et al., 1991). This is evident in a study in which 10, 12, and 14-year-olds designed experiments to explore the properties associated with the rates at which objects sink (Penner & Klahr, 1996). Expecting that heavier objects sink faster than lighter objects, 78% of all participants started by comparing objects in which one was heavier than the other, although objects of different shapes, sizes, and materials were also available.

These examples make clear that everyday expectations may or may not conform to scientific explanations. A child might rightly expect to observe the moon in the night sky but mistakenly believe this is due to clouds blocking the sun (Vosniadou & Brewer, 1994). Regardless of scientific accuracy, expectations can be quite persistent and pose a significant challenge to whether or not children successfully coordinate what they see with what they expect.

The ability to critically evaluate evidence in light of one's expectations is considered to be the hallmark of scientific reasoning (Feyerabend, 1965; Finley, 1982; Norris, 1984) and to be evidence of conceptual change (Kuhn, 1989; Kuhn et al., 1988). There is general agreement that young children can distinguish hypotheses from evidence and can make judgments about evidence. Children are greatly aided in these endeavors by prior knowledge, or in the absence of prior knowledge, when the hypotheses are plausible (Fay & Klahr, 1996), the variables are few (Sodian, Zaitchik, & Carey, 1991), and the phenomena provide clear feedback (Klahr et al., 1993).

Of course, everyday environments rarely—if ever—include few variables or provide clear feedback: Everyday environments are complex, populated with vast, diverse, and dynamic phenomena. Without sufficient knowledge or experience, it is extremely difficult for everyday observers to meaningfully decipher such overwhelming complexity, whether looking at the morphological features of fish in a school lab, birds in flight, or the moon in the night sky. This inability to decompose complexity into smaller and smaller parts may make it more likely that everyday observers will impose personal beliefs and expectations onto the phenomena. What's more, it may be more difficult for children to evaluate their observations or to modify robust expectations in contexts similar to those in which their expectations were formed initially (Penner & Klahr, 1996; Sodian et al., 1991).

Thus, the combination of complex phenomena, robust expectations, and the tendency to seek confirmatory evidence complicates the ability of children to critically evaluate observational evidence. Furthermore, prior expectations assume greater influence on what individuals see when sensory stimuli are difficult to decipher (Brewer & Lambert, 1993). This dynamic relationship is evident in the Penner & Klahr (1996) study in which observations and the interpretation of observations were influenced by the firm belief that weight causes objects to sink at faster rates. Recall that participants designed most of the experiments to compare the sink rates of heavier and lighter objects. Ironically, many comparisons were between objects with negligible differences in weight (e.g., 0.9, 0.5 grams) or sinking times (e.g., 0.8, 0.6 seconds).

The resulting similarities in weight and appearance would challenge any observer to detect such subtle differences. Yet, many participants reported observing heavier objects to "sink a little faster" and attributed faster sinking times to small differences in weight, a tendency that was more frequent among 10-year-olds (72%) and significantly less so among 14-year-olds (20%).

So it would appear that when phenomena are difficult to observe, children simply default to what they expect to see. However, this is not necessarily the case, especially when children have expectations with varying degrees of robustness. Consider a study in which fourth graders observed two rocks of similar size that were dropped simultaneously to the ground (Chinn & Malhotra, 2002a). Given the inherent weakness of the stimuli, it seems likely that all children would favor seeing what they expected to see. And, in fact, 72% of students who made the scientifically accurate prediction that the rocks would reach the ground simultaneously reported observations that matched their predictions. However, students who predicted that the rocks would reach the ground at different times were more likely to record an observation that differed from their prediction. Why the difference? The researchers hypothesized that student who made the scientifically accurate prediction had schemas which enabled them to "detect faint signals" of an existing pattern. If true, this might also suggest an alternative explanation: One group's beliefs were more entrenched than the other. Once a belief becomes entrenched, it is increasingly difficult to respond to surprising observations and to modify one's expectations (Chinn & Brewer, 1992, 1998). In scenarios where phenomena are so similar in appearance, we would expect students with strong beliefs to make observations that match their predictions. On the other hand, students with less entrenched beliefs might be expected to observe a range of possible results, including those that differ from their predictions.

The ways in which the children in these studies respond to surprising observations is far from remarkable. The tendency to seek evidence that supports one's expectations or to ignore, distort, or selectively observe evidence that contradicts preferred expectations is common, even among adults (Chinn & Brewer, 1992, 1998; Klayman & Ha, 1987; Kuhn et al., 1988). Nevertheless, observation plays a central and active role in how children and adults evaluate evidence (Brewer & Lambert, 1993; Driver, 1993) and can both impede and support conceptual change (Chinn & Malhotra, 2002a).

2.2.3 Using Observational Records

It is common knowledge that children spontaneously make drawings. Even when paper and pencil are unavailable, children find everyday materials such as sticks and dirt to sketch the world around them (Hart, 1979). In contrast, there is little or no evidence to suggest that children spontaneously record their observations of biological phenomena in out-of-school contexts. Even biologist E. O. Wilson, who spent countless childhood hours observing biological objects exhibited in natural history museums, did not chronicle his observations until later in adolescence (Wilson, 1995). It should not be surprising that children express little enthusiasm for recording their observations even when they are enthusiastic about making observations (Ford, 2005).

In fact, the science education and developmental literatures are rife with examples in which children make observations without productively generating or using records. Many times children either relinquish responsibility for recording data to others (Gleason & Schauble, 2000; Haslam & Gunstone, 1998) or fail to record observational evidence altogether (Garcia-Mila & Andersen, 2007; Schauble, 1990). For instance, during a shared experimental activity 9 to12-

year-old children recorded a mere 5% of the data whereas parents recorded 77% of the data (Gleason & Schauble, 2000).

It is also evident that children do not spontaneously use observational records in order to plan experimental strategies or to track data (Garcia-Mila & Andersen, 2007; Gleason & Schauble, 2000; Schauble, 1990), even when doing so positively correlates with experimental success (Siegler & Liebert, 1975). Nor do children spontaneously review or refer to observational records in order to derive meaning from experimental outcomes (Gleason & Schauble, 2000; Haslam & Gunstone, 1998; Klahr & Dunbar, 1988; Schauble, 1990). More often than not, children base inferences upon their own recall of events (Kuhn et al., 1995; Schauble, 1990) or from adult guidance (Driver, 1983; Gleason & Schauble, 2000; Haslam & Gunstone, 1996, 1998; Roth et al., 1997).

Even when children do record observations, their records do little work to support the development of scientific knowledge and reasoning. Keys (1999) noted that children fail to relate their observations to new hypotheses or knowledge claims. The missed opportunity for connecting recorded observations and scientific concepts may be due, in part, to the fact that children's observational records typically include information that is incomplete (Garcia-Mila, Andersen, & Rojo, in press; Haslam & Gunstone, 1998) or irrelevant to the experimental goals (Roth & McGinn, 1998; Schauble, 1990). We see evidence of this in a study by Ford (2005) in which third graders wrote highly detailed descriptions of rock and mineral samples, yet made few associations between their observations and deeper geological concepts. Their observations were both incomplete—individuals typically mentioned less than half of the eight possible observable properties—and featured geologically irrelevant properties (e.g., smell) and details unique to individual specimen (e.g., "mud on the bottom") rather than meaningful geological patterns (e.g., striations, layers). Interestingly, children's use of everyday language also constrained understanding such as when children's use of shape descriptors reflected everyday meaning (i.e., form) rather than geological meaning (i.e., cleavage). Sometimes children ignored the observed evidence and focused on making assertions and comments, suggesting they neither understood the purpose of observational records (Garcia-Mila et al., in press; Keys, 1999), nor the role of evidence in scientific argumentation.

Why is it so difficult for children to generate and use productive observational records that support scientific reasoning? Some research suggests that developmental constraints may be at work. After all, older children are more likely than younger children to generate notations, to produce notations that are increasingly recognizable, accurate, and complex, and which increasingly support problem solving and communication purposes (Eskritt & Lee, 2002; Triona & Klahr, 2006). Older children are also more likely to possess sufficient metacognitive awareness to recognize a need for creating and using memory aids (Garcia-Mila et al., in press; Siegler & Liebert, 1975).

However, there is substantial evidence to suggest that limited knowledge plays a more critical role (Roth & McGinn, 1998). Consider that the challenge of generating and using productive records is also common among older children and adults (Duschl et al., 2007). Children may simply not understand what is important to record due to lack of disciplinary knowledge, making identification of features or properties arbitrary, something students participating in Classroom FeederWatch possibly sensed when they judged their observations to be of little use to ornithologists. Likewise, other factors associated with knowledge may be at play, such as vague educational goals or research tasks (Driver, 1983; Triona, 2004), insufficient explanation about the record's purpose or protocol (Trumbull et al., 2005), and learner beliefs about the nature of science in which observations are perceived as fixed rather than subject to challenge (Norris, 1984; Smith & Reiser, 2005).

To summarize, children's everyday observations appear to be powerful in cultural contexts but weak and underpowered in scientific contexts. Children often attend to isolated instances of salient surface features and processes, which limits opportunities for making connections and building understanding of complex phenomena. It is very challenging for children to coordinate their expectations with observational evidence, particularly in environments that are complex or in which their expectations are especially robust. To be fair, this portrait is of children observing under knowledge-lean conditions, whereas authentic scientific observation is always situated in the context of disciplinary knowledge and practice (Daston & Vidal, n.d.; Norris, 1985).

2.3 LEARNING TO OBSERVE SCIENTIFICALLY

Can children learn to observe and reason more like scientists? Our review of the developmental and educational literatures might suggest that the answer is "no". Although they are often curious from an early age, and though they may learn some things through observation in ways that bear some interesting parallels to science, we see little evidence that most of children's observations are what we might consider scientific. Children may observe the things that interest scientists (e.g., plants, animals, insects), but the way children observe and the ways they use their observations to make inferences are not necessarily scientific.

We argue that children can indeed observe more scientifically when they learn deeper examples of biological knowledge and practice to support their reasoning. Too often, however, children are asked to observe, compare, and describe phenomena without adequate preparation. Doing so “belies the complexity and depth of disciplinary knowledge and reasoning associated with scientific observation” and ultimately produces “the minimal possibility of subsequent elaboration of deeper scientific knowledge” (Metz, 1995, p.118-119). Disciplinary knowledge, however, is not enough to successfully develop as scientific observers. Children also require supportive learning environments and tools.

In a supportive environment, children can develop the interest, knowledge, and skills that are necessary to transition from everyday observation to disciplinary-specific scientific observation. What kinds of learning environments support this transition? In many of the studies cited in this section, children often begin by making purposeful observations of biological phenomena and then, through a supportive and adult-scaffolded process, begin using these observations as a basis for investigation, argument, and explanation. This process typically involves building an intergenerational community of learners who co-construct shared knowledge, experiences, and skills. In this process, children explicitly learn to use the tools (e.g., comparison, questions, argumentation), and the representations (e.g., descriptions, graphs, maps) of a particular science. This general description of a learning environment is a model of science-as-practice—learners are engaged in authentic scientific thinking using real objects, tools, representations, and forms of argument and theory-building (Lehrer & Schauble, 2006). What would it look like if children were to make a transition from everyday to scientific observation? And how might this transition be facilitated? To address these questions, we have constructed a set of hypotheses of how observation might be transformed from everyday to increasingly scientific (Eberbach & Crowley, 2009). We lay out the pieces of this learning trajectory in Table 1, using birds as an exemplar organism.

Table 2.1. Observation Framework

	Everyday Observation (Novice)	Transitional (Intermediate)	Scientific Observation (Expert)
Noticing	Notice a bird is different from other organisms Notice more irrelevant than relevant features that distinguish one kind from others without explicit awareness Describe few features that may or may not conform to disciplinary structure Name kinds of birds, but naming doesn't do a lot of work	Notice more relevant features and identify patterns of features Use and describe features validated by others to identify birds (e.g., field guides) Connect features to function and behavior Name more kinds of birds Noticing stimulates related knowledge Name & organize birds into groups (shorebirds, birds of prey) by function and/or behavior Develop habits of attention that are more disciplinary specific than general	Notice & describe relevant features using disciplinary structure (e.g., taxonomy). Ignore irrelevant features Chunk observational information & use smaller search space for observation and grouping Name more birds (and at higher hierarchal levels) Identification and naming related to complex relationships and systems to identify bird and to organize it in a complex system Stimulates related knowledge Infer function and behavior from structure
Expectation	Vague expectations about observations Confuses the observational evidence with one's beliefs	More explicit expectations about birds that reflect plausible observation Explanations fluctuate between being more scientific & more everyday	Explicit hypothesis consistent with a theoretical framework shapes observation, search space, and documentation Skilled coordination of hypothesis & evidence
Observation Records	Observe without collecting or recording observations May cite a few factoids about a species	Record observations (e.g., use a personal list or journal) but begin to do so within disciplinary guidelines Compare personal data with other kinds of data Begin to use different representations of data	Record observations using established disciplinary procedures, standards, & representations Organize and analyze recorded observations Reason with observational data & representations
Productive Dispositions	Opportunistic and incidental observations Notice information about birds when it's easily available	Sustained engagement Intentionally talk about or seek out information and observations about birds Collects biological objects and related paraphernalia	Persistent, sustained engagement Love the organism

The four rows of the framework specify core dimensions of scientific observation. The first row, Noticing, is both perceptual and cognitive. As children move from everyday to scientific observation, the categories of what they notice about the world are more likely to correspond to those of a scientific discipline. Observations become more frequent and are more likely to be attached to labels that have scientific significance. The second row, Expectations, refers to the extent to which children coordinate their observations with big ideas and scientific theory. As children become more knowledgeable about a discipline, the ways they collect observations and the inferences children use to record and reason with observational data. As children become more expert observers, they are more likely to document their observations and to use a variety of representations to organize their observations. The fourth row, Productive Dispositions, refers to the extent to which children engage in sustained observation over time and in a variety of contexts.

For the remainder of this section, we use the observation framework to explore activities that support children's transition from everyday to scientific observers. Many of the following examples reflect the science-as-practice model and are intended to be suggestive rather than exhaustive.

2.3.1 Learning to Notice Scientifically

Question asking is an important heuristic used by biologists to navigate a complex world. A study by Smith & Reiser (2005) provides insight into how question asking can also be used to help students decompose and make sense of biological complexity. Working within a behavioral ecology framework, high school students used video data and computer software to observe and compare predator-prey behaviors of lion hunts. Question asking featured prominently among the various scaffolds. For instance, the teacher and the video software repeatedly modeled disciplinary specific how- and why-questions, which in turn, spurred an iterative cycle in which students noticed features and behaviors, asked more questions, and then re-examined and refined their observations across multiple video examples.

Differences between pre- and posttest performance suggested that question asking enabled students to notice critical features and behaviors that supported richer explanations. Specifically, their explanations identified and incorporated significantly more morphological and behavioral features to account for animal behavior after participation. In addition, the iterative nature of question asking and observation contributed to noticing recurring patterns and variations across multiple videos. For example, they compared animals of prey performing similar behaviors, such as stalking and chasing, and came to notice variations in how male and female animals captured prey. In contrast to everyday observers, these students filtered irrelevant evidence, focused on critical behaviors and features, and came to use the data as an aggregate rather than as isolated instances.

Question asking is also an important strategy for engaging young children in noticing the world around them. More often than not, these questions originate from children's interests and their observations of familiar biological organisms—rodents and crickets in Metz (2000, 2004) and apples and fruits flies in Lehrer, Schauble, & Petrosino (2001). One challenge that teachers faced in these studies was to strike a balance between children's questions and the demands of the discipline. The teachers in Metz's studies designed the environment so that children explicitly generated questions by observing animal behavior while they simultaneously learned zoological content and observational practices. Based upon their practical and content knowledge, the second and fourth/fifth graders then collectively created taxonomies of animal behaviors, which resulted in noticing more specific behaviors and generating new questions. By the end of the program, the majority of students used disciplinary heuristics to generate questions. In contrast, the teacher in the Lehrer et al (2001) study designed the environment so that children's questions were drawn from direct observations of phenomena and spirited classroom discussions. Throughout, the teacher carefully listened to children's comments and revoiced these into questions that reflected problems in plant biology. Similar to the prior examples, questions asking motivated a cycle of observation and investigation that led to the generation of new questions.

In addition to question asking, all three studies featured other scaffolds that supported noticing phenomena. First, each reduced complexity by constraining the environment (e.g., video segments, rodents contained in enclosures). Second, teachers were important mediators who modeled question asking and helped children to form questions that could be answered through observation. Third, learners conducted their observations in small groups, so that noticing was less of an individual process and more of a community practice.

What do these studies suggest about noticing? The selection of which phenomena to notice is not a matter of simply asking any question. Good questions stem from awareness of authentic disciplinary content, problems, and practices (Finley & Pocovi, 2000; Trumbull et al., 2005). When contextualized within disciplinary conceptual structures and practices, question asking can support disciplinary habits of attention that lead to complex reasoning. However, when questions are decontextualized from a discipline's concerns—such as wondering about the circumference of rocks (a question that has no place in any geological concept)—children cannot build meaningful conceptual understanding (Ford, 2005). Observational competence requires knowing the right questions to ask and the right evidence to notice (Norris, 1984).

2.3.2 Learning to Coordinate Expectations and Observational Evidence

Scientific argumentation is one of the many practices used by scientists to coordinate theory and evidence. Inscriptions are one tool in service of argumentation because they make public a scientist's reasoning and provide a platform for debate, elaboration, and challenge (Latour, 1990). Over the course of many classroom studies, Lehrer & Schauble have explored how inscriptions may be used to make explicit children's ideas and to understand how children reason with data (Lehrer & Schauble, 2001, 2004; Lehrer, Schauble, Carpenter, & Penner, 2000; Lehrer et al., 2001).

To better understand how inscriptions can scaffold children's scientific reasoning we turn to one study in which student-invented inscriptions helped fifth graders mediate their observations of plant growth and concepts of natural variation (Lehrer & Schauble, 2004). At regular intervals over an eight-week period, students observed and recorded the height of their individual plants. Eventually, the teacher posted the students' measurements and asked groups of students to organize and display the data so that it characterized the typical height of all the plants on a certain day. The process of graphing the data, and the ensuing discussions about which data to include, how to represent it, and how to interpret it, engaged students in scientific argumentation in which they had to explicitly state their expectations and explicitly connect their explanations to data. Through an iterative process of creating, explaining, and challenging how other students chose to represent the data, students came to observe and describe plant growth in ways that direct observation could not support. In particular, students gained a new understanding of plants as populations rather than as single cases.

As this study suggests, the use of inscriptions affords the opportunity to observe phenomena in new ways and to refine one's questions and inferences about that phenomena.

Furthermore, the challenge of deciding which data to include, how to represent it, and how to interpret it, forces children to articulate and to grapple with their expectations. This is important because articulating one's expectations is a necessary step towards theory change (Kuhn, 1989; Ohlsson, 1992).

2.3.3 Learning to Create Observational Records

Although our earlier review of the literature convincingly demonstrated that children typically do not create scientific records, examples from the research of Lehrer and Schauble as well as Metz suggest that children can and do generate observational records under certain conditions. Three factors appear to be critical to doing so: (1) the extent to which the record or inscription explicitly solves a problem that interests the child; (2) whether children use their own system of recording or whether they use systems created by others; and (3) mediation.

In order for children to generate field notes and to transform these into new formats the problem must be authentic (Chinn & Malhotra, 2002b). That is, observation of phenomena must be in the context of a problem that is of interest to the child as well as to the discipline. For instance, the teacher who used observational records to investigate rotting apples did so in light of children's questions and in light of plant biologists' interest in biological processes and ecological relationships.

Children's understanding improves when they generate their own notational systems rather than simply use an existing notational system, particularly when they have numerous opportunities to create, evaluate, and revise multiple forms of inscriptions (Lehrer & Schauble, 2004; Triona, 2004). Recall, for example, that when students created, explained, and challenged their own multiple representations of plant growth, they began to understand plant growth in terms of populations and distributions rather than as single occurrences (Lehrer & Schauble, 2004).

Because the generation and use of observational records is a learned practice, mediation by a more experienced person seems essential. According to Roth & McGinn (1998), children are more likely to generate observational records when the purpose is made explicit. Clearly, teachers serve this role in the classroom. In everyday contexts, parents may support their child's notational habits by helping them to understand which features are important to include and how well their notations communicate the intended purpose (Braswell & Callanan, 2003). Even so, it seems doubtful that children will generate observational records in everyday contexts. Instead, children are more likely to be users long before they are generators of observational records. Even a nature enthusiast like E. O. Wilson only refers to using field guides when he was in his teens, and then, only with a friend who was experienced with the use of field guides.

2.3.4 Developing Productive Dispositions

As previously noted, the interests and identity of individual biologists can drive their habits of attention and pursuit of knowledge. So, it may not be too big of a leap to imagine that children, who develop robust interests, also tend to look for and seek information about the objects that interest them. Metz (2004) noted this pattern when she attributed children's tendency to observe closely and to engage deeply for extended periods when they pursued their own questions about the behavior of rodents and crickets.

What supports the emergence and persistence of children's interests? To address this question, we once more turn to Stephen Jay Gould, who reflected on the motivations of observational scientists to study the natural world:

> We become natural historians because we loved those dinosaurs in museums, scrambled after those beetles in our backyard, or smelled the flowers of a hundred particular delights. Thus, we yearn to know, and cannot be satisfied until we do, both the general principles of how mass distinction helps to craft the patterns of life's history, and the particular read on why Pete the *Protoceratops* perished that day in the sands of the Gobi (Gould, 2002, p.1338).

Although this is the reminiscence of an expert scientist, we think that Gould’s comments offer insight into the development of biological interest generally. First, objects—be they beetles, flowers, or dinosaurs—are powerful sources of inspiration for observation and the desire to know more. Objects are often the catalysts that inspire opportunistic situational interest, but under the right conditions, can also support individual interest that fuels persistent, sustained engagement (Renninger, 1992). Recall Ford’s study of third graders learning about geological rocks and minerals (2005). An interesting thing happened as these children observed and described the study samples over several weeks: Some children began claiming samples as “my rock” and “my mineral.” Whenever possible, they purposely sought “their rock” from the sample set, imbued “their rock” with meaning, and carefully noted unique characteristics in order to recognize “their rock”. This seems like a missed opportunity: Could the situational interest of some children have been transformed into an individual interest had an adult noticed and supported this interest?

Second, Gould’s reflection also suggests something about the necessity for opportunity and external support to form and sustain individual interests**.** It would seem that Gould enjoyed generous access to nature and to scientific collections. Similarly, E.O. Wilson attributed his interest in biological organisms to long days wandering around the countryside or in the National

Museum of Natural History, often simply looking for hours at a time (Wilson, 1995). So it would seem that using free time to observe and engage with an object of interest is a condition for supporting a child's emerging interest (Leibham, Alexander, Johnson, Neitzel, & Fabiola, 2005).

Recent research into children's emerging interests in conceptual domains like science and technology suggests that sustained individual interests are distributed across contexts, people, and time (Barron, 2006; Renninger, 1992). Often, parents assume the role of providing opportunities, resources, and shared experiences (Crowley & Jacobs, 2002; Johnson, Mervis, Spencer, Leibham, & Neitzel, 2004; Korpan, Bisanz, Bisanz, & Boehme, 1997; Palmquist & Crowley, 2007). For James D. Watson, sharing bird watching activities, knowledge, and experiences with his father throughout childhood fueled an early interest in biology (Friedberg, 2004).

2.3.5 Summary

In this review, we have argued that authentic scientific observation is a complex and challenging enterprise that is always practiced within a disciplinary framework. The science education and developmental psychology literatures suggest that everyday and scientific observers notice, filter, and reason about the natural world differently: When in the hands of expert observers, observation plays a key role throughout the inquiry process, whereas everyday observers tend to apply observation primarily in the service of data collection. We have also argued that children can develop as scientific observers when they have the knowledge, tools, and experience to support their reasoning.

In order to explore how children learn to observe more scientifically, we have proposed a framework for thinking about how this transition might occur and presented examples that suggest hypotheses of what this transition might look like. Three qualifications seem important to note. First, each dimension described in the framework functions as part of a system, so that changes to one necessarily affect another. For instance, a child's emerging interest may stimulate finding out something about a bird, which in turn, may inspire asking new questions and noticing specific features or behaviors. Second, the intent here is not that young children become expert scientific observers, but that their observations can become increasingly more powerful, productive, and scientific in educational settings.

Third, although this journey began by reflecting upon the observation of birds during a school activity, the proposed framework is a general statement about scientific observation that would hold true across formal and informal learning contexts. Essentially, we have described a learning trajectory for the practice of scientific observation that may occur wherever and whenever children engage with biological phenomena. We offer the proposed framework as a tool for thinking about observation in the context of disciplinary practice and as a roadmap for future research.

3.0 METHODS

This chapter describes the design of the materials and methods of data collection and analysis used in this study. Section One describes the purpose for investigating parent interventions and knowledge and outlines the research questions. A description of the design of the study is featured in Section Two and an analysis of the data is laid out Section Three.

3.1 PURPOSE OF THE STUDY

The purpose of this study is to understand how parental interventions and disciplinary knowledge influence children's observations of biological phenomena during shared activity in an everyday learning context. In particular, we explore how differences in parent conversational style and knowledge of pollination biology could support a child's transition from an everyday observer to a more scientific observer.

Thus, this study presents an opportunity to extend both developmental and informal learning research about how parents scaffold children's emerging everyday and scientific knowledge during shared activity. Although parents may highlight evidence (e.g., features, behaviors, processes), engage in thematic talk, and build shared knowledge, they also miss opportunities to support the development of more powerful observations and deeper understanding of biological phenomena. Frequently left to their own resources in informal science education contexts, parents may need additional support to fulfill their role as primary teacher to their children, particularly when a parent's prior knowledge does not support deep engagement with the demands of scientific disciplines or when they simply do not use strategies that support a child's scientific reasoning.

More specifically, this study addresses the following research questions:

1. What is the effect of parent differences on children's observation of biological phenomena?
   a. What is the effect of parent conversational style on children's observation of biological phenomena?
   b. What is the effect of parent disciplinary knowledge on children's observation of biological phenomena?
   c. What is the relationship between parent disciplinary knowledge and parent conversational style to children's observations of biological phenomena?
2. Can parents, regardless of disciplinary knowledge, be trained to use a teaching strategy (i.e., elaborative conversational style) that can be implemented in informal learning contexts?

3.2 DESIGN OF STUDY

To address these questions, we designed a controlled study in which pairs of parents and children jointly observed pollination activity during a visit to a botanical garden. Parents were assigned to different knowledge conditions and then randomly assigned to either an elaborated conversational style condition or a control condition in which parents used their natural conversational style. The general sequence of the study involved recruiting parents, screening parent knowledge of pollination biology, assigning to knowledge conditions, randomly assigning parents to treatment or control conditions, and obtaining consent (**Appendix A**). Data collection of parent-child activity occurred during an observation event, which was preceded and followed by individual parent and child activities. A detailed description of the study's design is organized as follows: (1) Participants; (2) Study context and setting; (3) Observation event; (4) Parent activities and materials; and (5) Child activities and materials.

3.2.1 Participants

Seventy-nine parent-child pairs participated in this study. Consistent with family research conducted in informal learning environments, there were more mothers (n = 68) than fathers (n = 11). Overall, parents tended to be well educated and to be frequent visitors to museums. Ninety-two percent held a college or advanced graduate degree and 56% completed at least one college-level biology course. Although most parents (71%) visited museums with their family at least four times each year, only 24% frequently visited the museum where the study was conducted. This suggests that while museums were familiar environments, the study's setting was a relatively novel environment for the majority of study participants.

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 we expected that prior experience at home and at school would make it more likely for children to have knowledge that could support more complex observations and talk. Children were not recruited to distribute difference in gender, as this was not the focus of the study.

Parents and children were primarily recruited from visitors to two informal learning organizations where families with interest in nature activities or gardening might gather. During recruitment, 105 parents volunteered to participate in the study, of which 92 parents completed all recruitment activities. Of those, eleven parents withdrew from the study prior to the observation event due to scheduling conflicts, lack of interest, or illness. In addition, two families were eliminated from analysis: one family due to equipment failure and the other because the child did not understand the study's tasks. Families received two free museum passes for their participation.

3.2.2 Study Context and Setting

This study focused on parents and children as they jointly observed authentic episodes of pollination, which is a key biological process fundamental to understanding biodiversity. At its most basic, pollination is moving pollen from stamen to stigma. At more complex levels, pollination reveals intricate ecological relationships between plants and animals. Pollination provides fertile ground from which families can notice and elaborate upon observable features, behaviors, and processes—from simply identifying flower parts and pollinators, to talking about the apple in the lunchbox, to supporting explanations about form and function. Given its accessibility in home and school environments, the topic of pollination can serve as an important platform from which families might make more powerful observations that support deeper understanding about biological structures, processes, and functions. Finally, pollination occurs in minutes, making it particularly suitable for exploring shared parent-child activity in an informal learning environment.

The study occurred at the outdoor Discovery Garden of Phipps Conservatory and Botanical Garden during summer (July through September), 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) that are connected by a winding pathway along which visitors can brush up against plants in an array of colors, textures, and floral structures. Plants were selected and designed to attract bees, butterflies, and other pollinators, all of which frequently populate the garden, resulting in many opportunities for flowers, pollinators, and pollination events to be easily observed.

3.2.3 Observation Event Materials and Activities

Each parent-child pair participated in the observation event, during which time they observed living plants and pollinators. In order to increase the opportunities for seeing pollination events, participants were asked to visit four adjacent garden areas. To allow for the vagaries of pollinator activity and to be consistent with informal learning practice, families could visit these areas in any sequence, could engage deeply or superficially according to their interests, and could return to any area as desired so long as they visited each area. After completing this sequence, participants were asked to visit a fifth area, which featured a table with a large-scale flower model (a median section of atypical 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 event, each participant was given a magnifying lens and instructed in its use. The researcher then 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. It addition, the researcher reminded the parent to talk with their child according to prior instruction (details to be described in the following section). Finally, in order to frame their activity in the garden, both parents and children heard the final instruction: “You can learn a lot about bugs and plants by looking for and talking about pollination together.”

Each observation event 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 gestured towards or appeared to be observing. All participants observed at least one pollination event as confirmed by video analysis. Observation events lasted for an average of 14 minutes, 40 seconds (*SD* = 3.56) and ranged from approximately 6 minutes to 25 minutes.

3.2.4 Parent Materials and Activities

This section describes the independent variables used to define study conditions as well as the materials used to assess parent knowledge, to train parents randomly assigned to the treatment condition, and to solicit parent interests and reactions to the observation event.

3.2.4.1 Parent Knowledge Conditions

All parents completed a Knowledge Survey that was used to assess observational and disciplinary knowledge of pollination biology and to assign parents to different knowledge conditions (Appendix B). The survey was piloted using a sample of 65 adult visitors to a botanical garden and consisted of three parts: (1) feature analysis; (2) declarative knowledge; and (3) theoretical relationships. In part one, 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. In part two, parents responded true, false, or unsure to seven statements about pollination biology. In part three, parents were asked to describe and explain observable form and function relationships that appeared in two sets of floral images.

Researchers conducted the survey in person or via the telephone, read the questions aloud, and recorded parents' responses. In each case, parents had access to the same images and viewed them in the same sequence. When surveys were conducted via telephone, parents accessed the images via their home computer. Parents' responses were scored using a predetermined scoring system, which could potentially range from 0-42 points, with part one accounting for 31 points, part two for five points, and part three for six points (**Appendix C**). Based upon the pilot survey scores, scores of 14 and greater were assigned to the high knowledge condition and scores of 13 and smaller to the low knowledge condition.

Actual parent scores ranged from 5-28 points (M = 13.54, SD = 5.178).[1] Two researchers coded all of the surveys; interrater reliability was 95% and differences were resolved through discussion. Parents were assigned to high knowledge (n = 40) and low knowledge (n = 39) conditions based upon their Knowledge Survey score. 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), which are discussed in the following two sections.

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[1] Midway through data collection it became evident that the knowledge scores were converging toward the mean. In order improve the chance that there could be sufficient variance between knowledge conditions, only parents who scored 9 and lower or 18 and higher were accepted into the study from that time. As a result, six parents completed the survey but were not accepted into the study.

3.2.4.2 Treatment Conditions

Parents in the treatment condition received training in the four elaborative conversational style strategies described in Boland, Haden, & Ornstein (2003). When parents used these strategies during a shared activity in that study, preschool children recalled more features and described them in greater detail than children whose parents did not use these strategies. Of particular interest to the current study, the four strategies appeared to help children focus on and encode critical aspects of objects and events, to draw out what children noticed, and to extend parent-child talk in time, substance, and understanding. The four strategies are to:

1) *Ask Wh-questions.* Parents were instructed to use open-ended questions that begin with what, when, where, why, who, or how in order to draw the child's attention to specific aspects of objects or events, solicit information from the child, and help the child to make sense of the objects and events that they notice.
2) *Link present to past experiences.* This strategy involved making connections between what is happening during the activity and what a child already knows or has already experienced.
3) *Focus the conversation on the child's interests*. Here parents based conversations on objects and events that the child appears to be showing interest, particularly things the child is already looking at, touching, or talking about.
4) *Provide positive feedback.* In this strategy, parents explicitly acknowledge the child's observational and content contributions to the conversation.

Training involved a two-step process similar to the one developed by Boland, Haden, & Ornstein (2003). Approximately one week prior to the observation event, parents received an eight-page pamphlet that described and illustrated the four conversational strategies (**Appendix**

D). 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 conservations with their child.

Immediately prior to the start of the observation event, parents watched a 12-minute DVD that showed examples of parents applying each of the conversational style strategies with their child during a visit to a natural history museum. The training materials were modified from the Boland, Haden, & Ornstein (2003) study in several ways: (1) each focused on parent conversational style to support children's observation and understanding of biological phenomena; (2) each featured authentic objects and disciplinary content within a natural history context; and (3) each included mothers and fathers as well as school-age children.

Parent Interview & Questionnaire. Prior to the observation event, parents were interviewed to ascertain if they had read the pamphlet and understood the strategies. Thirty-one parents stated they had read the pamphlet twice as instructed. However, eight parents reported reading the pamphlet only once and were asked to immediately read it once more, which they all then did. When asked, all parents were able to identify and describe the four strategies. Following the interview, parents watched a 12-minute DVD on a Macintosh Powerbook 17" screen computer and wore headphones in order to minimize distraction from other visitors. Once the DVD ended, a researcher answered any questions about the conversational strategies and then instructed the parent to incorporate the four strategies into their natural conversational style as they engaged in the observation event with their child. A second researcher at the start of the observation event repeated this instruction.

Following the observation event, parents completed a questionnaire (**Appendix E**) consisting of four parts: 5-point Likert scales rating the parent's interests, knowledge, &

experiences; 5-point Likert scales rating the child's interests, knowledge, & experiences; and demographic questions related to parent education and museum experience. The fourth part included 5-point Likert scales rating the usability of the strategies and an open-ended question about the potential value of the strategies.

3.2.4.3 Control Conditions

In order to compare parents' naturalistic style with that of the elaborative conversational style of the treatment condition, parents in the control condition received no training and were instructed to talk with their child using their natural conversational style. A second researcher at the start of the observation event repeated this instruction. Parents also completed a questionnaire in which questions about demographic information and the interests, knowledge, and experience of the child and parent were identical to those in the treatment condition (**Appendix F**). Unique to the control condition, however, the questionnaire included open-ended questions about parent reactions to the observation activity and 5-point Likert scales rating the observation event and their interest in future parent training. Parents completed the questionnaire as pre and post activities for convenience.

3.2.5 Child Materials and Activities

At the same time that the parent carried out activities prior to and after the observation event, another researcher interviewed the child at a nearby table in the garden. The interviews were situated so that the child and parent could easily see each other but could not overhear one other. One researcher conducted all of the child interviews, which consisted of a core set of tasks and two counterbalanced sets of semi-structured questions (**Appendix G**).

3.2.5.1 Core Tasks

Children completed five tasks, which included photo sorts, observations of a living flower, and an activity using the flower model and pollinator puppets described previously. The tasks were repeated prior to and after the observation event in order to investigate the effects of conversational style and parent knowledge on which features and events that children notice and how they reason about these. Thus, the tasks were designed to provide children with multiple opportunities to: (1) identify, describe, and draw out the observational evidence that they noticed; (2) to observe and compare more complex aspects of phenomena; and (3) to explore children's reasoning about pollination-related phenomena. The specific purposes, materials, and protocols for each task are described below.

The first task involved a photo sort designed to elicit children's understanding of pollination and supporting evidence such as features of organisms, proximity of pollinators to plants, and environmental conditions. Materials included eight 4"x6" laminated digital images, of which four 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 four depicted scenes unrelated to pollination (i.e., bees on a peach, a butterfly resting on a leaf, a bee resting on a closed flower bud, and a bee on a leaf but with a flower nearby). Some images had been digitally manipulated in order to alter the prominence or placement of some features. The researcher laid all photos onto the table in a random order and asked the child to sort the images into a pollination pile and a non-pollination pile. Children were encouraged to look carefully, to handle the images, and to take as much time as needed. After looking at all eight images, children sorted the images into the two piles and then identified which pile was pollination related and which pile was not pollination related. At the researcher's request, children selected the pile they wanted to begin the interview with. The researcher asked children to explain why they sorted these images into this pile. In order to understand which features and behaviors influenced their choice, the researcher probed what they noticed that affected their decisions, and whether they noticed anything specifically about the flowers or insects. This procedure was then repeated for the second pile. [Children occasionally changed their answers about which group a specific image belonged during the follow-up probes. These changes, and children's explanations for these changes, were the final reported responses.]

The second task involved a photo sort activity intended to further elicit deeper levels of knowledge associated with what children notice and how well children can coordinate perceptions of phenomena with expectations. Materials included two laminated 4"x6" digital images that appeared to be the same close up image of a bee flying near the pistil of a single day lily flower. However, one image included the flower with its stamen darkened but in tact, whereas the other image had been modified to remove the stamens' anthers. The researcher laid the photographs on the table in a random order and asked the child, "Could a bee pollinate these flowers?" Once the child responded, the researcher asked the child to explain their choice.

The third task was designed to explore whether children could distinguish observation from inference. It involved the observation of a single living flower (i.e., *Fuchsia spp. or Anemone japonica*) plucked from the garden adjacent to the interview site. To begin, the children were invited to look at, touch, and smell the flower. As children explored the flower, the researcher asked a series of yes/no questions that began with "Just by looking at this flower, can you tell if … (insert statement). Each response was followed by a request to explain how they knew that this flower (insert statement). To ensure that children understood the actual task, the researcher began by asking each child to describe the color of the flower and then asked, "Just by looking at this flower, can you tell if it's (insert color)?" Only when children understood the activity's premise, did the researcher proceed with four other statements, of which one could be directly observed (i.e., if the flower has pollen), two could be inferred but not directly observed (i.e., if the flower is making its own food; if the flower must contain nectar); and one could be either inferred or observed (i.e., if the flower came from California).

Using the same living flower, the fourth task provided an additional opportunity to extend deeper, specialized knowledge and explanation relevant to form and function. While holding the flower, children were encouraged to imagine how a hungry bee would look for something to eat in *this* flower. Once children responded, the researcher followed up with additional questions in order to probe for specific features that a bee might notice in the search for food.

The fifth task used the same large-scale flower model and pollinator puppets described in the observation event. This task was included to explore children's awareness of pollination as a biological process and the relationship between form and function. The researcher asked the child to imagine that a friend wants to know something about bees visiting flowers and then invited the child to use the model and puppets to help their friend understand. As needed, children were prompted by questions about what they would show their friend and what would they say to their friend.

3.2.5.2 Child Interest Questions

Pre and post interview questions and were asked to increase children's comfort during the interview and to ascertain the child's interests, opportunities for prior related experiences and knowledge, and their familiarity with the concept of pollination. Each set consisted of three, counterbalanced yes/no questions that could be probed for more detail. Once all post-interview questions were completed, children were asked if they had previously learned about pollination, and if so, to describe the sources of that knowledge.

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 child interviews lasted a total of 12 minutes, 38 seconds and ranged from approximately 7 minutes to 18 minutes.

3.3 CODING AND ANALYSIS

Three main coding passes were conducted in order to explore the research questions. First, to understand the effect of treatment on parent talk, codes were developed to describe the kinds and amount of elaborative conversational strategies that parents generated during the observation event. Second, to understand the effect of parent knowledge, codes were also created to describe the nature and amount of disciplinary content talk that families generated during the observation event. Third, to address children's learning, pre- and posttest measures were developed and are included with the results for the children's tasks. Finally, a model of parent-child observation was proposed and evaluated using regression analyses.

Data were transcribed and verified from the videotaped data of parent-child interactions during the observation event and from child pre-post interviews. Individual coders conducted reliability using both transcripts and videotapes. After an initial coding pass by one researcher, a second researcher coded 20% of the data to verify the reliability of the coded data. Interrater agreement was at or above 87% for all coding categories, and all differences were resolved through discussion.

3.3.1 Parent Elaborative Conversational Style

Coding and analysis of data focused on describing and quantifying the effect of training on parent talk as evident during parents' use of the four conversational strategies during the observation event. These strategies included: asking *Wh*-questions, focusing talk on child's interests, linking present to past experiences, and offering positive feedback for child participation and contributions to the activity.

Coding drew upon the categories identified in Boland, Haden, & Ornstein (2003). However, because coding was not made available from these researchers, the coding plan used in this analysis reflects how parents applied the four conversational strategies during the observation event.

The coding plan 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. See **Appendix H** for details of the coding plan.

3.3.2 Parent Disciplinary Knowledge

In addition to the structure of parents' conversational style, elaborative conversation must also account for content (Abu-Shumays & Leinhardt, 2002; Leinhardt & Knutson, 2004). Coding and analysis of parent disciplinary knowledge concentrated on describing and quantifying disciplinary talk and practice as these occurred during the observation event.

We developed a Pollination Model (Table 3.1) that reflected the sub-disciplines of systematics, ecology, and evolutionary biology that comprise pollination biology (Estes, Amos, & Sullivan, 1983). Thus, the model emphasizes the morphology of plants and pollinators as well as their ecological and historical relationships. In addition, the model's scientific content was contextualized for everyday science talk so that coding reflected what families observed in the garden rather than what experts may have observed. In short, this is an emergent model that is simultaneously grounded in disciplinary practice and in the everyday science talk of families.

The structure of the model was informed by Machamer, Darden, and Craver's (2000) analysis of the concept of mechanism which can be understood in terms of the between entities and activities that make up phenomenological processes. The columns organize the conditions under which pollination can occur (Set Up Conditions), the relationships that make pollination possible (Intermediate Activities), and the resulting biological states (Termination Conditions). The three rows specify the three essential entities of pollination—plants, pollinators, and environment. The first two rows refer to the two organisms required for insect-driven pollination to occur. Environment refers to the temporal, spatial, and ecological relationships between these entities.

Table 3.1. Pollination Model

Set-Up Conditions		Intermediate Activities	Termination Conditions	
Entity/Structure	**Properties**	**Pollen Transfer (process)**	**Actual State of Post-Pollination**	
-Plant -Flower -Kind -Petal -Pistil -Stigma -Stamen -Anther -Pollen -on anther -outside -Nectar - base of petal/pistil	-Petal Color -bright -outer/inner color change -Petal Lines (*nectar guides*) -Floral Shape -Floral Scent -Pollen availability -Nectar availability	-Pollen moved from stamen *(anther)* to pistil *(stigma)* -Pollen is moved between same kinds of flowers -Gets nectar -uses proboscis / long tongue -Floral Rewards -Pollen as food source -Nectar as food source	-Fertilization -Fruit develops *(ovary swells)* -Seeds develop as the result of pollination / fertilization.	-Petal Color (faded, dull) -Petal Fallen off, missing -Scent (faded, none) -Pollen absent
-Pollinator/Insect -Bee -Kind -honey -bumble -sweat -other -Butterfly -Kind -monarch –other -Moth -Ant -Other	-Hairy, fuzzy body -Leg of bee/butterfly -hairy, fuzzy -pollen sac -Proboscis -Long tongue/ straw -Ability to see floral patterns -Ability to smell floral scent	-Gets pollen -Picks up pollen on body -Move / carry pollen (from flower to flower) -Transfer pollen from flower to flower -Unintentional pick-up / drop off of pollen -Behavior not connected to foraging -Foraging behavior in search of pollen/nectar	-Take pollen to hive -Take nectar to hive	-Feed colony -Make honey
Environment **Temporal - Phenological** **Spatial** **Orientation/Alignment** **Entity Relations**	-Seasonal -Temperature **Orientation** -Flower is open -Position of flower is upright **Form/Function** -floral structure attract pollinators -floral properties attract pollinators -pollinator structure allows access to floral reward	-Repeating behavior -Amount of time (efficiency) -Amt/duration of activity rel. to amount of food **Alignment** -Pollinator to flower (middle of flower) -Orientation of bee to flower (in flower) -Orientation of butterfly to flower (on flower) **Form/Function** -floral structure/foraging behavior (getting) -floral structure/pollinator behavior(landing)	**Orientation** -Position of flower is down	-Bees & butterflies avoid flowers in decline

For pollination to occur, entities must have particular structural features and/or particular properties that can support particular activities. Thus, disciplinary talk in the Set-Up Condition emphasizes: (1) Identification of the entities and their properties (i.e., kind of organisms, structures of organisms, and properties of structures); and/or (2) Locations of the structures of entities. Intermediate Activities focus on the connections between entities, properties, and activities. Thus, disciplinary talk in the Intermediate Activities focuses on *how* pollen is transferred: (1) the activities and behaviors of pollinators, and (2) the relations between floral structures and properties, the pollinator activities, and the environmental conditions. Once pollination occurs, the floral entities may be altered and the later stages of floral and pollinator life cycles are possible. Termination Conditions disciplinary talk explicitly connects these changes to the pollination process.

The coding plan applied these general guidelines: (1) Coding reflects family pollination-related talk that occurred during the entire Observation Event; (2) Each condition (i.e., Set-Up Conditions, Intermediate Activities, Termination Conditions) can be distinctly identified and segregated; and (3) Once an entity, feature, property, and/or activity is counted in a particular condition, it is not counted again. See **Appendix I** for details of the coding plan.

4.0 RESULTS

The chapter describes how the two parent study conditions were expressed during the observation event and the effects of these on children's observations of biological phenomena. Section One focuses on how parents implemented the elaborative conversational style training. Section Two explores parent-child talk for evidence of disciplinary knowledge and practice. Section Three reports the results of the children's task analyses. The remaining section synthesizes these collective results and considers the impact of parent conditions on children's observations.

4.1 PARENT CONVERSATIONAL STYLE IN THE GARDEN

In this study, we asked half of the parents to use their natural conversational style and the other half to use particular conversational strategies as they and their children observed pollination events. The primary purpose for training parents to use these strategies—asking *Wh*-questions, focusing on a child's expressed interests, linking to prior experience, and giving positive feedback—was to extend family observations and talk related to biological phenomena. Our interest here is to understand whether training changed family conversation and whether differences in parent knowledge may have also played a role. We begin by comparing overall parent use of an elaborative conversational style (ECS), followed by analyses of each strategy.

Did the training protocol modify parent use of the strategies in the treatment groups? A two-way ANOVA on parent conversational style yielded a significant main effect for treatment, F (1, 75) = 47.56, p = .000, d = 1.53, and for parent knowledge, F (1, 75) = 4.079, p = .047, d = .38. Looking at Figure 4.1, we can 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).

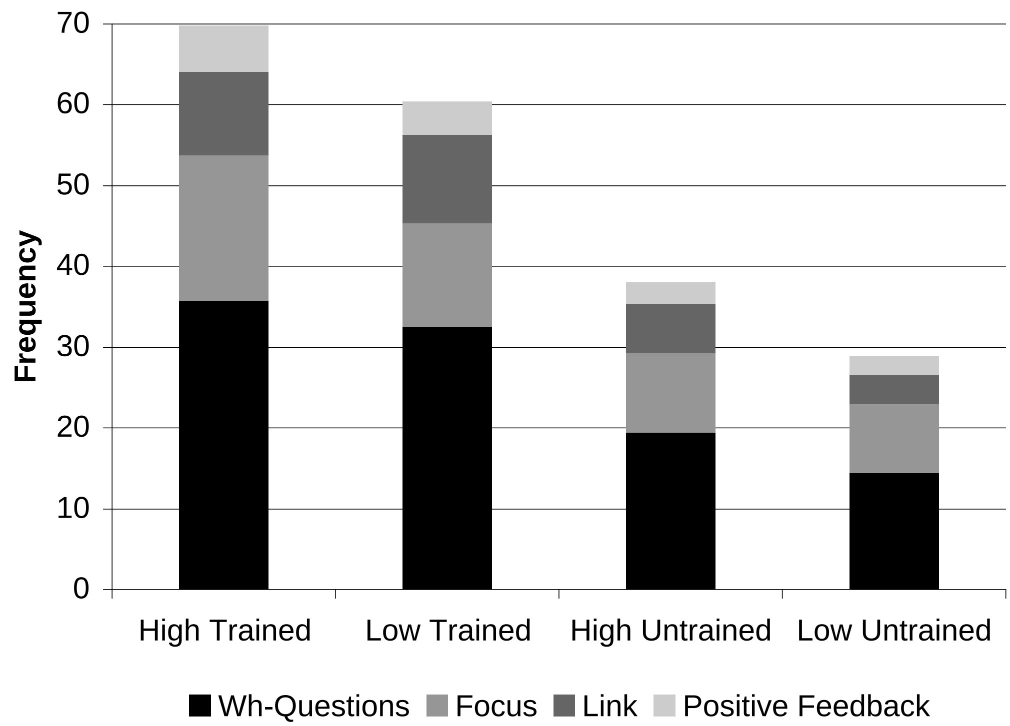

Figure 4.1. Mean Number of Parent Elaborative Conversational Strategies

To further understand the results of parent training, individual strategies were examined with the expectation that parents in the treatment groups would use each strategy more than parents in the control groups. For those strategies that made demands upon parent knowledge—

specifically 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) = 40.642, p = .000, d = 1.43, as expected. However, we were surprised to find no significant effect for parent knowledge, F (1, 75) = 2.276, p = .136. Given that there was also no interaction, the results suggest that parents in the treatment groups used *Wh*-questions more frequently than those in the control groups.

The next two strategies—child focus talk and linking to children's prior experiences—exhibited 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) = 10.606, p = .002, d = .64, as expected. However, there was no effect for parent knowledge, F (1, 75) = 2.929, p = .091. Similarly, a two-way ANOVA for use of the linking strategy also revealed a significant effect for training, F (1, 75) = 18.554, p = .000, d = .71, but not for parent knowledge F (1, 75) = .532, p = .468.

The finding that there were no significant implementation differences between high and low knowledge parents for 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 understandings 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 they have not previously observed:

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 (1x).*
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 children's 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. Because parents might offer praise in response to a child's participation and in response to a child's content contribution, we expected an effect for training but no effect for parent knowledge. And, in fact, a two-way ANOVA for positive feedback found only one significant effect, F (1, 75) = 11.122, p = 001, d = 0.75, revealing that parents in the treatment groups (M = 5, SD = 3.34) generated more positive feedback during the observation event than parents in the control groups (M = 3, SD = 3.09).

4.1.1 Parent Elaborative Conversational Style Summary

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. In fact, an examination of Figure 4.1 illustrates that parents in the treatment groups used every strategy about twice as often as parents in the control groups. The finding that training minimizes the effect of parent knowledge—such that parents use more domain general strategies regardless of differences in knowledge—suggests that even parents who have limited disciplinary knowledge may support children's observations of biological phenomena.

At the same time that training increases the attentive behaviors of parents, manipulating the substance of their observations appears to be more challenging. This was made evident in their use of *Wh*-questions. We were particularly surprised that parent knowledge appeared to play no significant role in the use of this strategy 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 should result in only a significant main effect for treatment, F (1, 75) = 15.06, p = .000, d = .86. In contrast, parent use of the *Wh-content* questions resulted in significant main effects for treatment, F (1, 75) = 34.809, p = .000, d = 1.3, and for parent knowledge, F (1, 75) = 5.277, p = .024, 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), suggesting that more attention to the disciplinary demands of observational practices is needed.

It seems interesting that high knowledge only manifests itself in one conversational strategy. That parent knowledge is not manifested in the remaining strategies may suggest that the strategies could support parents in their role as teachers regardless of how knowledgeable they are about a disciplinary topic. On the other hand, this pattern could also suggest that the training protocol requires some redesign if it were important to integrate disciplinary content and learning processes.

4.2 WHAT FAMILIES OBSERVED IN THE GARDEN

This section describes what families noticed as they observed pollination events in the garden. Working from a sociocultural perspective, in which conversation is a socially mediated activity (Leinhardt & Crowley, 1998; Wertsch, 1991), parent-child conversation is treated as the primary evidence of what families noticed and understood about pollination during the observation event. Therefore, a critical challenge is to describe how family talk conveys both disciplinary knowledge and practice during shared observational activity in an informal learning context.

To address this challenge, a Pollination Model was developed (Table 4.1, but see Methods 3.3.2 for details). The content for the model drew upon the scientific disciplines associated with pollination but also reflected parent-child talk in the garden. The columns organize the conditions under which the process of pollination can occur (Set Up Conditions), the relationships that make pollination possible (Intermediate Activities), and the resulting biological states (Termination Conditions), along increasingly complex relations. The three rows specify the essential entities of pollination—plants, pollinators, and environment. The first two rows obviously refer to the two organisms required for insect-driven pollination to occur. Environment refers to the temporal, spatial, and ecological relationships between these entities.

Table 4.1. Pollination Model Structure

	Set-Up Conditions	Intermediate Activities	Termination Conditions
Plants			
Pollinators			
Environment			

It is anticipated that differences in parent knowledge will affect which entities and which activities are noticed, and the extent to which families create complex connections between those entities and activities. High parent knowledge should support noticing more phenomena generally and specifically more observations that link an entity's properties (e.g., 'the bee's hairy leg") with intermediate activities (e.g., "getting pollen"). In contrast, low parent knowledge should notice fewer phenomena and make fewer connections between entities and their properties and activities (e.g., "there's a bee"). Finally, if ECS training contributes to what families notice, then treatment groups should notice more of these components and behaviors when compared with the corresponding control group.

4.2.1 Pollination States

To begin to understand the effect of parent conditions on family observations, we compared parent-child talk in the Set-Up conditions, Intermediate Activities, and Termination Conditions using a 3 (pollination state) x 2 (parent conversational style) x 2 (parent knowledge) ANOVA with repeated measures. Three significant effects resulted. First, there was a significant main effect for pollination state, F (2, 150) = 151.554, p = .000, d = .64. Families observed significantly more phenomena in the Intermediate Activities (M = .34, SD = .16) than in the Set-Up Conditions (M = .28, SD = .09), and each of these more than the Termination Condition (M = .13, SD = .13).[2]

There was also a between-subjects main effect for parent knowledge, F (1, 75) = 23.496, p = .000, d = .84. Looking at Figure 4.2, it is clear that families with high knowledge parents noticed more pollination-related phenomena than families with low knowledge parents. However, a significant interaction between pollination state and parent knowledge, F (2, 150) = 13.216, p = .001, d = .03, suggests that high and low knowledge groups observed pollination events differently within the three states. A paired t-test found that high knowledge parent groups

[2] Proportional mean scores were generated because each row and column of the Pollination Model summed to different values.

generated disproportionately more pollination disciplinary talk within Intermediate Activities (*M* = .42, *SD* = .15) than within the Set-Up Conditions (*M* = .32, *SD* = .09), *t*(39) = -5.463, *p* = .000, *d* = .81. In contrast, low knowledge parent groups noticed pollination phenomena in the Intermediate Activities (*M* = .26, *SD* = .13) about as often as they did in the Set-Up Conditions (*M* = .24, *SD* = .07), *t*(38) = -.90.4, *p* = .372.

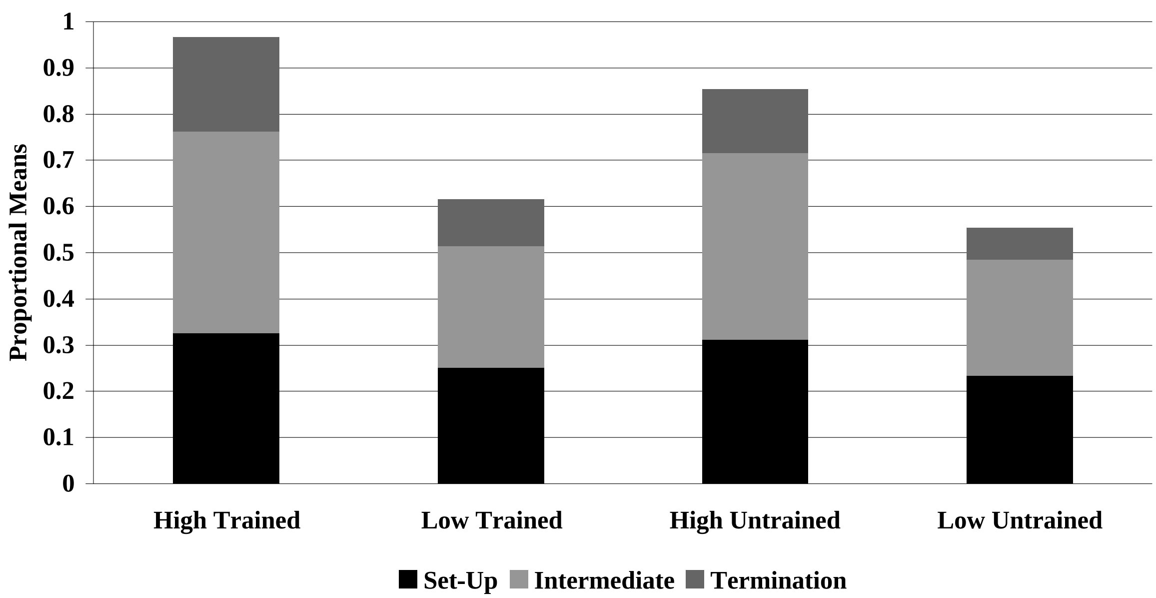

Figure 4.2. Parent-Child Observations Within and Across Pollination States

That low knowledge groups observed phenomena with similar frequency within the Set-Up Conditions and Intermediate Activities was unexpected. This finding shows that having some pollination knowledge supports noticing plants and pollinators in ways that also focus on how pollination occurs. That high knowledge groups observed significantly more phenomena in the Intermediate Activities than the Set-Up Conditions was expected and is potentially an important transitional characteristic of observations that are increasingly scientific. Noticing more phenomena and in more complex ways that focus on how a process occurs is a critical facet of scientific reasoning generally (e.g., Hmelo-Silver & Pfeffer, 2004; Machamer et al., 2000) and the practice of scientific observation specifically (Mayr, 1982; Norris, 1984).

4.2.2 Pollination Entities

To create a more complete picture of parent-child observations, we compare what they observed across the rows of the Pollination Model. A 3 (entity) x 2 (parent conversational style) x 2 (parent knowledge) ANOVA with repeated measures with entity as the dependent variable yielded results consistent with the pollination state analysis. First, high knowledge parent groups (*M* = .27, *SD* = .11) noticed more pollination phenomena than did low knowledge parent groups (*M* = .18, *SD* = .11), *F* (1, 75) = 25.488, *p* = .000, *d* = .77.

Similarly, a significant main effect for pollination entity, *F* (2, 150) = 243.76, *p* = .000, *d* = .74, revealed that families tended to focus more on pollinators (*M* = .32, *SD* = .13) than plants (*M* = .27, *SD* = .13), and pollinators and plants much more than the environment (*M* = .09, *SD* = .06). As with the comparison across columns, families tended to not notice the extremes of the pollination model and generated fewer connections to the broader contexts of pollination, including the environmental conditions that support pollination and to related life processes.

What seems to be interesting here is the significant interaction between pollination entity and parent knowledge, *F* (2, 150) = 8.148, *p* = .000, *d* = .03. Figure 4.3 indicates that high knowledge parent groups observed more plant and pollinator entities than low knowledge parent groups, but there appears to be little difference in numbers of observations in the environment entity.

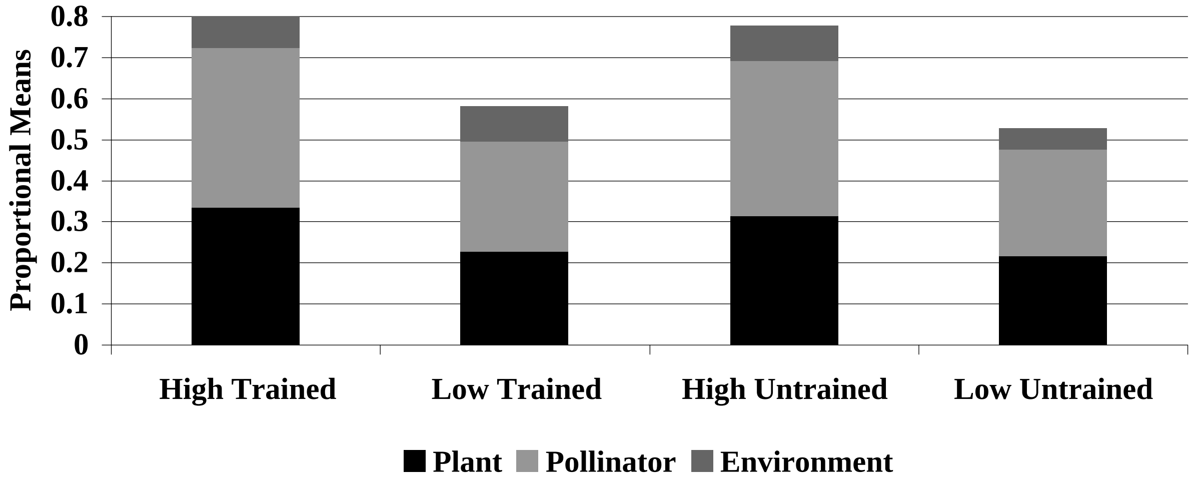

Figure 4.3. Parent-Child Observations Within and Across Pollination Entities

4.2.3 Pollination State and Entity Summary

What do these findings suggest? Parent disciplinary knowledge was critical to what pollination-related phenomena families noticed. Whether compared across pollination states or entities, groups that included high knowledge parents noticed more features and properties of entities and connected these to more Intermediate Activities of pollination than groups with low knowledge parents. Furthermore, treatment did not have its anticipated result of enhancing the type of parent-child observations, whatever the level of parent knowledge.

Looking across the entire Pollination Model, it is easy to see that the bulk of family observations concentrated on the Set-Up Conditions and Intermediate Activities of plant and pollinator entities. Less attention is given to either the Termination Conditions or the Environment Entity. This is important for two reasons. First, this pattern suggests that families pay more attention to highly observable and immediately present phenomena than to the conditions that necessitate more nuanced and complex observations and inferences. A rare exception was one parent's observation that, "All the pollen is gone from this one. The bees must have been here" recognized that the pollen had been used up (termination) rather than simply not present (set-up). Second, it is interesting to note that novice and more expert families focused more on the causal interactions of the Intermediate Activities rather than the end states of pollination. This is in contrast to the science education literature, which often describes children as noticing final experimental results without also noticing intermediate causal interactions (e.g., Schauble et al., 1991; Smith & Reiser, 2005; White, 1993). It is possible that families noticed the most salient activities of pollination in ways that children notice the most salient phase of experimentation. However, Abrams et al (2001) have also reported that children neglect physical mechanisms when explaining biological change.

Although groups with high knowledge parents observed more pollination phenomena overall, families still observed a relatively small proportion of what may be important or possible to observe from a disciplinary perspective. This is consistent with Ford's (2005) findings that children noticed a relatively small number of variables important to geological reasoning.

Finally, what becomes increasingly evident from the analyses of Sections One and Two is just how little crossover occurs between parent pollination knowledge and parent conversational style. With the exception of *Wh*-content questions, there are few bridges connecting the two study conditions.

4.3 CHILDREN'S TASK ANALYSIS

Children completed five tasks prior to and immediately following the observation event. Their responses were scored and probed 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 parent knowledge reflected differences in children's knowledge. In effect, did high knowledge parents have high knowledge children? A 2 (parent treatment) X 2 (parent knowledge) way ANOVA for children's pre-test summary scores found a significant main effect for knowledge, F (1, 74) = 13.084, p = .001, d = .78. Because children with high knowledge parents scored higher (M = 17, SD = 4.52) on average than children with low knowledge parents (M = 14, SD = 3.02), a series of two-way ANCOVA analyses for posttest scores were used, in which pre-test scores functioned as the covariate to adjust for these differences.

We then asked whether children's knowledge scores—derived from the collective scores for each task—changed in response to any of the study's conditions and activities. Overall, the posttest scores were not significantly different from the pre-test scores. (See Table 4.2 for means of pre- and posttest means.) A two-way ANCOVA for summary scores yielded no significant effects for treatment, F (1, 73) = .758, p = .387, nor for parent knowledge, F (1, 73) = .089, p = .766.[3]

Why were there no significant differences between conditions on posttest scores? One reason may be that observation events lasted about 15 minutes on average, leaving little time for measurable shifts in children's pollination knowledge. This suggests that movement across the observation framework requires more substantial effort than a single, brief episode can support. Second, it is also possible that the tasks did not accurately anticipate what parents and children actually observed and talked about in the garden. If true, there would be little reason to expect change in children's scores.

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[3] One child did not complete each question so the sample size for this task was correspondingly reduced.

Table 4.2. Means of Child Pre and Post Task Scores

	Knowledge Groups	Treatment Group Pre M	Treatment Group Pre SD	Treatment Group Post M	Treatment Group Post SD	Control Group Pre M	Control Group Pre SD	Control Group Post M	Control Group Post 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	*2.9*	14.6	*2.8*	16.0	*3.4*

Even in the absence of statistical significance, however, it is possible to glean insights into children's observations of pollination. Thus, the remainder of this section includes the statistical results for each task as well as a description of what children did and did not notice about pollination-related phenomena. The following descriptions refer to the posttest mean score for the entire sample.

In the first task, children viewed eight photographs and sorted these into two piles based upon whether they thought a photograph was or was not pollination-related. Each correct choice was scored one point, with a maximum score of eight points being possible. A two-way ANCOVA for the posttest score found no significant effect for parent treatment, F (1, 74) = .300, p = .585, nor for parent knowledge, F (1, 74) = .040, p = .843, indicating that children's ability to distinguish pollination from non-pollination features and activities was about the same at posttest. (See Table 4.3 for adjusted posttest means for each task.)

Overall, children were able to accurately assign the photographs to the correct group 76% of the time. The four most highly scored photographs featured images in which the pollinators and plants conformed to typical forms and were easily identifiable. Importantly, three of the images included pollinators that were positioned *on the flower*. Children commonly explained that, "It's on the flower," as primary evidence that a photograph had something to do with pollination. The fourth image of bees on a peach also privileged a pollinator's position, but in reverse: "They're not on a flower."

Table 4.3. Adjusted Mean Scores on Post Interview Results of 2-Way ANCOVAs

	Knowledge Groups	**Treatment Group M**	***SD***	**Control Group M**	***SD***
Task 1	**High**	6.1	*2.3*	6.9	*2.3*
	Low	6.3	*2.4*	5.9	*2.2*
Task 2	**High**	1.2	*1.6*	1.4	*1.6*
	Low	1.3	*1.2*	1.4	*1.6*
Task 3	**High**	1.5	*1.1*	1.3	*1.1*
	Low	1.4	*1.1*	1.2	*1.1*
Task 4	**High**	1.5	*1.3*	1.3	*1.3*
	Low	1.5	*1.3*	1.1	*1.3*
Task 5	**High**	6.1	*5.2*	5.9	*5.4*
	Low	6.0	*5.5*	6.4	*5.3*
Total	**High**	16.4	*6.0*	16.8	*5.7*
	Low	16.5	*5.8*	16.0	*5.7*

In contrast, the four lowest scoring photographs required greater sensitivity to spatial and temporal relations. For instance, slightly more than half of children identified two photographs of bees hovering *near flowers* as being related to pollination. Less than half recognized the significance of timing when they failed to assign the image of a bee resting on a closed floral bud to the pollination pile. Given the findings that families infrequently observed spatial and temporal relationships (i.e., environment entity), it is not surprising that children had more difficulty deciphering these differences. In the remaining case, children were challenged by an unexpected plant form, suggesting that plant variation increased the difficultly of interpreting pollination scenarios.

Task two involved comparing two photographs of a flower, in which one had pollen and the other did not have pollen on its stamen. Children were asked if these flowers could be pollinated. Each correct response was scored one point and a maximum score of two points was possible. A two-way ANCOVA for posttest scores yielded no significant difference for parent treatment, $F(1, 74) = 1.106$, $p = .296$, nor for parent knowledge, $F(1, 74) = .145$, $p = .705$.

Two-thirds of children recognized that pollen must be available for pollination to occur and correctly noticed when pollen was either present or absent from the stamen. Of these, many claimed that the flower with pollen (e.g., “the brown stuff”) could be pollinated and the one without pollen could not be pollinated. A few children proffered more nuanced explanations. For example, one child observed, “The bee could pollinate the flower without pollen if it goes to the one with pollen first, but it cannot do it the other way around.” Although both sets of responses are technically correct, the latter is more complex and integrates some relationship between space and time.

The remaining children (33%) either did not notice the missing pollen or did not know where to look for pollen. In both cases, children seemed to expect pollen to be on flowers and therefore "observed it" even when pollen was absent. Some children voiced general rules that explained their decisions ("All flowers have pollen.") while others simply viewed these as exact copies ("I think they could pollinate them. They're the same."). For those less able to recognize plant variations, the base of the petal was often identified as pollen due to its yellow color. Consistent with Chinn & Brewer (1992, 1998), it can be challenging for children to alter expectations in light of unexpected phenomena, especially when the differences in phenomena are difficult to detect and children's expectations are strong.

For task three, children were asked a series of yes/no questions that began with, "Can you tell just by looking if (e.g., the flower is pink) as they observed a living flower. Children were scored one point for each response that accurately matched whether or not the phenomena could be observed, for a total of three points. (The fourth statement referring to "if this flower is making its own food" was eliminated from analysis because some children did not know that "making its own food" referred to photosynthesis.) A two-way ANCOVA found no significant main effect for parent treatment, F (1, 71) = 1.725, p = .193, nor for parent knowledge, F (1, 71) = .955 p = .332.[4]

Although the original purpose for this task was to understand if children distinguished observation from inference, we should be cautious about interpreting the results to suggest anything of the kind. First, 84% agreed that observing the flower was not enough to determine if

[4] Three children did not complete each question so the sample size for this task was correspondingly reduced.

the flower came from California. In addition, many of those who believed it possible pointed to physical evidence (i.e., color, the shape, a similar flower in the garden) to explain their answer.

With regard to the two remaining statements (i.e., if this flower has pollen, if this flower has nectar), children's responses were more likely to reveal differences in knowledge. For example, 81% agreed that pollen could be observed and pointed to pollen on the stamen as evidence. Many of those who claimed that pollen could not be observed were either confused about the location of pollen—pointing to the base of the petal—or expressed ideas that would make it unobservable by the naked eye, such as "It's too small to see." Similarly, many children who claimed to observe nectar (unlikely in the case of the sample flower), simply did not know where to find nectar, confused it with pollen, or assumed the water at the base of the petals had to be nectar. Parent-child talk in the garden reflected similar confusion.

Task four explored form and function relationships between plants and pollinators. Children were asked to explain how a hungry bee would find food on the same living flower that they had observed in task three. Each response was scored one point for mentioning a single entity's form, two points for describing a form and function relationship, and additional points for specific elaborations, up to a total of four points. A two-way ANCOVA resulted in no significance for parent treatment, F (1, 70) = 3.094 p = .083, and there was no significant difference for parent knowledge, F (1, 70) = .459 p = .500.[5]

Only 10% of children could identify this particular form and function relationship between the bee and the flower (i.e., following the lines on the petal to locate nectar, bees are attracted by the floral color). Indeed, few parent-child observations focused on this particular

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[5] Four children did not complete each question so the sample size for this task was correspondingly reduced.

form and function relationship and were more likely to observe form and function relationships associated with pollinator's landing or foraging behavior in relation to floral structure.

For the final task, children were asked what would they tell a friend about bees visiting flowers and were invited to use the flower model and pollination puppets as needed. Similar to the parent knowledge survey, children were scored one point for each feature (e.g., pollen, bee, pollen basket) and two points for each concept (e.g., orientation of bee to flower, color attracts pollinators) mentioned. A two-way ANCOVA for posttest score found no significance for parent treatment, F (1, 74) = .029, p = .866, nor for parent knowledge, F (1, 74) = .212, p = .646. As with all previous tasks, there was no significant change between the pre-test and posttest.

Consistent with parent-child observations in the garden, children only referred to a small portion of the 21 features and concepts possible to observe (25% at pre-test, 29% at posttest). For instance, only half of the children mentioned pollen or nectar. Children's descriptions were also typically non-specific. In contrast to parent-child observations, which included focus on the intermediate activities of pollination, children were more likely to describe pollen transfer more generally: "It goes down here and gets some pollen."

Overall, these findings add to an area of children's scientific knowledge that is under-researched (Schussler, 2008; Wandersee & Schussler, 2001). Evident here, children expressed basic knowledge of pollination, including awareness of general processes, animal and plant entities, and typical plant morphology. Many children, however, demonstrated little knowledge about the explicit mechanisms of pollen transfer, spatial and temporal relationships, and variation in plant forms.

4.4 EXPLANATORY POWER

In this study, we have described how two parent factors contributed to how and what children observed in an informal learning environment. Here we synthesize the results thus far to better understand the relationships between parent disciplinary knowledge, parent training, parents' use of ECS strategies, and children's knowledge.

We do this by exploring a series of multiple stepwise regressions and proposing a model that expresses the significant relationships between these variables (Figure 4.4). This model of parent-child observation in an informal learning environment conceptualizes disciplinary talk—that is, talk related to pollination states and entities—as being influenced by parent knowledge, parent training, and children's knowledge. In addition, use of ECS—whether occurring as a result of treatment or as a result of parents' natural style—also bears some influence on disciplinary talk. This model then assumes that children's knowledge at the conclusion of the garden experience is influenced by children's prior knowledge and is also mediated by the disciplinary content generated during the observation event. If families generate more disciplinary talk related to pollination, then children will notice pollination-related phenomena.

The correlation matrix (Table 4.3) shows how the variables used in developing this model related to one another. With the exception of children's knowledge scores and parent treatment, all relationships are positive and some are significantly so.

Table 4.4. 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	.063	1				
Disciplinary Talk	.497**	.118	1			
Parent Use of ECS	.207	.595**	.449**	1		
Child Pre Knowledge	.380**	-.164	.395**	.074	1	
Child Post Knowledge	.336**	-.021	.426**	.183	.702**	1

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

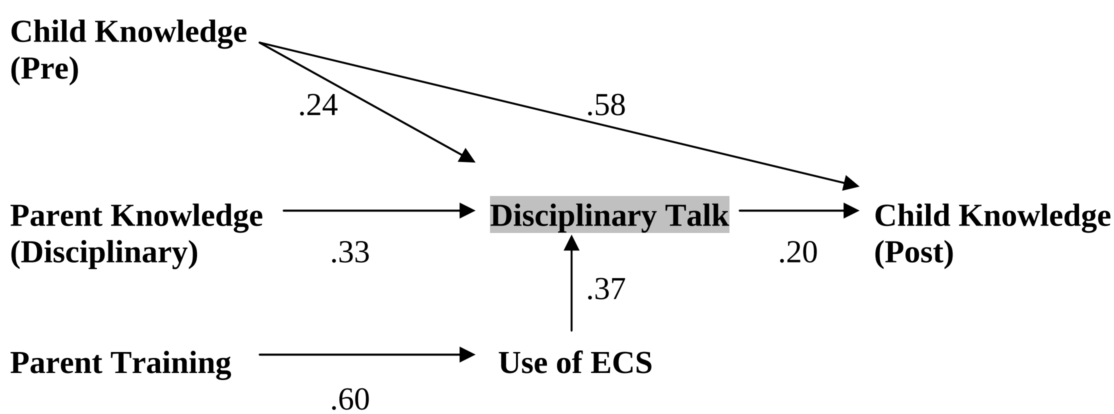


Figure 4.4. Model of Parent-Child Observation with Significant Effects

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 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 was significant and accounted for 35% of the variance for parents' use of the ECS, (**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 of pollination, parent training, use of ECS, and child pre-knowledge as the independent variables. Here parent knowledge accounted for 25% of the variance, use of ECS accounted for 13% of the variance, and child knowledge accounted for 5% of the variance on pollination content. Taken together, parent knowledge, ECS, and child knowledge accounted for 43% of the variance in disciplinary talk related to pollination, (**Disciplinary Talk** = 1.86 + .33 Parent Knowledge + .37 ECS + .24 Child Knowledge, R^2 = .43).

The final step-wise multiple regression analysis was conducted with the total Child Posttest 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 accounted for 45% of the variance and disciplinary talk accounted for 3% of the variance of child posttest knowledge scores. Taken together, child knowledge and pollination content account for 48% of the variance in child posttest scores, (**Child Posttest Knowledge** = 6.53 + .58 Child Knowledge + .20 Disciplinary Talk, R^2 = .48).

To summarize, the elaborative conversational strategy training resulted in parents using the four strategies more often in the garden. Parents and children who knew more about pollination at the start of the study exhibited higher levels of disciplinary talk in the garden, which is to be expected. Families who know more about pollination should notice more phenomena in the garden, and what they notice should more closely align with what experts might notice. More interesting, however, is that the use of the elaborative conversational strategies also increased the amount of disciplinary talk in the garden, independent of what families knew about pollination. In other words, use of the ECS strategies alone was enough to increase disciplinary talk. Finally, although the earlier analyses of children's pre- and posttest scores did not show any significant effect for condition or prior knowledge, the regression analyses revealed that the extent to which families engaged in disciplinary talk in the garden predicted significant variance in children's post-test scores.

5.0 DISCUSSION

This chapter discusses the findings as they relate to the two sets of research questions. Section One focuses on parent training and the use of an elaborative conversational style during family observations in the botanical garden. Section Two considers the findings related to disciplinary talk, with special attention to its relationship to the observation framework proposed in Chapter 2. Finally, implications for future research of engagement in scientific practices in informal learning environments are considered.

5.1 PARENT TRAINING AND USE OF ELABORATIVE CONVERSATIONAL STYLE

Parents and children observed pollination activity during a visit to a botanical garden in which half of the parents were provided training about the use of four elaborative conversational strategies. We expected that training would increase parent use of certain strategies, which in turn, would change what children noticed and understood about pollination. Two major findings emerged. First, a simple training protocol significantly modified parent talk and interactions with their children. Parents who received training used ECS strategies nearly twice as much as parents who simply used their natural conversational style. Second, parent use of ECS strategies accounted for significantly more disciplinary talk in the garden independent of parent knowledge. In effect, the regression analysis revealed that the use of an elaborative conversational style enabled parents to support more disciplinary talk whether they knew a lot or knew a little about pollination.

These results suggest that the collective use of ECS strategies provided tools that parents may use to extend and support children's observations of naturally occurring biological phenomena. Because implementation of ECS strategies also occurred regardless of differences in parent knowledge, training parents may be a promising educational practice that begins to equalize learning opportunities between families with access to different knowledge resources. Further, use of these strategies over time could be expected to develop shared habits of attention across disciplinary-rich contexts, including museums, citizen science programs, and other informal learning environments.

But must it be only these strategies that encompass an elaborative conversational style? Although the four strategies used here are a good starting point for supporting joint attention and talk, we are mindful that they were conceptualized to support children's memory development (Boland et al., 2003). There may be reasons to preserve some but not all strategies in keeping with the goals of noticing for understanding.

In particular, the use of *Wh*-questions and child focus talk seem especially relevant to the broader goal of supporting children as they transition from "seeing" the natural world 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 (e.g., King, 1994; Smith & Reiser, 2005). When parents ask *Wh*-questions they effectively filter complex environments and consequently children may be better equipped to notice and elaborate upon particular entities, features, and activities. Likewise, child focus talk is another strategy that filters complexity, albeit from the perspective of learner interests. Building upon an individual's motivations for learning and engagement is a valued practice in free-choice learning environments (Bell, Lewenstein, Shouse, & Feder, 2009). But we also see this strategy successfully used by teachers who have adopted a science-as-practice framework and who strive to balance the interests of the students with the demands of the discipline (see Lehrer et al., 2001; Metz, 2000 for examples).

In contrast, linking to prior experience may have done little 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.

Ironically, linking to prior experiences seemed to be genuinely challenging for parents in the trained condition. Perhaps, in an effort to conform to training, parents were grasping at any opportunity to make connections and could inadvertently undermine the purposes of ECS strategies. For instance, recalling prior experiences with bee stings did little to encourage children to closely observe bees. Parents in the untrained condition, however, appeared to use this strategy more successfully, in part, because linking surfaced when it was needed to support children's understanding. For instance, to explain how pollinators get nectar one parent compared a pollinator's proboscis with something more familiar: "It's like a straw and that's how he sucks the nectar out." Given that linking also occurred naturally, and then for purposes of understanding rather than for purposes of implementation, excluding this strategy from future ECS models may be warranted.

Even with such challenges, this study shows that this training protocol can be realistically implemented in informal learning environments, which is an accomplishment in its own right. Three characteristics of this model may have contributed to its success and may be important to preserve in future modifications. First, training was both brief and convenient. Preparation 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. Much of the training occurred when it was convenient for parents to participate.

Second, these are strategies that 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 event. This degree of familiarity is important for several reasons. Familiarity with these strategies makes training fairly easy. It also makes ECS a relatively simple tool that can be implemented in demanding informal learning environments where there can be an abundance of dynamic and distracting stimuli. Finally, the use of familiar strategies may also reduce cognitive load by asking parents to implement something they already know.

A third critical characteristic is that the use of ECS strategies required no specialized disciplinary knowledge for successful implementation. This suggests that ECS strategies can be flexibly applied across diverse informal learning environments.

There is a great need in informal learning environments to engineer learning conversations without also destroying the interests and motivations that engage individuals in learning in these places. The use of ECS strategies did a good job of striking a balance between parents' roles as teachers and what parents already do. Training essentially got parents to use strategies that they already use in everyday experiences with their children, and encouraged them to use these more frequently. That conversations did not sound very different in treatment and control conditions suggests that use of ECS changed the balance of parent talk without also replacing it with an alternative learning system.

5.2 DISCIPLINARY TALK AND ITS PLACE IN THE OBSERVATION FRAMEWORK

One interest of this study was to explore the effect of parent disciplinary knowledge on children's observations of biological phenomena during a visit to a botanical garden. As expected, families who knew more about pollination noticed more pollination phenomena overall. We were surprised, however, that both parent knowledge and parent use of ECS significantly predicted disciplinary talk during observation of pollination. In turn, the extent to which families engaged in disciplinary talk in the garden, predicted children's posttest scores. Thus, the most important consideration here is that disciplinary talk—whether a result of prior knowledge or use of ECS—mediated observation of phenomena. The more disciplinary talk, the greater the children's scores.

What do these findings suggest about the proposed observation framework? Specifically, how is the transition from everyday to scientific observation facilitated in an informal learning context? First—and at the risk of stating the obvious—the availability of phenomena with scientific interest seems fundamental to this transition. The fact that families were visiting a botanical garden designed to support repeated encounters with pollinators and plants provided opportunities to repeatedly observe and talk about morphological structures, ecological conditions, and historical relationships of these organisms. Without phenomena of scientific interest—and arguably of individual interest—there would be little opportunity to develop as a scientific observer.

Second, these findings reveal that disciplinary family talk is a critical mechanism for learning to observe scientifically in informal learning contexts. Given that scientific observation is bound by disciplinary knowledge and practice (e.g., Ault, 1998; Daston & Vidal, n.d.; Mayr, 1997), we should expect that content-rich talk is important in this learning context. Of special interest here is that the style of parent talk—when focused on biological phenomena—can also contribute to learning to observe scientifically. By training parents to ask questions or to follow up on children's interests, parents help to extend talk in ways that also develop habits of attention. In effect, using ECS strategies increases the likelihood that parents and children will observe and talk about disciplinary content.

But the observation framework by itself does not help us fully anticipate what the transition from everyday to scientific observation looks like. For this to occur, we need new disciplinary models, especially models that can be used in informal learning environments. This is for several reasons.

First, it enables us to develop a better understanding of scientific reasoning that is more closely aligned with scientific practice. In order to design measurable learning trajectories, we need to understand the endpoints of disciplinary practice as well as the spaces in between.

Second, this emphasis develops and applies a model drawn from science studies, pollination biology sub-disciplines, and emergent parent-child talk. Consequently, it is useful for teasing apart evidence of disciplinary observational practices in an informal learning context.

Use of the pollination model enabled us to recognize that families observed complex relationships associated with pollination as well as the basic conditions that make the process of pollination possible. That is, they observed the intermediary activities of pollination—mechanisms—regardless of differences in knowledge. This may have been due, in part, to the salience of the phenomena; however, the fact that families observed these mechanisms is incredibly important to scientific explanation. Use of the pollination model also let us detect that families focused on a relatively narrow range of pollination phenomena and less so on aspects that connect their observations to other life processes, as well as to ecological and historical relationships. Thus, we might reason that the transition from everyday observation should not only include noticing more features and properties of organisms, but should also simultaneously include noticing relationships between these features and the mechanisms associated with biological processes. An everyday observer may simply notice the parts of a biological process, but someone who is observing more scientifically notices how those parts interact with one another and other related life process and systems.

Finally, these findings have practical implications for the design of informal science education experiences and environments. First, if a critical mechanism for observation is disciplinary talk, then the design of these environments should be considered in light of what it is needed to support complex, disciplinary-rich talk and observations. That ECS can be implemented regardless of differences in parent knowledge does not mean, however, that informal learning organizations have less responsibility to align with disciplines. They have more. A designed environment that is connected to how people talk and observe is critical. As noted in the previous section, there is a great need in informal learning contexts to engineer talk in ways that build upon learner interests. Similarly, we need to design informal learning environments that can engineer talk in such a way as to cultivate disciplinary practices.

5.3 IMPLICATIONS FOR FUTURE RESEARCH

As this study explored the effects of two parent conditions on children's observations, it allowed us to begin to assess the proposed observation framework. We wanted to find out if our interests in the daily habits and characteristics of individual learners could support movement in the direction of increasing scientific observation. For this reason the study focused narrowly on noticing rather than the entire framework. To what extent the use of ECS strategies and unaided parent knowledge would support a child's development as a scientific observer in the broader context of scientific observation—expectations, observational records, and productive disposition—is unknown. These gaps suggest certain limits of the current study as well as opportunities for future research. Two of these are considered here.

First, the study was admittedly narrow in its focus on noticing. Likewise, the study was narrow in other ways, including disciplinary focus (pollination), a single informal learning environment (botanical garden), and time (an average of 15 minutes for the observation event). To more fully develop the observation framework—and to have a more robust understanding of the development of scientific observation in informal learning contexts—we need broader studies that cover the breadth of the framework along these dimensions. For example, although pollination is interesting and highly observable, future work should include other kinds of biological phenomena that can be experienced everyday and the scientific disciplines that study these. In addition, longitudinal studies that cross learning contexts would allow us to better understand other mechanisms and how these affect the development of scientific observation over time and place. Finally, studies that cross time and/or context would enable us to understand what habits of attention, individual interests, and interactions beyond family contexts support children as productive observers of the natural world.

Second, the first analysis of children's knowledge scores suggested no significant difference between the pre-test and the posttest. Although it is possible that there was no change in what children noticed and understood about pollination, had we used more sensitive measures that reflected the disciplinary talk generated by families, we may have detected changes in children's observations. For these reasons, there is a great need for the development of more sensitive instruments that measure changes in disciplinary knowledge and practices. These measures should reflect the idiosyncrasies of informal learning environments, such as the limits of time, differences in individual interests and knowledge, and the range of disciplinary contexts and learning environments.

Even so, we should remain mindful about the richness and integrity of data sources that reflect real participation and engagement in informal learning environments and avoid placing too much emphasis on pre- and posttests. In this study, parent-child talk during shared observation of pollination activity in the garden proved to be a rich resource for understanding some of the mechanisms that support children's development as scientific observers.

APPENDIX A

IRB LETTER OF APPROVAL

University of Pittsburgh

3500 Fifth Avenue

Ground Level
Pittsburgh, PA 15213
(412) 383-1480
(412) 383-1146 (fax)

Institutional Review Board

MEMORANDUM:

TO: Catherine Eberbach, Ph.D.

FROM: Christopher Ryan, Ph.D., Vice Chair

DATE: July 21, 2006

SUBJECT: IRB# 0606116: Eyes of Science: Families Learning to Observe the Natural World

The above-referenced proposal has received expedited review and approval from the Institutional Review Board under 45 CFR 46.110 (6,7).
If applicable, please include the following information in the upper right-hand corner of all pages of the consent form:

Approval Date: July 21, 2006
Renewal Date: July 20, 2007
University of Pittsburgh
Institutional Review Board
IRB#0606116

Please note that it is the investigator's responsibility to report to the IRB any unanticipated problems involving risks to subjects or others [see 45 CFR 46.103(b)(5) and 21 CFR 56.108(b)]. The IRB Reference Manual (Chapter 3, Section 3.3) describes the reporting requirements for unanticipated problems which include, but are not limited to, adverse events. If you have any questions about this process, please contact the Adverse Event Coordinator at 412-383-1504.

The protocol and consent forms, along with a brief progress report must be resubmitted at least one month prior to the renewal date noted above as required by FWA00006790 (University of Pittsburgh), FWA00006735 (University of Pittsburgh Medical Center), FWA00000600 (Children's Hospital of Pittsburgh), FWA00003567 (Magee-Womens Health Corporation), FWA00003338 (University of Pittsburgh Medical Center Cancer Institute).

Please be advised that your research study may be audited periodically by the University of Pittsburgh Research Conduct and Compliance Office.

APPENDIX B

PARENT KNOWLEDGE SURVEY

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?

Anther Filament Petal Pistil Pollen

Stamen Stigma Style

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

Abdomen *Pollen Pocket* *Proboscis* *Thorax*

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.**			

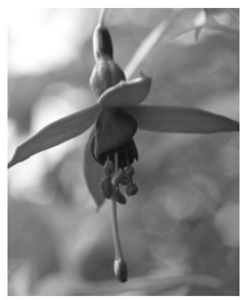
12. In a few words, explain your response to, "A flower has ovaries to make pollen."

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



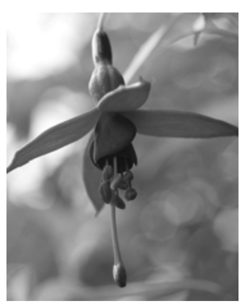
A **B** **C**

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**

APPENDIX C

PARENT KNOWLEDGE SURVEY SCORING

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?

[Total possible value: 1 point]
0 point: not about pollination
1 point: about pollination (either term, definition, or process)
Term: Pollination; pollinating
Definition: moving pollen from one flower to another flower
Process: the bee picks up pollen on its body; the bee gets nectar; the bee is getting pollen
*Note: Taking pollen to hive is not part of pollination process. No points for this explanation

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?

[Total possible value: 18 points]

1 point for each named feature

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*

Note: Do not count feature more than once. Ex: Mentions bee and mentions pollen on bee. This is 2 points total rather than 3 points.

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

Anther	*Filament*	*Petal*	*Pistil*	*Pollen*
Stamen	*Stigma*	*Style*		

[Total possible value: 8 points]

1 point for each named floral part*
Pistil (Style, Stigma)
Stamen (pollen, anther, filament)
Petal

0 points
Leaf (leaves) Sepal
Stem

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

Abdomen *Pollen Pocket* *Proboscis* *Thorax*

[Total possible value: 4 points]

<u>1 point for each of the following</u>
Abdomen, Pollen Pocket (pollen sac), Proboscis, Thorax

<u>0 points</u>
head, body, wings, leg

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."**

[Total possible value: 5 points]

2 points for each correct answer.
2 points for Q.12 if #9 is right.
0 points for incorrect or "don't know"
0 points for questions: 5, 8, 10

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

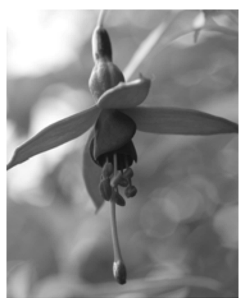


A **B** **C**

[Total possible value: 2 points for each question, #13-15]

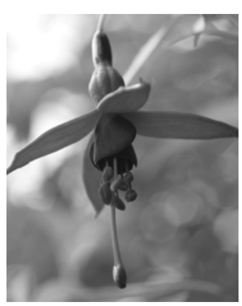
Score for each in section:
0 points if answer to first question is wrong.
1 point: 1st question right, second question wrong
2 points: 1st & 2nd questions correct

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

APPENDIX D

TRAINING PAMPHLET FOR TREATMENT CONDITION

We are interested in the link between parent-child talk and how children learn to observe the natural world. We think that observation and learning go hand in hand. One way that children come to make more powerful observations and to understand their experiences is through conversations with their parents as events unfold. For this reason, we encourage parents to concentrate on talking with their children in ways that support children's observations as they occur.

What Can Boost Children's Learning?

What can boost children's learning about the natural world? In this pamphlet we illustrate four strategies that can enhance what children notice and understand, and which may boost children's learning.

Please read this pamphlet carefully and consider how you might incorporate these strategies into conversations with your child.

The first strategy is to ask Wh- Questions. The questions ask the child to provide information—such as when, where, why, what, who, or how.

The first strategy is to ask Wh- Questions. The questions ask the child to provide information—such as when, where, why, what, who, or how.

The second strategy is to link present to past experiences. This involves making connections between what is happening at the moment and what a child already knows or has experienced.

The third strategy involves focusing the conversation on your child's interests. A good way of including children in active conversation is to talk about objects and events that they find interesting.

The fourth strategy four is to provide positive feedback. Children may be encouraged to say more when they are praised for their comments.

Strategy One:
Ask Wh- Questions

The first strategy we illustrate is the use of *Wh*- questions such as when, where, why, what, who, or how as events take place. These types of questions can call a child's attention to specific aspects of an event or object, and help a parent to determine what a child may or may not know. In this way, *Wh*- questions may be important in helping a child make sense of an experience.

Example 1

In our first example, the mother asks a *Wh*- question about animal identification. Although the child does not know the answer, the mother continues to ask follow-up questions and provides more information. With each conversational turn, the child contributes to a conversation that builds greater understanding.

P: We have to see if the eyes are visible it says. <u>Why do you think that makes a difference?</u>

C: I have no idea.

P: <u>I know, but why do you think? I have no idea either, but I'm wondering why</u>.

C: Why? Yeah.

P: <u>Why do you think it would matter</u>?

C: Cause, [shrugs].

P: If you could see your eyes, if you can see eyes. <u>What do we have that helps us protect our eyes</u>?

C: Oh, um, eyelids?

P: Yeah, we have eye - well, is that a question or do you think you know?

C: I think I know.

P: I think you know too and my guess is that eyelids, I mean that seeing visible eyes, seeing the eyes, might, um, help protect them or not.

C: Okay.

P: <u>What do you think</u>? Does that seem reasonable?

C: Cause if they try and hide or something then their eyes glare from the sun.

Example 2

The next example shows how questions that request names and functions of objects encourage a child to participate in a conversation, and may increase what a child observes about an object. Notice that the father asks a series of *Wh-* questions about an ancient object and its function.

P: So, <u>what is this</u>?
C: It's a cup. Like a…I mean a bowl.
P: A bowl? <u>How did you know it wasn't a cup</u>?
C: Because cups aren't shaped like this and you can also use it for a vase.
P: You could also use it for a vase, that's right. So you can use a bowl for a vase. So, <u>what do you think you could've put in there</u>?
C: Um, you mean for a bowl?
P: Either one.
C: You could put flowers in it for a vase.

Example 3

In the third example, a mother and daughter observe an aquarium. Notice this mother's use of questions. She first asks her child to name the object and then asks questions to explore what her daughter understands about amphibians.

P: What kind of animal does he look like to you?

C: Amph-

P: Like another animal that-

C: He's an amphibian. I know that.

P: He's an amphibian? What's an amphibian?

C: Uh-

P: I think you're right.

C: It's a…it's kind of like things like turtles and salamanders and frogs and toads and whatever you like to call them.

P: Well, okay. Yeah, I think you're right about that. I wonder why they call them…why they're all in that same group? Does it have something to do with their living in the water or -

C: Yeah, it's their body temperature, probably.

In summary, use Wh- questions as events take place. Although children may not provide answers, continuing to add information and to ask different questions that help children to name, observe, and describe objects, as well as to understand their functions is important. Talk that accompanies activities can increase what a child observes and understands about an object or experience.

Strategy Two:
Link Present to Past Experiences

Strategy two involves linking observed objects and activities to past experiences that the child has already had.

Example 1

In the first example, the mother begins by asking her son a Wh- question about a turtle's claw. In order to extend discussion and understanding, she encourages her son to recall experiences during a family vacation. Note that strategies can be used in combination.

C: Look at his claws!

P: What do you think it does with the claws?

C: Dig. Dig in the sand.

P: Well, I'm thinking of when we go to North Carolina when we go on the beach. Do you remember seeing those big, um, screens on the beach and they put a fence around it?

C: Yeah, that was cause they laid eggs there. Turtles laid eggs.

P: Who did? Oh, turtles did, yeah. So they came in from the ocean?

C: Yeah, and they just abandoned their kids. Well, they'd lay eggs and then just go into the sea.

Example 2

In the next example, the mother refers to a familiar everyday experience in order to extend the discussion and to help her child understand what was necessary to make this ancient bowl.

P: Well, what they'd have to do something else too to make sure it doesn't rot, right? Because if I took a big old watermelon and-

C: Oh, like, clean it! Oh, yeah.

P: Yeah, like, clean it. But if I took a big old pumpkin shell and I hollowed it out and I decided to use it for water every day for the next year, what would happen to it?

C: Oh, it would get rotten.

P: It would totally get rotten. So, I wonder what they did so that this thing doesn't get rotten?

C: Yeah, I have no clue. Maybe, like, put something on it.

Strategy Three:
Focus Conversations on Your Child's Interests

Strategy three involves basing conversations on what your child is already looking at, touching, or talking about. By commenting on things that already interest the child, parents may help a child to focus on important aspects of objects or events.

Example 1

In our first example, the mother asks a number of questions that encourage a detailed discussion about a geode that the child has noticed.

C: All right, let's look at this.

P: Oh, you can move it. You want to pick it up? *(Note: Parent picks up large geode.)*

C: That's kind of big.

P: *Well, where do you think you're going to find this*?

C: Um, this, somewhere that I wouldn't think of.

P: *What does it look like*? *What does it remind you of*?

C: Crystals.

P: Uh huh. Do crystals remind you of something hot or cold?

C: Kind of cold.

P: I think so. I think it is.

C: This looks like ice, but it's not.

P: Yeah, that's exactly what I was thinking, that it looks like ice.

C: Glass.

P: Mmm hmm. It looks like glass.

Example 2

In the next example the mother shifts the discussion to talk about a different sea animal that has captured her child's interest.

P: **Where is he, yeah?** (*Note: Looking for a chocolate chip sea star*)

C: Where did you go? Where did you go?

P: I see some-

C: I see the brittle star, but-

P: Okay, the brittle star. How can you tell what the brittle star looks like?

C: 'Cause it says…it shows the picture right there.

P: Right, okay, but *what are we looking at*? *How would I know the difference between the chocolate chip sea star and the brittle star*?

C: Well the chocolate chip sea star, as you see in the picture there, it's brown and it has black spots that looks like chocolate chips hanging off.

P: Well he's got little sort of brown dots where his…his little sticky parts are sticking out-

C: Yeah, I mean…but they stick out, and his doesn't. I mean, like, and they're black.

P: Have you found him yet?

C: No.

P: Maybe his chocolate chip-ness is his camouflage? Do you remember *what camouflage is?*

C: Mmm. It makes the, uh, so that…uh, you can't see it 'cause it, like, blends in.

Strategy 4:
Provide Positive Feedback

Strategy four illustrates how directly praising a child's contributions to conversations may encourage a child to respond to questions, and to actively engage in a discussion.

Example 1

Here the mother uses praise, in combination with asking many questions that probe for information, and centers the conversation on a fossilized jaw that the child had expressed interest in observing.

C: Well, why do we need these teeth?

P: Well, yeah, *why do we need those teeth*?

C: So we look better?

P: You think it's all about looks?

C: Yeah.

P: I don't know about that. Think about what they're useful for. *What are they used for*?

C: Um, eating?

P: Yeah. So, *why do you think bears have teeth like this?*

C: So...I don't know.

P: Well, think of one reason why we…*why they might*?

C: To eat food that is smaller maybe so they can get a better grip while eating them.

P: *Hey, that's a great idea*. *I think that probably would work* because look how they're right behind those big teeth, big giant ones. So those are like extra grippers. I don't know for sure, but *it sure seems like that would work*.

C: Like, they were carnivores right?

P: Mmm hmm.

C: So that means that they only eat, like, meat.

In Summary…

This pamphlet has emphasized four strategies that parents can use to support children's observations and understanding of objects and events, and which may enhance children's learning. We ask that you…

- *Ask Wh- Questions*. ***Use many questions that ask your child to provide information, such as when, where, why, what, who, or how***.
- *Link present to past experiences*. ***Make connections between what is happening at the moment and what your child already knows or has experienced before.***
- *Focus conversations on your child's interests*. ***Notice objects and events that interest your child. Talk about and elaborate on the things on which your child is focusing.***
- *Provide positive feedback*. ***Compliment your child for contributing observations and information to the conversation.***

You may already use many of these strategies. Our purpose here is to highlight these strategies and to ask you to use them with your child as much as possible during everyday activities. As you do so, you may find that your child makes more powerful observations and develops a better understanding of the natural world.

Thank you for participating in the Eyes of Science Study!

APPENDIX E

TREATMENT CONDITION

PARENT PRE-INTERVIEW & POST-SURVEY

TREATMENT CONDITION PARENT PRE-INTERVIEW

Instructions: Researcher interviews parent and records information.

1. Did you read the pamphlet twice as instructed?

   Yes   No   If no, explain____________________________

2. What are the four strategies identified in the pamphlet? Please briefly describe.
   (*Note: if parent doesn't recall a strategy, follow up on descriptions she/he does know, then once more ask if she/he is able to recall any other strategy? If yes, ask for a description. If no, show video.)*

   _____ wh- questions
   description:

   _____ link to past experience
   description:

   _____ focus on child's interests
   description:

   _____ praise contributions
   description:

3. Ask parent to watch video (12 minutes).

4. Do you have any questions about any of these strategies that I can clarify now?
   (*Note: respond to parent's questions. If parent could not recall all 4 strategies, check here to confirm she/he recalls this now.)*

   Yes   No   If yes, list question(s).

At the end of the interview question 4, let the parent know that once the child finishes his/her interview they will be doing an activity together. Then read the following instruction to the parent:

"Please try to incorporate these four conversational strategies into your natural conversational style as you engage in the study activity with your child."

TREATMENT CONDITION PARENT POST-SURVEY

***Instructions*: Please answer ALL questions.**

1. **Overall, rate how difficult it was to use the four conversational strategies with your child today.**

1	2	3	4	5
Very Difficult		Neither difficult, nor easy		Very Easy

2. **Rate how difficult it was to use the *Wh- Question strategy* with your child today.**

1	2	3	4	5
Very Difficult		Neither difficult, nor easy		Very Easy

3. **Rate how difficult it was to use the *link present to past strategy* with your child today.**

1	2	3	4	5
Very Difficult		Neither difficult, nor easy		Very Easy

4. **Rate how difficult it was to use the *focus the conversation on your child's interests strategy* with your child today.**

1	2	3	4	5
Very Difficult		Neither difficult, nor easy		Very Easy

5. **Rate how difficult it was to use the *provide positive feedback strategy* with your child today.**

1	2	3	4	5
Very Difficult		Neither difficult, nor easy		Very Easy

6. **What value, if any, do you think using these strategies has to you or your child? Please describe.** (*Use back of page if needed.)*

7. **How likely is it that you would use these strategies with your child when visiting other museums or other informal learning centers?**

1	2	3	4	5
Not at all likely		I may or may not		Very likely

Questions about Your Child's Interests & Experiences

8. **How interested is your child in plants?**

1	2	3	4	5
Not interested in plants		Interested in plants & has other interests		Prefers playing or learning about plants more so than other things

9. **How interested is your child in gardening?**

1	2	3	4	5
Not interested in gardening		Gardens & has other interests		Prefers gardening more so than doing most other things

10. **How interested is your child in bugs?**

1	2	3	4	5
Not interested In bugs		Likes bugs & has other interests		Prefers playing or learning about bugs more so than other things

11. **How knowledgeable is your child about plants?**

1	2	3	4	5
Knows very little, if anything		Knows some		Knows a lot

12. **How knowledgeable is your child about bugs?**

1	2	3	4	5
Knows very little, if anything		Knows some		Knows a lot

13. **How knowledgeable is your child about pollination?**

1	2	3	4	5
Knows very little, if anything		Knows some		Knows a lot

Questions about Your Interests & Experiences

14. **How interested are you in gardening?**

1	2	3	4	5
I rarely seek out information about gardening		I sometimes seek out information about gardening		I seek information about gardening as often as I can

15. **I am an experienced gardener.**

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

16. **I know a lot about pollination.**

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

17. **I completed at least one college-level biology course.**

No Yes

18. **My knowledge of plants and insects is from:** (*Please circle ALL answers that apply*.)

Gardening	Nature Activities	Elementary School	High School	College
Graduate School	Professional Work	Books	Media/TV	Web/Internet

Other______________

19. **I garden with my child**. (*Note: child who participated with you in the study*.)

Never	Rarely	Occasionally	Often	Very Often

20. **What kinds of outdoor activities do you and your family do together?**

<u>Please circle only ONE response for the remaining questions</u>.

21. **Number of *family* visits to <u>PHIPPS</u> each year**	0-1	2-3	4-5	6+
22. **Number of *family* visits to <u>museums</u> each year**	0-1	2-3	4-5	6+
23. **I am a member of Phipps**	No	Yes		
24. **My child and I visited the Butterfly Exhibit today**	No	Yes		
25. **Your Gender**	Female			Male

26. **Highest level of education YOU have completed**

Less than High School	High School/GED	College	Graduate School

APPENDIX F

CONTROL CONDITION

PARENT PRE- AND POST SURVEYS

CONTROL CONDITION PARENT PRE-SURVEY

Instructions:* *__Please answer ALL questions__.

Questions about Your Child's Interests & Experiences

1. **How interested is your child in plants?**

1	2	3	4	5
Not interested in plants		Interested in plants & has other interests		Prefers playing or learning about plants more so than other things

2. **How interested is your child in gardening?**

1	2	3	4	5
Not interested in gardening		Gardens & has other interests		Prefers gardening more so than doing most other things

3. **How interested is your child in bugs?**

1	2	3	4	5
Not interested In bugs		Likes bugs & has other interests		Prefers playing or learning about bugs More so than other things

4. **How knowledgeable is your child about plants?**

1	2	3	4	5
Knows very little, if anything		Knows some		Knows a lot

5. **How knowledgeable is your child about bugs?**

1	2	3	4	5
Knows very little, if anything		Knows some		Knows a lot

6. **How knowledgeable is your child about pollination?**

1	2	3	4	5
Knows very little, if anything		Knows some		Knows a lot

Questions about Your Interests & Experiences

7. **How interested are you in gardening?**

1	2	3	4	5
I rarely seek out information about gardening		I sometimes seek out information about gardening		I often seek out information about gardening

8. **I am an experienced gardener.**

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

9. **I know a lot about pollination.**

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

10. **I completed at least one college-level biology course.**

No Yes

11. **My knowledge of plants and insects is from**: (*Please circle ALL answers that apply*.)

Gardening	Nature Activities	Elementary School	High School	College
Graduate School	Professional Work	Books	Media/TV	Web/Internet

Other______________

12. **I garden with my child.** (*Note: child who is participating with you in the study*.)

Never Rarely Occasionally Often Very Often

13. **What kinds of outdoor activities do you and your family do together?**

CONTROL CONDITION PARENT POST-SURVEY

Instructions:* *<u>Please answer ALL questions</u>.

1. What is your reaction to today's experience with your child? *(Use back of page if needed.)*

2. Rate how difficult it was to do the observation activity with your child today.

1	2	3	4	5
Very Difficult		Neither difficult, nor easy		Very Easy

Please explain your rating.

3. What would make this activity more interesting and engaging for you and your child? *(Use back of page if needed.)*

4. Would you be interested in a participating in parent training that helps you to support your child's learning during family visits to museums and other informal learning centers?

1	2	3	4	5
Definitely No	Probably Not	Maybe yes, Maybe no	Probably Yes	Definitely Yes

Please turn over and complete the survey.

Please circle only <u>ONE</u> response for the remaining questions.

5. Number of *family* visits to <u>PHIPPS</u> each year	0-1	2-3	4-5	6+
6. Number of *family* visits to <u>museums</u> each year	0-1	2-3	4-5	6+
7. I am a member of Phipps	No	Yes		
8. My child and I visited the Butterfly Exhibit today.	No	Yes		
9. **Your Gender**	Female			Male

10. **Highest level of education YOU have completed**

Less than High School	High School/GED	College	Graduate School

11. I have not discussed the content of the parent survey's with my child prior to participating today.

No Yes

APPENDIX G

CHILD INTERVIEW

Note to Researcher: *In the event that a child is not familiar with pollination or doesn't know what it is, do not define or explain pollination to the child.*

Set A

1. So, what are your favorite outdoor activities?

1.B. PROBE: What outdoor activities do you and your family do together?

1.C. Do you ever garden with your family?

YES NO

If yes, with whom? What do you like to grow?

2. Do you think you know more about plants or more about bugs?

PLANTS BUGS

2.B. PROBE: How come?

3. Have you ever noticed bees near flowers?

YES NO

3.. IF YES, PROBE, "Why do you think bees are near flowers?"

CORE SET

1. **Here are some photographs. These are not in any special order. (*Display photos*.) Some photographs have something to do with pollination and some don't. I'd like you to make two piles. In one pile put all the photographs you think have <u>something</u> to do with pollination. In the second pile put all the photographs that you think have <u>nothing</u> to do with pollination.**
    a. Once child sorts all of the photographs, ask child:
        i. *Confirm which pile this is with child*. Why did you put these photographs into this pile? *<u>PROBE</u>:*
            1. What features influenced your choice?
            2. <u>Probe:</u> What did you notice?
                a. Anything specifically about the flower?
                b. Anything specifically about the bugs?
            3. If child makes inference statements: What (features/behaviors) did you notice that made you think (fill in child's explanation)?
        ii. Repeat for second pile.

        Special Instructions: Researcher to record which photographs are in the pollination pile and which were in the non-pollination pile at end of interview.

        Special Instructions: Video data must zoom in on what the child is pointing at.

2. **Here are 2 photographs. (*Display photos.)* Could a bee pollinate these flowers?**
    a. <u>Probe</u>: Why or why not?

3. **Here's a flower. So, what color is this flower? I'd like you to look at, touch, and smell this flower. As you're doing that, I'll ask you to answer some questions JUST BY LOOKING AT THE FLOWER.** (*Use child's choice of color to test understanding of question.*)

So, just by looking at this flower, can you tell if …

Statement	YES	NO
…the flower is (child's color)?		
…the flower came from California?		
…the flower must contain nectar?		
…the flower has pollen?		
…the flower is making its own food?		

Ask child to elaborate…

How can you tell that (*fill in child's explanation*)?

Special Instructions: Video data must zoom in on what the child points

4. **Imagine that you're a hungry bee. Looking at this flower, how would you find something to eat?**
   a. <u>Probe</u>: Where would you look? What clues might a bee look for?

5. (BRING OUT MODEL/PUPPETS) **Imagine that a friend of yours wants to know something about bees visiting flowers. You can use this model of a flower and puppets to help your friend understand. What would you show your friend? What would you say?**

Special Instructions: Video data must zoom in on what the child is doing with the puppet.

Set B

1. **If you had to choose between going to a summer camp about bugs OR going to a summer camp about flowers, which would you choose?**

   BUGS FLOWERS

   PROBE: **Why?**

2. **Do you like to draw pictures?**
   YES NO

   If yes, PROBE:

   a. **What kinds of things do you draw?**
   b. **Why do you like to draw (fill in child's preferences)**
   c. **Would you say your drawings are more from your imagination or from looking at things?**

3. **What do you think pollination is?**
   Note to Researcher: In the event that a child is not familiar with pollination or doesn't know what it is, do not define or explain pollination to the child.

Always the Last Questions:

4. **Did you see any bees or butterflies flying close to flowers today?**

   NO YES

5. **Before today, did you learn about pollination?**

   NO YES

   PROBE: **Where did you learn about pollination? (School? Home? Other?)**

APPENDIX H

ELABORATIVE CONVERSATIONAL STYLE CODING

<u>Goal</u>: To identify the number of instances in which parents use the elaborative conversational strategies during the Observation Event.

<u>Coding follows these general guidelines</u>:

(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 used.

(4) Individual statements may be coded for multiple strategies. For instance, the question "What about the moth we just saw?" should be coded both as a *Wh*-question and as linking present and prior experience.

<u>Coding Constraints</u>:

(1) Only Parent/Child conversation that occurs within the study areas is coded.

(2) Parent/Child talk that discusses the research study is not coded as elaborative talk.

<u>Examples</u>:

P: “What did you talk about with her?

C: “Oh everything.”

(2) Parent talk that simply repeats what a child has said is not coded as elaborative talk.

Examples:

C: “The bee is fuzzy.”

P: “It is fuzzy.”

C: “What is the bee doing?”

P: “What’s it doing?”

Strategy Coding Definitions:

1. Ask *Wh*-questions include parents’ questions that begin with what, when, where, why, who, or how. *Examples*: “So, what’s it doing?” or “How do you know it’s a moth?” “The bee is looking for what?” Closed questions directly targeting child response are also counted as *Wh*-questions when they are specifically targeted to the child. *Examples*: “Do you know where the pollen goes?” is coded as a *Wh*-question, whereas, “I wonder what this is?” is not.
    a. Each *Wh*-question in a conversational turn is counted as a single instance. The exceptions to this rule are:
        i. When parents repeat the same or very similar question in a single conversational turn. *Example*: “What’s in here? What are those little things?” are coded as one *Wh*-question.

ii. When parents make multiple attempts to form a question within a conversational turn. *Example*: “What could be – could be producing – what could be inside making the scent?”

b. Occasionally, a parent’s *Wh*-question may be asked across two conversational turns, such as when a child interrupts a parent’s talk or makes listening “talk” such as “Uhmm” or “yeah”. Code such interrupted—but completed—use of a *Wh*-question as a single instance.

Example:

P: What do you think//

C: /Yeah?

P: //that bee is doing?]

c. Incomplete questions are not coded as *Wh*-questions. *Example*: “Why does-?” and “Where do you think-?”

d. Rhetorical questions that are not really intended for children to answer are not coded as *Wh*-questions.

Examples:

“You know what? I think we should go there.”

“Why don’t you look `through the magnifying glass?”

“You know why I think this is true?”

However, some questions—in particular, “What do you think?”—may be either rhetorical or genuine *Wh*-questions. The distinction depends upon whether the child actually answers the parent’s question and tells the parent what he/she thinks. [Note: In contrast, a parent asking the question, "What do you think this stamen is for?" is a *Wh*-question.]

Examples:

- *Rhetorical*: "What do you think? Let's go over there."
- *Wh-Question*:

  P: What do you think?

  C: The bee's getting pollen.

e. Wh-questions are sub-coded as Content and Non-Content Wh-questions.

Content: These questions focus on questions related to the topic of pollination (e.g., plants, insects, conditions under which pollination occurs) as well as scientific comments (e.g., evolution, intentionality, process). Likewise, questions that ask, "How do you know that?" are also considered to be content questions in certain contexts. For example, asking questions that seek to identify a source (book, tv, camp) or evidence (P: "How do you know there's pollen?" C: "I see pollen there."). Essentially, "how do you know questions" are related to a learning process.

i. Non-Content: Examples include questions related to direction ("Where is it?" "What's next?"), making a choice ("Which one do you want to start at?" "Which one do you like best?" "Why do you like this one more than that one?), clarification ("What?" as in "What did you say?"), and operational issues ("How do these work?" "How do you know that?"). Questions about magnifying glasses are non-content.

ii. Where Questions: Note that *where* questions may be either content or non-content. These are content when the focus is pollination related (C sees a butterfly and P asks: Where?). Non-content questions include these operational examples: "Where is your magnifying lens?" or "Where do you want to go next?

f. Categories of Content Wh-questions

i. Learning process (e.g., how did you learn/know that?)

ii. Biological Process (e.g., pollination, life cycle, growth, fertilization).

iii. Form/function (e.g., pollinator/floral structure, attraction, etc)

iv. Identification: (e.g., identify organisms, such as plants, pollinators, by name, identification of parts, kinds)

v. Evolution: (e.g., questions related to intentionality, how does it know; plant/pollinator relationships)

2. Link present activity to past experiences include instances in which parents connect what is happening during the activity with *what a child already knows or has already experienced.* Prior experience and knowledge may refer to those that have occurred *prior to* the observation event or to those that have occurred *earlier during* the observation event. Prior experience is often contextualized in terms of *time* (e.g., before, long ago, when you were in 1st grade), *place* (e.g., school, home, camp, previous garden section), *activity* (e.g., gardening, being stung by a bee), and *people* (parent, family, teacher, neighbors).

Examples:

- "What about the moth we saw over there?"

- “You’ve seen this before.”
- “What color spots do ladybugs usually have?”[6]
- “…like the bees in our backyard”
- “Didn’t you learn this in school?”
- “That’s like the plant in grandma’s garden.”
- “Remember when that bee landed on you and you were so scared?”

a. *A parent or child may initiate a link*. In the case of the former, parent talk is considered a link only if it elaborates or extends the connection identified by the child.

Example:

C: …Remember when we were on vacation and we saw those huge bees?

P: I know. There were tons of them.

b. A parent may also make statements or ask the child questions related to *what the child remembers as a way of activating links to prior experience or knowledge*. Such statements or questions may or may not qualify as links. For example, questions that simply ask, “Do you remember?” with no explicit object are not true links. However, “memory” statements or questions that include “*targets*” are links.

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[6] Mentioning “before” or “usually” suggests a child has prior experience with the object/experience.

Examples:

"Do you remember *how a bee gets nectar*?"

"What does *this* remind you of?" (Note "this" is the target.)

"Do you remember *doing that in school*?"

i. *In cases where the targets are not specifically identified, at least 2 of the following conditions must be met in order to code as linking*:

   1. The statement or question must connect to the ongoing activity or pollination content.
   2. The child's response elaborates upon the parent's statement.

      Example: P: Have you seen the bee do this before?

      C: Yeah, in Cissy's garden.

   3. The parent mentions a prior experience that the child doesn't recall, and then provides additional elaboration. (In this case, the parent's talk suggests that the child should recall the event.)

ii. *What is NOT coded as a Link*:

   1. Parent talk that refers to the research study (e.g., "Did you learn this today?").
   2. Talk in which the parent explicitly says the child was too young to recall the events or would otherwise be unaware of an event are not coded as links. These do not conform to the expectation that the parent refers to something already experienced by the child.

c. Parents may also make explicit analogical connections to the surface or structural aspects of phenomena. The most straightforward connections are those in which the parent suggests that the target object (proboscis, nectar, stamen) is *LIKE* something more familiar (straw, syrup, powder).

<u>*Examples*</u>:

"It looks *like* honeycomb …. or coral."

"It looks *like* little hairs."

"The proboscis is *like* a straw."

"What's inside the bee's suitcase?" (*implies function of a pollen basket*)

"That straw thing" (*implies function rather than surface appearance*)

i. *What is NOT coded as a Link*:

1. Parents may use descriptive terms ("that stick thing" "that powder stuff") when they simply *do not know* the technical terms ("stamen" "pollen") or for some reason (i.e., thinking the term is unfamiliar to the child). A reasonable check is to look for evidence that the parent uses technical terms elsewhere in the conversation.
2. Statements or questions of identification. "What do these look like?" In addition, these include statements that refer to a *kind*. For example, "It looks like parsley …tulips …roses" could all be interpreted as identifying an object. However, if the statement is, "It looks like parsley in our garden" is a link.

d. Comparisons between plants or pollinators at different garden sections ARE coded as links.

   Example: A parent points to a plant in another garden section and says, "That's like the one I showed you over there."

   i. *What is NOT coded as a link*:

      1. Comparisons between plants or pollinators in the same garden section. These occur is an immediate condition; no actual past condition is actually targeted. "See how this one is more pink on the inside ad that one is more orange?"

3. PROVIDE POSITIVE FEEDBACK includes those opportunities when parents *explicitly* acknowledge the child's observational, content, and participatory contributions. Although parent feedback often assesses the accuracy of a child's comments, other positive evaluations may refer to initiating activity or talk, as well as the nature of the activity.

Acknowledge Content Accuracy or Contribution Examples

"That's right" or "Exactly" or "I think so too" "That's happening just like you said" or "Good question" or "There you go" or "Very good"

In the following example, the parent first challenges the child's observation, but looking more closely, appears to agree that the child is correct:

C: Look at this bug it's the same bug we saw at the pool.

P: Oh really? Let's see. Oh yes.

Some parents also offer positive feedback by comparing something the child says or does, with something the parent doesn't know or do as well.

P: Maybe. I don't know. You're probably right.

<u>*Acknowledge Observational or Participatory Activity Examples*</u>

"Hey! That's a really cool thing to notice"

"You like using that magnifying glass, huh?"

"You seem to be getting used to being around the bees."

"I'm so glad that you opened that up."

What is NOT coded as Positive Feedback:

a. Statements that punctuate talk rather than explicitly acknowledge contributions are not coded in this category.

   <u>*Examples include*</u>: "Ok," or "Right," or "Uhhuh." or "True." "Nectar and pollen right."

b. In addition, talk that is generally positive about aspects of the event itself—but is independent of the child—are not coded as positive feedback.

   <u>*Examples*</u>:

   "This is a beautiful flower"

   "I like this butterfly bush."

   "I thought this would be a really fun experience for us to do together."

In the following example, the parent is actually commenting on the phenomena rather than the child's contribution or participation:

C: Wow! Look at that big bee.

P: Oh wow-that's amazing!

c. Parent talk in which the parent tries to soften the blow when he/she thinks the child may be misguided in some way.

   Example:

   "That could be right."

   "You may be right." (note the parent talk does not infer child knowledge)

4. CHILD FOCUS TALK includes episodes when parents guide or extend conversations towards pollination-related objects and activities in which *the child already has expressed interest*. The primary function of focus talk is that the parent supports the child's observation of the pollination-related phenomena and helping to elaborate or support understanding, helping to notice and to encode what they are observing, or to extend the child's noticing behavior. A child's interest could be positive ("*Cool. Look at those bees*.") or negative ("*I hate bees*.").

   There are two required conditions: (1) child initiated; and (2) pollination related.

   a. Who initiates change in topic or focus?

      i. Child initiates change in topic or focus & parent follows up with that topic or focus = possible child focus talk.

      ii. Child initiates change in topic or focus & parent acknowledges but DOES NOT elaborate = NOT child focus talk.

      iii. Parent invites child to choose direction/topic, the child accepts

         a. And parent follows up = possible child focus talk.

b. And parent sets new direction or does not follow up = NOT child focus talk.

iv. Parent invites child to choose direction or topic and child declines = NOT child focus talk.

b. Is the object or topic pollination–related?

   i. *If yes, then it is possible child focus talk.*

   ii. If no, then it cannot be child focus talk. For example, parent/child talk about sculptures is not focus talk.

c. Identifying a child focus episode requires that there is a change in topic or focus.

   i. Change in topic

   ii. Change in focus

      1. From one object to another object.

      2. From one ANATOMY of an object to BEHAVIOR of an object or vice versa. For example, a parent is talking about a bee's ANATOMY and the child shifts the focus to the bee's BEHAVIOR.

d. The nature of Focus Talk is that it often occurs over multiple parent/child conversational turns. Therefore, identify an episode of Focus Talk and code each parent conversational, coding only those turns as focus talk in which parent elaborates or focuses on child's observations.

   Example in which all parent talk is focus talk (in bold):

   C: Look at that.

   P: It looks like they have a lot of pollen.

C: Look at that really, really tiny one.

P: It's a bug. Is that a bug or a bee?

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.

Example in which some parent talk is focus talk (in bold):

C: Look at all those bees up there!

P: What? Oh wow! [Note: clarification, non-descriptive exclamation]

C: It's three bees on one flower!

P: And there's two over there.

C: Three bees on one flower!

P: I thought their favorite was over there at the pink ones.

C: This is their favorite. I knew this would be their favorite!

P: Oh, let's look closer.

C: They're on that yellow stuff.

P: Yeah, they are on the yellow stuff. [Note: repeat, not focus]

C: It's all over that bee!

P: Is that pollen?

C: I don't know

P: You don't remember? [Note: not elaboration, not in this time/place]

Example in which parent invites child decision (focus talk in bold):

P: Where would you like to start?

C: Here. [This is the start of the Focus Talk episode.]

P: Here? Ok. Well these are nice colors, aren't they?

A child focus talk ends at the last conversational turn before a change in topic or focus, whether initiated by the parent or child.

e. What is NOT coded as Focus Talk:

   i. Parent talk that merely repeats what a child has noticed or observed. In these cases, a parent acknowledges the child's interest but does not extend or support the observation with elaborative talk. Neither is it coded as Missed Focus Talk (see #4).

   ii. Parent Focus Talk is the result of a parent's initiation of an observation or topic. Although a child may becomes engaged and elaborative, unless the child initiates a focus or topic change, this remains Parent Focus Talk.

APPENDIX I

POLLINATION DISCIPLINARY TALK CODING

The purposes for coding pollination content are to understand: (1) how families in an informal learning context talk about pollination; and (2) how "disciplinary talk" is expressed in parent-child talk during shared observation of biological phenomena.

Summary Guidelines

1. Coding reflects parent-child pollination-related talk that occurs during the entire Observation Event.

2. Coding is based upon a <u>Pollination Model</u> that represents the biological process of pollination, including (relatively immediate) post-pollination results. Building from the work of Machamer, Darden, and Craver (2000), this model is organized into three parts: Set-Up Conditions, Intermediate Activities, and Termination Conditions. An important assumption is that each part is distinct such that parent-child pollination talk can be identified and segregated. For example, here is how pollen might be observed in the three parts:

Set-Up Condition	Entities must have structural features and/or properties that can support particular activities	*"Look, there's pollen."*
Intermediate Activities	The relevant entities, properties, and activities that link them together	*"See how that bee is crawling inside that flower and getting pollen on his legs."*
Termination Condition	The post-pollination and fertilization conditions of the entities	*"The pollen is all gone so the bees must have been here."*

3. Unless noted in the Pollination Model, privilege is given to the use of terms that are more scientific. For example, *pollen* is coded as pollination talk whereas the descriptive "yellow stuff" is not. Both refer to pollen, however the former reflects knowledge that more closely aligns with disciplinary knowledge. Even so, families may not use terms precisely: piston for pistil, "probissuss" for proboscis and so on. There are close enough to be coded as pollination content.

    a. References to pollen basket and proboscis: Note that "pollen basket" may also be referred to as pollen sac or pollen bag, or more popularly, suitcase. Popular educational use of alternative names for "proboscis"—long tong, tube, straw, trunk—and reasonable similarities are coded as descriptive properties. However, proboscis is coded only when the term is used.

4. Once a term (feature, property, activity) is counted in a condition, it is not counted again in *the same* part. For example, a family may repeatedly *identify* pollen during the event, but pollen is counted only once in the Set-Up Condition. Similarly, if the family repeatedly describes a bee to be eating pollen, it is only counted once in the Intermediate Activities.

5. Unless specified, coding is less interested in the accurate *application of the terms* than in the fact of their use. For example, a parent or child may point to the stigma and refer to it as *stamen*. In this case, the use of the term *stamen* is coded. On the other hand, elaborating about the location of nectar or pollen is only coded when accurate.

6. Reading interpretive signage verbatim is not coded as pollination talk. However, talk in which families re-voice interpretive signage is coded as pollination content.

CHARACTERISITCS OF THE THREE PARTS

1. Set-up Conditions
    a. For pollination to occur, entities must have particular structural features and/or particular properties that can support particular activities. In the case of pollination, entities include flowers and agents that transfer pollen. Although parents and children primarily observe bees and butterflies, other pollinators such as moths, beetles, and ants may be identified.

    b. Pollination Talk in the Set-Up Condition emphasizes (1) Identification of the entities and their properties (i.e., kind of organisms, structures of organisms, and properties of structures); and/or (2) Locations of the structures of entities.

        Examples of Identification:
        - *"That's a bee"—"Is that a monarch?"—"That's the petal"*
        - *"I think the pollen is the yellow stuff."*
        - *"That butterfly has a long tongue!"*
        - *P: "So which part has the pollen?" C: "The small purple ring"*
        - *"This flower sure has a lot of pollen."*

Examples of Location:
- *"I think the pollen is on the outside of the stamen"*
- "*The pollen is on the top of the flower"* (points to stamen).
- "*Wow! There's a big chunk of pollen on his back leg."*
- *"The nectar is in there."*

c. Helpful Distinctions between set-up and intermediate talk:
   i. Pollen/Nectar: "That looks like pollen" is set-up talk whereas "They (*sic* bees) eat pollen" is intermediate talk. The former identifies a feature critical for pollination to occur, the latter connects the pollinator's activity with the pollen as a floral reward.

   ii. A Pollinator's Legs: "Look at his hairy little legs" identifies the critical features that enable a bee to trap and transfer pollen, however it falls short of an intermediate stage observation: "See how he's sticking that yellow stuff to his hairy legs."

d. Some properties may be noticed from a biological or a human pov: Families may talk about floral cues (i.e., color, patterns, scent, lines) as properties that attract pollinators and/or as properties that attract people ("Oh, that's a pretty blue flower."). Only the former talk is coded as pollination talk.

e. Availability quantifies the amount of pollen and/or nectar that is present.

   Example: "There must be a lot of good nectar in these flowers."

   Not Example: "I don't see any pollen" is different from "There's no pollen on these plants," which can be coded for this category. The former may reveal some limitation of the observer or the use of inadequate tools.

f. Ability refers to a pollinator's visual or olfactory abilities to sense appropriate floral entities.

g. Temperature and seasonal codes refer to the environmental conditions necessary for pollinator activity or plant conditions to occur.
- "*The butterflies can only fly when it's warm enough."*
- "*Yeah you don't see a lot of blooming flowers in winter, right?"*

h. Form/Function:
   i. Because one function of floral structures and properties is to attract pollinators, form and function relationships associated with attraction are coded in the set-up condition. Families may specify attraction and/or they may refer to pollinator preferences that suggest attraction (e.g., "what colors bees like").

Examples of floral structures/properties attracting pollinators:

- *"Does the color attract the bees?"* (property)

- *"Do butterflies like flat flowers better than teeny ones?"* (property)

- *"They come to get the nectar."* (structure)

ii. In addition, pollinator structures must have particular characteristics and/or properties that provide the necessary conditions for accessing floral rewards (i.e., nectar, pollen). This code requires that families *refer to both* a characteristic pollinator's structure and how it supports getting pollen or nectar. In the case of a proboscis, the use of the term by itself would allow one to assume an important structural factor without additional description.

Examples:

- *"Look how far he (bee) has to go (referring to shape of flower). That's why they have that long thing (referring to proboscis)."*

- *"So butterflies have really long tongues to get the nectar out of those flowers."*

- *"See the bees have just the right shape to go way down in those (sic, flowers)."* [way down = location of nectar]

Not Examples: because neither connects some characteristic of a pollinator's form to enabling access to floral rewards.

- *"See how that bee fits right in that flower."*
- *"Bees couldn't. I don't think bees could not get in there. They would only squeeze out from in the side – in right there."*

2. Intermediate Activities
   a. Focus here is on the relevant entities, properties, and activities that link them together. For insect pollination to occur, pollen must be moved from one flower to another flower.

b. Pollination talk during Intermediate Activities focuses on *how* pollen is transferred between flowers. Thus, talk focuses on: (1) the activities and behaviors of pollinators, and (2) the relations between floral structures and properties, the pollinator activities, and the environmental/ecological conditions.

c. When are references to pollen and/or nectar coded as food rewards? Families must convey the idea that the pollinator consumes the pollen and/or nectar. This may be as straightforward as using the term "eat" but other terms that suggest consumption may also be used: slurping, tasting, sipping, drinking, chewing.

   Examples:
   - *"He's sipping the nectar!"*
   - *"He seems to be licking it!"*
   - P: *What are they eating there?* C: *Pollen?* P: *I think it's the nectar.*

   i. Other ways in which talk conveys the concept of nectar and pollen as food rewards:
      1. References to mouth activity: "He's getting the pollen with his mouth" or "The butterfly unfurls its tongue to get nectar."

      2. References to taking pollen and/or nectar to the hive to feed the colony.

   ii. Simple references to "getting nectar" or "getting pollen" can only be coded as food source talk when accompanied by additional supporting evidence as noted above. This supporting evidence may occur at any time during the Observation Event.

   iii. Finally, it can be difficult to determine it a family is specifically referring to pollen or nectar in the context of food rewards. When this occurs, the general floral rewards code is applied. Otherwise, use the pollen or nectar as food sources when these are specified.

   iv. Should families simply refer to "getting nectar" or "getting pollen" without reference to it as a food source, the "Get nectar" and "Get pollen" codes should be used.

d. Breaking Down Pollen Transfer
   i. Families notice the actual transfer of pollen with varying degrees of specificity, as noted in the pollination model. The four "levels" are coded *independently* of the other. A summary score will be devised.

Pollen Transfer

Pollinators get pollen, but no reference to carrying pollen or transferring it.	*"The bee gets the pollen"* *"Do they get pollen?"*
Pollen is on some part of the pollinator's body without reference to getting it or carrying/ transferring it.	*"See he gets that pollen on his tummy"*
Pollinators carry pollen without also conveying the explicit idea of depositing pollen onto another flower. In (a) the pollinator carries pollen and in (b) the pollinator carries pollen to another flower.	*(a) "So he carries the pollen on him"* *(b) "And the butterfly carries pollen to anther flower."*
Pollinator transfers pollen from flower to flower, making explicit reference to depositing pollen. *	*"And he takes it from here and then puts it on another flower."* *"…and then he leaves some (sic pollen)."* *"…they take it and spread the pollen to other flowers."*

ii. In order to code pollen transfer, families must refer to pollen. The clearest reference is the use of the term pollen. Alternatively, if a family has referred to pollen in some way (i.e., "that yellow stuff is pollen.") and then uses that SAME description in a transfer context, that description could be coded here. However, simple references to *"the bee moves the stuff"* without an explicit connection to pollen should not be coded here.

<u>Example</u>:

-In an earlier comment P says, *"Yeah look at that yellow stuff. That's pollen isn't it?"* Then later says, *"Oh he's getting that yellow stuff."*

e. <u>Distinctions between Behavior and Foraging Behavior</u>

i. <u>Foraging behavior</u> refers to pollinator behavior associated with trying to get nectar or pollen (i.e., food). Among other activities, it may involve crawling, digging, hugging, rummaging, but always in relationship to pollen or nectar.

<u>Example</u>:

-*"That bee's crawling all over that pollen and getting it all over himself."*

ii. Behavior is general activity that describes a pollinator's activity at a flower that is not explicitly connected to gathering pollen or nectar.

    Example:

    - *"Oh look! That bee's crawling in circles."*

f. Repeating behavior talk focuses on the repetitiveness of (an individual) pollinator's activity. This is distinct from statements that pollinators move *pollen* from flower to flower.

    Examples:

    - *"He just keeps doing that over and over again."*
    - *"He's going to every single flower."*
    - *"Do you think he'll go to another flower and do that again?"*

    Not an Example:

    - *"That bee is going to a flower and this bee is going to a flower."*

g. Time/efficiency talk: conveys the idea that pollinators are efficient in their behavior and effort.

    Examples:

    - *"They're trying to pollinate very fast."*
    - *"Look at how fast that bee is getting pollen. It doesn't stop."*

    Not an example:

    - *"That's a busy bee."*

h. Orientation refers to orientation of the pollinator in relation to the flower.
    i. Middle: *"Oh he's right in the center part!"*
    ii. Bee: The bee's head is in the direction of the nectar and the body and legs in proximity of the pollen. *"Look how he [sic bee] is sticking his head right in there!"*
    iii. Butterfly: *"The butterfly is on the flower."*

i. Form & Function in the Intermediate Activities refers to talk that focuses on pollinator behavior in relation to floral structure. Form and function talk is grouped according to whether the emphasis is on getting floral rewards or *landing* on floral structures.

Example:

- "*Butterflies <u>land on flat flowers with their long legs</u> and <u>use their long tongues to get the nectar</u>*"

3. Termination Conditions
   a. Once pollination occurs, the floral entities may be altered and the later stages of floral and pollinator life cycles are possible. Noticing these changes is important to understanding the broader role of pollination in an entity's life cycle.

   b. Termination Conditions talk explicitly connects the post-pollination state to pollination activity (i.e., moving pollen).

   c. Plant: Once pollination occurs, the floral entities may be altered, specifically, flowers change in ways that make them unattractive to pollinators.

      Examples:

      - "*Looks like the bees have already been here. The pollen looks all dried up.*"
      - "*It looks like these have already been pollinated.*"
      - "*So after the pollen gets in here, the plant makes new seeds*"

      i. In addition to pollination, changes in floral condition may occur as part of natural senescence. Therefore, it is important to distinguish talk that refers to changes that result from pollination and those that result from a flower's life cycle.

         Example (not codable as pollination talk):

         - "*Do you think that plant's finished? I don't see any flowers.*"

      ii. Families may also state something like: "And then it makes new flowers." This is not coded as termination talk because there are many processes between pollination and "making new flowers". We limit the talk to immediate post pollination stages, specifically fertilization (evidenced by swollen ovaries, seeds forming as a result of fertilization or pollination which may lead to fertilization).

   d. Pollinator: This talk focuses on what pollinators do after they finish collecting pollen.

   e. Orientation and pollinator changes in visitation: Coding identifies changes to floral orientation and to pollinators avoidance of flowers in decline.

4. Counting Codes
    a. As previously noted, terms are counted once as they occur in each of the three parts.
    b. Unless noted, terms have a value of 1 point.
    c. However, some terms are given a hierarchical value in which ONLY the highest level of coding is scored and counted. See the following:

        1. Floral rewards

            -Floral rewards—1 point

            -Pollen OR Nectar as food source—2 points

            -Pollen AND Nectar as food source—3 points

        2. Pollen Transfer

            -Get pollen—1point

            -Pick up pollen on body—2points

            -Carry pollen on body—3 points

            -Carry pollen on body and take to another flower—3.5 points

            -Pollinator transfers pollen—4 points

        3. Behavior
            a. Describing behavior is credited at 1 point
            b. Foraging behavior is credited at 2 points.

Example: A family talks about bees eating the flower (1 point) and also mentions the bees suck nectar (2 points). In this case, the score would total 2 points.

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