ABSTRACT

Title of Dissertation: KNOWING TO ASK AND ASKING TO KNOW: THE RECIPROCAL NATURE OF INQUIRY AND SELECTIVITY

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Children are resourceful learners, capable of learning about the world both through hands-on experience, and by engaging with other members of their communities. Questions play a particularly central role in children's early learning, allowing them targeted, direct access to what others know. In this study, children aged 4-7 were presented with animations of puppet characters playing a Question Game in which one character reliably asks more efficient questions than the other. In three generalization trials, children were asked to extend their judgments of the characters' questioning abilities to determine which character would be more reliable, which would be a better teacher, and which would be a more competent problem-solver. Children as young as 4 were able to identify the more efficient questioner and could generate their own overall assessment of a character's questioning ability given previous experience with their use of strategy. Children did not generalize

questioning strategy to reliability, but they did appear to view better questioners as broadly more knowledgeable and more competent. The extent to which children justified their choices by referencing relative information gain did not predict their identification of a better questioner in the generalization trials, though it did increase significantly with age and was significantly predicted by their scores in the Question Game. This suggests that, with age, children become more adept both at identifying better questions and in providing cogent explanations for their reasoning. Future work is needed to explore older age groups and develop strategies to help children make direct connections between questioning strategy and relative information gain.

KNOWING TO ASK AND ASKING TO KNOW: THE RECIPROCAL NATURE OF INQUIRY AND SELECTIVITY

by

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Dedication

I dedicate this dissertation to my family. To Mom, Dad, Tarah, and Geoff, without whose love, support, encouragement, and unflappable patience, I would never have achieved this dream. To Sandee, Courtney, Zach, buddies Liam and Logan, who brought joy to moments of self-doubt. To Chris—you are my home.

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Table of Contents

List of Figures

List of Tables and Graphs

Chapter 1: Introduction and Theoretical Considerations

“Judge a man by his questions rather than by his answers.”

Voltaire

Children are incredibly resourceful learners. From early in development, they engage both in active, hands-on exploration of the world around them, and with other people as sources of information about the various physical, biological, and social phenomena that they encounter. Using the data that they gather from their direct experience and from others, children construct intuitive theories about these phenomena to track regularities, make predictions, and experiment with their developing knowledge structures representing how the world works (e.g., Carey, 1985; Gopnik & Wellman, 1992; Ronfard, Zambrana, Hermansen, & Kelemen, 2018). While active, hands-on exploration is, in many ways, foundational for children’s learning, it is the ways in which children leverage their social relationships with others to learn about the world that is of particular interest here. This is for two primary reasons: (1) how successfully children gain new information from the people around them is subject to how they approach a problem (e.g., using their pre-existing knowledge, the efficiency of their information searches); and (2) what children subsequently learn is subject to the quality of the information people provide them. Children must, in these ways, be highly selective and strategic from the outset of an information exchange to maximize their learning. Exchanges between children and the social peers with whom they engage—parents, teachers, other children—are both ubiquitous and particularly beneficial for children’s learning. These exchanges, themselves a sort of active exploration, contain information both about the topic under investigation and about people with which those children are engaged. The social dynamics of the various relationships that children have with others can, in turn, inform their understanding of what constitutes a reliable ‘teacher’ and shape their future information searches.

One central aspect of children’s learning is the ability to ask questions. The knowledge they gain from question-asking interactions helps children to build a coherent and reliable knowledge base about the world and its structure. Children ask questions often, and the content and structure of those questions has significant implications for what children learn (e.g., Carey, 1985; Chouinard et al., 2007; Frazer, Gelman, & Wellman, 2009; Ronfard et al., 2018). The ability to pose good-quality questions, however, requires additional cognitive and experiential skills that children gain over the course of early development. For example, in a study with 4-, 5-, and 6-year-olds, Legare and colleagues (2012) found that performance on a cognitive flexibility task correlated with the ability to use more efficient questioning strategies to solve a complex problem. The capacity to evaluate the kinds of responses that they receive for their questions mirrors this development and improves during the preschool and early school years, when many of those foundational cognitive skills appear or are undergoing significant development.

These skills put together— (1) the ability to pose good questions (i.e., those that sufficiently yield the information that they seek) and (2) being appropriately skeptical of the responses they receive— provide the foundation for children’s learning on the broadest level, independent of any specific content area. These foundational capacities give children an extraordinary amount of autonomy to guide their own learning. As children cultivate these capacities and over the course of development learn to leverage them strategically, they move from their use of others as sources of largely domain-general, adaptive knowledge, to content-specific knowledge, such as that of formal learning settings (e.g., classrooms). By examining how the development of children's information search skills takes place and establishing robust and reliable empirical frameworks for investigating these abilities across contexts, researchers can streamline their attempts to intervene at critical points in this development to help enhance children's social learning.

The Development of Information Search Skills

Children begin using others for information about the world from very early in development, and their information-seeking skills undergo significant growth throughout preschool and early elementary school. As their vocabulary develops, and their verbal skills become more refined, children begin to make explicit requests for information from others in the form of questions. Children use questions as a means of engaging in targeted searches for information to enhance their own learning, and it is this kind of collaborative learning that is central to their cognitive development (Chouinard, Harris, & Maratsos, 2007; Rogoff, 1998).

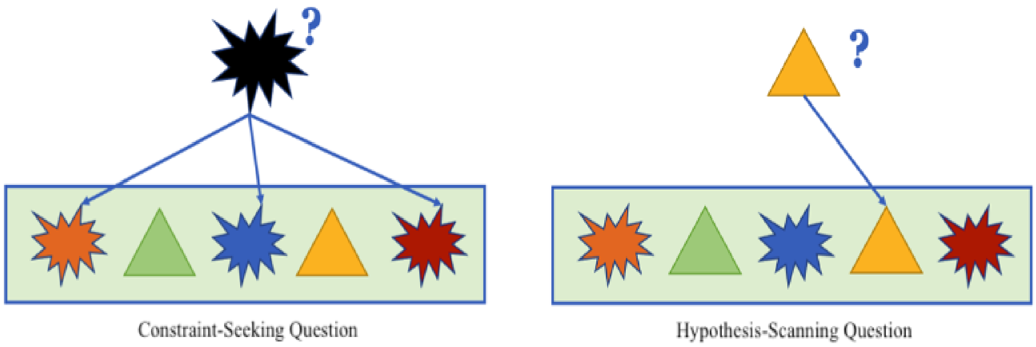
Asking questions is a robustly effective learning tool: Chouinard and colleagues (2007) found in a study of informal, nonspecific parent-child interactions that preschool-aged children ask nearly 80 information-seeking questions per hour—more than a question per minute on average. This rapid-fire search for information is essential for children's learning, as it gives them both access to the information that they seek in the moment, and a platform for evaluating the candidacy of their conversational partner as a potential candidate for helping them solve problems or provide information in the future. Throughout children's development, they show both individual and age-related differences in the capacity to phrase effective questions (e.g., Ronfard et al., 2018).

Question Types

Questions are largely distinguished in their effectiveness by type: constraint-seeking and hypothesis-scanning (e.g., Ruggeri, Sim, & Xu, 2017). Constraint-seeking questions, typically thought of as more effective than hypothesis-scanning questions, enable the question-asker to eliminate several plausible responses at once. Hypothesis-scanning questions, by contrast, typically isolate single plausible responses at a time.

Consider the game of 20-Questions as an example: in this game, one player is tasked with thinking of a target response (e.g., an animal) and the remaining players must ask questions to identify the target of their peer's thinking. Asking broad, constraint-seeking questions (e.g., "is the animal a mammal?") is more effective, particularly to start with, given a lack of existing useful information, because they group items by shared features or characteristics, thereby helping to eliminate a much wider range of plausible answers at once. Once the range of possible responses is sufficiently narrow, it becomes more efficient to use hypothesis-scanning questions (e.g., "are you thinking of a platypus?") to identify the correct response.

Figure 1 Question Types (Constraint-Seeking, left vs. Hypothesis-Scanning, right)



The distinction between these two question types is critical when comparing their expected or relative information gain: the information, given a set problem space, that each question is likely to generate. Problem space, in this context, refers to the range of possible answers or solutions to an unknown question or problem. When there are more similar, as opposed to non-similar, items in a problem space, then asking a broad constraint-seeking question has a higher expected information gain, because it can reasonably exclude many items at one time. In deciding what to ask someone, understanding how much information that person is likely to have about a problem space (e.g., concept, construct, theory, or explanation) is a tool for maximizing information gain with comparatively little effort on the part of the learner. However, there are limitations both to young children's abilities to generate effective questions (e.g., "questions that are clearly on-topic and worded in a way to gather the desired information") and to pose those questions to a person who is likely to know more about that topic, at least until later in development, or only with targeted training (Mills & Sands, 2020, pg. 148).

Children show very gradual improvements in their ability to pose questions strategically as they develop. Herwig (1982) found, for example, that even up to age 7, children ask predominantly hypothesis-scanning questions, but that they transition to generating predominantly constraint-seeking questions in later adolescence and adulthood (e.g., Ruggeri & Feufel, 2015; Ruggeri & Lombrozo, 2015). Ruggeri, Sim, and Xu (2017) took previous paradigms further in probing children's understanding of effective questioning by introducing a limited series of options, such that children did not have to generate their own questions to complete the task. In their study with 3- to 5-year-old children, these authors found that children can flexibly and strategically adapt their choices of questions that others produce to elicit an accurate response and that this skill improved with age.

Children show an ability to pose specific questions to people who they know will be apt or able to answer them. They can also, over the course of development, refine the types of questions that they ask to control the problem space. Legare, Mills, Souza, Plummer, and Yasskin (2013), in a study with 4-, 5-, and 6-year-olds, found that older children tended to ask more constraint-seeking questions (those questions designed to strategically eliminate several plausible responses at once) than the younger children, who more often asked redundant or ineffective questions (see also Ruggeri & Feufel, 2015; Ruggeri & Lombrozo, 2015). In fact, the number of constraint-seeking questions children asked in this study served as the only predictor of the accuracy of the response they acquired in solving the problem at hand.

The process of strategically posing different question types and directing them in effective ways plays a central role in children's ability to navigate information searches and solve problems. Another salient factor in these exchanges is the role of social peers, such as parents or caregivers. Parents and caregivers help children construct new knowledge through these iterative exchanges by answering children's questions and offering questions of their own.

Using cues such as relative information gain, parents and caregivers can scaffold the inquiry-based exchanges they share with young children, helping children to learn critical skills necessary for commanding these interactions and leveraging them for their own learning. This role of scaffolding and its contributions to various aspects of cognitive growth in young children has roots in some of the foundational theoretical perspectives in experimental psychology, which will be discussed in this next section.

Theoretical Considerations

The following passages will examine three groups of theoretical considerations underlying the present dissertation: (1) constructivist approaches, including work by Vygotsky, Piaget, and more recent theories under the broad umbrella of neoconstructivism, including Theory Theory; (2) Information Foraging Theory, which helps inform an understanding of what motivates children to engage in an initial information search; and (3) the empirical perspective, which outlines children's information search strategies as a naïve scientific approach, aiming to gather explanatory information about the world and its functions in a way that mirrors formal scientific inquiry.

Constructivist Approaches

Vygotsky and Piaget were among the first to recognize that children, too, are active constituents of their own learning (e.g., Rogoff, 1998; Vygotsky, 1978)—a key theoretical perspective underlying the present dissertation. This emphasis on “shared thinking,” or the collaboration between social peers which contributes to one or both party’s knowledge acquisition, is a primary commonality between the theories proposed by Vygotsky (1978) and Piaget (1964). These theories have informed the early development of constructivism, an overarching theory of learning and education which posits that “learning is a process of constructing meaning” (Caffarella & Merriam, 1999).

By interacting with social peers, particularly those more knowledgeable, children can build on existing cognitive structures and co-construct new knowledge. Vygotsky captures this process in his classic theory of the “Zone of Proximal Development,” in which adults or more knowledgeable peers scaffold a learning exchange to capitalize on what the learner already knows and enhance their potential to learn more challenging concepts or skills (e.g., Vygotsky, 1978; 1986). In these exchanges, learning occurs organically by virtue of the engagement the child has with a peer.

The roots of constructivism are not new: this theoretical view is believed to date back to the time of Socrates, who championed the since-coined Socratic Method, a pedagogical strategy which emphasizes teacher-learner engagement to interpret and construct knowledge through asking questions of one another (e.g., Amineh & Asl, 2015). In this way, this learning theory also necessarily places the child at the center of her own learning, echoing themes explored in the literature detailed in this dissertation. When children ask questions, they capitalize on this role and show an early-emerging capacity to their direct learning exchanges toward the construction of new knowledge of the kind that they want, at the time that they want it.

The environments in which children develop necessarily have significant implications for how, and under what circumstances, they will explore the world around them, or prompt others for information in the future. One of the more salient examples of the distal and proximal effects of their early environment on children's development is in their language learning. This area is of particular interest here, both because it emphasizes this critical role of early experiences, and because language development also has marked consequences for the quality and frequency of children's questions (e.g., Hoff, 2006; Kurkul & Corriveau, 2018; Rowe, Leech, & Cabrera, 2017).

Environments that encourage children to interact with their caretakers show marked power in improving children's language development. Hoff (2006) notes that all linguistic environments are beneficial for children's language learning—providing them with opportunities for shared communicative experiences, and therefore the tools to pose information-seeking questions to others around them. However, different linguistic environments encourage communication and inquiry to different degrees, resulting in differences in the acquisition and functional use of language across development. In fact, there are some documented socioeconomic (SES) differences both in how caregivers respond to their children's questions, and how children respond to unsatisfactory responses. In a study with 4-year-olds, for example, Kurkul and Corriveau (2018) found that mid-SES caregivers tended to offer more explanatory responses to their children's questions compared to their lower-SES counterparts. By contrast, low-SES caregivers offered significantly more circular explanations to their children's questions (e.g., CHILD: "Why didn't you like them?"; CAREGIVER RESPONSE: "Because I decided I didn't like them when I go home.") (p. 284). Children's responses to fact-based questions did not differ, but their reactions to unsatisfactory responses to causal questions diverged significantly. Mid-SES children were significantly more likely than their low-SES counterparts to repeat or rephrase their questions or to invent their own explanations in the face of unsatisfactory caregiver responses. Lower-SES children may be less likely to use questions as a medium for extracting information from social others, perhaps because low-SES caregivers provided more unsatisfactory responses than their mid-SES counterparts. These disparities can have longer-lasting implications for children's language development: Hirsh-Pasek and colleagues (2015) found in a study involving 60 low-income families from the National Institute of Child Health and Human Development Study of Early Child Care and Young Development that the quality of both nonverbal and verbal interactions when children were two years of age accounted for more than a quarter of the variance in their expressive language skills at age three.

Socioeconomic status may thus serve as one crucial indicator for caregivers' and children's views of the role of question-asking in knowledge acquisition (Kurkul & Corriveau, 2018). Walker, Greenwood, Hart, and Carta (1994) and Hart and Risley (1995) have documented both systematic differences in language acquisition by stratifications in socioeconomic status and subsequent differences in outcomes in elementary school, such as elementary language and academic competencies. In a study of low-SES African American fathers and their toddlers, variation in the number of more linguistically complex questions (*wh*-questions, e.g., who, what, where, when, why, how) was significantly correlated both with the children's vocabulary and with their reasoning outcomes (Rowe et al., 2017). These findings serve to reinforce the notion that both the makeup of the social environment and the quality of the input children receive in those environments, variable though they may be, produce significant differences in children's learning.

What children come to know about the world is motivated by what they can leverage from the people around them. Bergstrom, Moehlmann, and Boyer (2006) point out that the "ecological niche" (p. 531) that humans occupy is composed of information about the physical and social world. In the same way that animals adapt to and take advantage of specific aspects of their environments, so do human beings cultivate specific capacities for acquiring and transmitting culturally and adaptively useful information. Understanding how questioning abilities come about and are refined, in coordination with the ability to evaluate the quality and reliability of responses, is critical for describing the human ability to gain more information about the world than other species by orders of magnitude (e.g., Bergstrom et al., 2006).

Neoconstructivism. Neoconstructivism, an emerging theoretical perspective born out of the constructivist tradition, seeks to unify the work of Piaget with more recent findings pointing to the role of empiricism in children's development, over and above native influences. Rooted in earlier Piagetian traditions of the developmental origins of human knowledge, neoconstructivism represents a new-age attempt to characterize children's initial cognitive capacities and the trajectory these capacities follow over the course of early development (e.g., Newcombe, 2010). Newcombe (2010) offers a concise representation of the central tenets of neoconstructivism, including that "experience expectancy is a key concept... [and] the world is richly structured and well-equipped [sic] with perceptual redundancies and correlations that support experience-expectant learning" (p. 158). Humans bring to bear on the world an intuitive sense of there being rich information available for mining—both via direct experimentation and by capitalizing on what others already know. The integration of this experience expectancy and the structure of the world enables young children to come to conclusions about the presence of fundamental underlying properties, such as causality and spatial location, that shape their early knowledge structures.

This experience expectancy orientation can also be thought of in terms of an intuitive epistemology—"the conceptual resources contained in a set of epistemological concepts which [sic] facilitate the formation of accurate belief" (Fedyk, Kushnir, & Xu, 2019, p. 122). This intuitive epistemology includes a theory of evidence: young children expect to encounter discrete units of information (i.e., evidence) which can be organized in such a way as to inform the construction of new knowledge structures. A theory of evidence is thought to be domain-general in that it can be used to develop many different domains of knowledge. It is even more critical, then, that the evidence children encounter can be trusted—the breadth and depth of the consequences of encoding misinformation are vast. In other words, an unreliable informant can inflict widespread damage on children's intuitive theories in other domains, such as physics, biology, theory of mind, or any other critical domain of human knowledge (Fedyk et al., 2019).

Theory Theory. In many ways, a child's intuitive epistemology can be thought of as one many intuitive theories—captured most clearly in early work by Gopnik and Wellman (1994) on Theory Theory. Theory Theory, an explanatory position suggesting that children cultivate working theories for many domain-specific bodies of knowledge (e.g., a theory of mind) over the course of development. The primary hypothesis of Theory Theory, Gopnik and Wellman (1994) write, is that "there are deep similarities between the underlying cognitive mechanisms involved in the epistemological endeavors of childhood and of science" (p. 259). As children encounter new evidence—which, according to a theory of evidence, they have some understanding of and show some capacity to integrate effectively into their more global understanding of novel problems—they revise these theories accordingly. This "child as scientist" perspective allows both for a nativist view of the fundamental building blocks of cognition which enable children to encounter new data and assimilate it into their knowledge structures, and for an empiricist perspective in which the child is at the center of her own learning and accumulates new data by which to update her intuitive theories through active exploration and interactions with other people.

Children undergo radical conceptual change as they incorporate new data into their existing theories. Researchers (e.g., Harris, 2012; Kidd & Hayden, 2015; Xu, 2019) accept that children play a critical role in their own theory revision, and that this revision is a central component of learning. Some go further (e.g., Gendler, 2000;

Lombrozo, 2012, 2018; Xu, 2019) by subscribing to radical constructivism—a scientific theory which both supports the notion that children begin life with a set of primitive conceptual vestibules, ready for data input, and that they use a set of co-existing learning mechanisms to revise beliefs and construct new ones.

Information Foraging Theory

Information Foraging Theory serves as a helpful theoretical view in thinking about what promotes children's desire to seek out information in the first place. Chin, Payne, Fu, Morrow, and Stine-Morrow (2015) note that because information is universal, how human beings go about gathering and making sense of it is a critical area for research. One foundational theory in the information search literature is the information foraging model—so named for its reference to food foraging patterns adapted by animals in the wild (Chin et al., 2015). It has primarily informed research examining how people use external sources as a means of accruing information (e.g., Pirolli, 2007). Relatedly, researchers studying curiosity suggest that one major component has to do with seeking to close an information gap, or resolving some information conflict, and that this orientation has significant implications for what children learn, in addition to other notable outcomes, such as academic achievement and general wellness (e.g., Livio, 2018; von Stumm et al., 2011). While this work falls somewhat short in its ability to characterize the child's search for information (which does not always cease on the occasion that an answer has been provided, and indeed may prompt further foraging in a way that is inconsistent with the behaviors that natural foraging models describe), it can still be helpful for imagining some of the initial influences in children's search for information.

The Empirical Framework

Butler (2020) offers an integrated theoretical model for capturing children's empirical thinking across the full scope of the information exchange, which they must apply both in their search for information and in making sense of the information they obtain in their searches. This model describes the underlying capacities supporting, and obstacles hindering, young children's abilities to meet the demands of three overarching goals: (1) to ask questions and form relevant, supporting hypotheses; (2) to collect and analyze "data" that can serve to address their questions; and (3) to communicate this evidence to others. This framework describes both the steps children must engage in when exploring the world empirically, and the assessments they must make of others' approaches to the world. The foundational building blocks supporting children's engagement in each of these steps is critical both for the narrower aim of scientific learning in a formal, pedagogical sense, and for the broader aim of learning about the world using a sufficiently critical, evaluative lens.

It is this model which offers the most insight into the work that will be described in the present dissertation. It similarly portrays the stepwise fashion by which empirical and scientific reasoning appears to take place, and though not exclusively focused on social learning, can also be employed as a representation for the cyclical nature of children's question-asking exchanges about any topic, wherein they return to the first phase when they receive additional information which must be used to refine their existing knowledge structures and as a basis for approaching new learning goals. As the amount of information in the world grows at a rapid pace, and most of the information is acquired through sources which do not typically undergo stringent checks for accuracy, children in particular benefit from developing strategies that help them to seek out information in strategic, effective ways, and to identify reliability resources for their learning.

A Proposed Theoretical Revision

Ronfard and colleagues (2018) point out that the most powerful thing about children's abilities to probe others for information is that they can initiate exchanges for the express purpose of constructing knowledge which they did not have before, and that they can "redirect pedagogical exchanges" (p.101) to most efficiently extract the information that they desire when they want it. This gives children an extreme amount of control over the conceptual systems they construct and enhance through their interactions with other people.

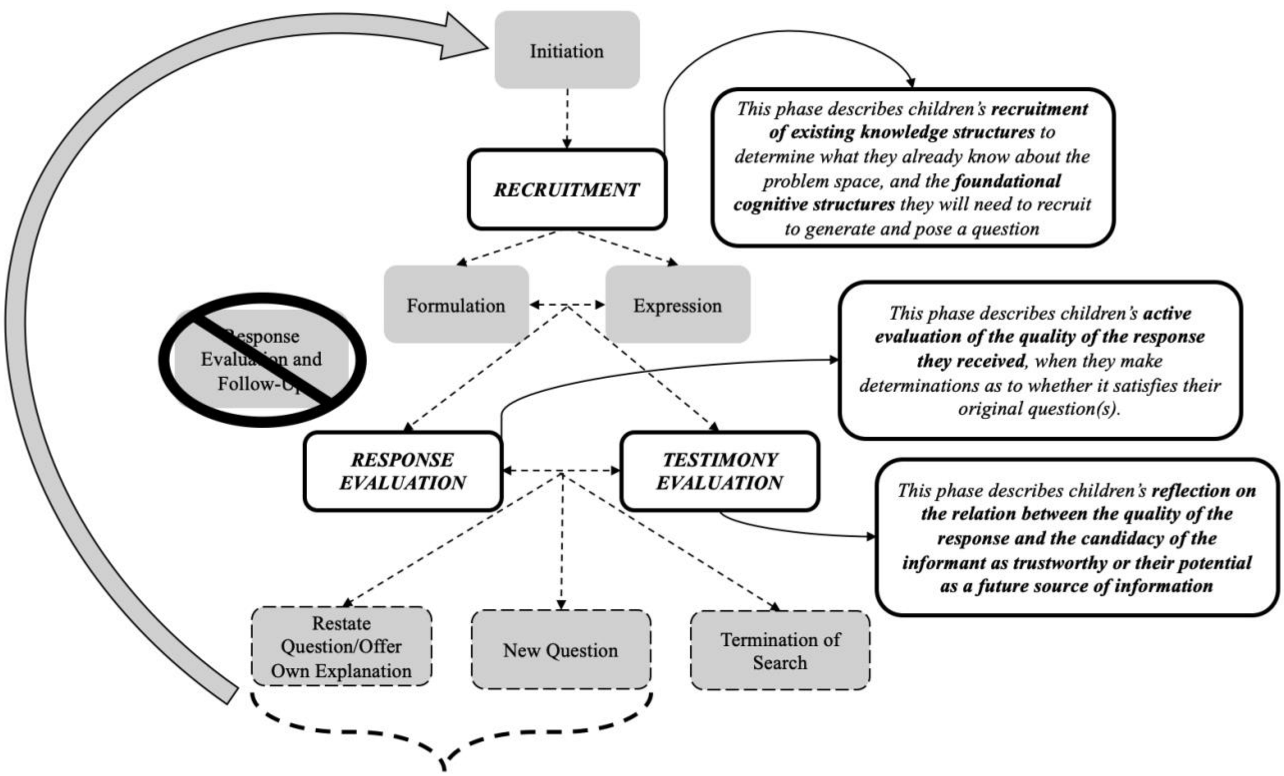
According to Ronfard and colleagues' (2018) model (see *Figure 1* in the Appendix), there are four primary stages underlying children's question-asking: (1) initiation, in which the child identifies a problem space they want to explore or ask about; (2) formulation, in which children must compose their question; (3) expression, in which children determine whether it is something worth asking (if the expected information gain is significant enough); and (4) response evaluation and follow-up, in which children assess whether the response they received was sufficient and whether they should a) end the question-asking exchange; b) generate a new, follow-up question; or c) restate their original question, presumably because the response they received was unsatisfactory.

The ability to ask good-quality questions is central for effective learning, as it enables flexible responses to new informational inputs and adaptations to changes in the social and physical environment which may ultimately reshape the problem space. However, Rothe, Lake, and Gureckis (2018) found in a study using Bayesian ideal observer analysis for identifying the best quality questions (i.e., the most effective questions in closing a given problem space and approaching a reasonable answer) that adult participants from Amazon Mechanical Turk tend not to produce the most effective questions, even though they show a capacity to adjudicate the better-quality question, given a choice between two. In other words, when provided with a choice of existing questions, adults can flexibly alter their selections to reduce the cost (the amount of time spent searching for information) in favor of gain (effective access to the information they seek). While this data comes from an adult population, similar findings have been demonstrated in studies with children as well.

While existing research has established that children use their social relationships as instruments to achieve their learning goals, there are some critical ways in which this work falls short. First, the previously proposed model synthesizing much of this work only partially captures the role of the underlying cognitive capacities which underly children's abilities to construct and pose questions. This model also does little to explicitly connect the literature on children's trust in testimony that would be informative and fruitful to include in a robust model of children's question asking.

It is this latter consideration that is of particular interest in the present dissertation. Children use the responses that they receive to their questions to reason both about the degree to which that response closes the gap in their knowledge for which they posed the initial question, and about the individual providing that information. Proposed revisions to the Ronfard and colleagues (2018) framework therefore include: (1) an additional phase during which children use and incorporate their existing knowledge and foundational cognitive capacities to initiate, formulate, and express their question of interest; (2) a phase explicitly representing the judgments children make of the responses they get, specifically as they relate to informant reliability; and (3) a minor restructuring, such that the model reflects the reciprocal, circular nature of children's question asking.

Figure 3 Revised model of children's question-asking



This model aims to better capture the ways in which children's questions can shape what they learn about the world by guiding their exchanges with others, and how they determine whether the responses they receive for their questions should be accepted and incorporated into their pre-existing knowledge structures.

The proposed model also seeks to represent the cyclical nature of children's inquiry: they must use an informant's response both to evaluate the quality of that information, given their question, and the quality of that individual as a trustworthy source of information in the case that they pose new questions. The question of whether children attribute other kinds of competencies, such as ability or knowledgeability, more generally, to people who ask good questions may be particularly informative for understanding whether and how children choose to cease or continue an information search with those people.

This model has the potential to frame future research about the mechanisms underlying children's active exploration, information searches, and selectivity, and may also inform additional work in children's scientific learning and reasoning (e.g., Legare, 2014). Gelman, Brenneman, Macdonald, and Román (2010) note that the act of explaining and exploring various phenomena is a foundational component to the scientific process, and in scientific reasoning more generally. Legare (2014) notes that the process of generating explanations for scientific phenomena and actively exploring the mechanics of these phenomena may be foundational to children's causal learning, broadly.

The revised model also captures the cyclical nature of children's learning strategies, as they refine them with the input of new data (whether that data be accrued by active experimentation on their part, or with the information they receive from other people). Children must regularly begin anew, crafting new hypotheses based on revisions to their knowledge structures. To add to this complicated process, children must also use their accumulating experiences to determine whether the people from whom they learn can be trusted to add to those knowledge structures in accurate and reliable ways. This process, much like the formal scientific process, is both inherently social and inherently cyclical. It requires the ability to identify novel problems, collect data in some fashion to address that problem, make sense of the data, and make decisions about whether the initial problem—or a new one—still exists. Understanding how young children leverage their relationships with other people to accomplish their learning goals could be hugely instrumental in accelerating the rate by which children achieve these foundational scientific reasoning skills.

Chapter 2: Literature Review and Implications

Children's curiosity is a powerful motivator of their causal exploration, and this inquisitive orientation is featured in all central domains of epistemic exploration including the arts, physics, psychology, and philosophy (see Livio, 2018, for more on this point). Curiosity is a guiding mental phenomenon early in development and children's subsequent exploration and manipulation of their environment underpins many critical learning capacities. For example, 3- to 5- year-old children show an ability to adaptively select more informative exploratory actions to reveal the location of a hidden object (Swaboda, Ruggeri, Sim, & Gopnik, 2018). Their exploration also privileges surprising stimuli that violate their expectations (e.g., Bonawitz, Schijndel, Friel, & Schulz, 2011a), or are causally confounded. In other words, children selectively explore and seek to account for belief-violating phenomena that present opportunities for new learning.

This exploration serves to enrich children's understanding in a variety of domains and helps to explain how children gain a huge amount of information about the world exceptionally quickly (e.g., Swaboda et al., 2018). Six- and 7-year-olds, for instance, explore violations of their beliefs about the relation between mass and gravity more than stimuli that are consistent with their beliefs (e.g., when the geometric center, but not the mass center, of an object was balanced on a point; Bonawitz et al., 2011a). Similarly, preschool-aged children engage in intentional exploration of a toy more often and for longer periods when the cause of its function was ambiguous or confounded in some way (Schulz & Bonawitz, 2007).

As noted in Chapter 1, however, active, causal exploration is not the only means by which children can extract explanatory-rich information from the world. Children also learn from others, and the earliest forms of interpersonal inquiry, or seeking information from other people, seem to manifest as interrogative pointing—gesturing to specific objects or phenomena in the world as a means of requesting explanatory information from others (Begus & Southgate, 2012). As children age and their verbal skills become more refined, they begin to make explicit requests for information from others, enabling them to extend the bounds of their understanding beyond that of their own experiences by pulling vicariously from others.

Asking questions is a robustly effective learning tool, and in the face of the immense number of questions young children ask of others, their caregivers tend to be accommodating of children's constant questions. Chouinard and colleagues (2007), for example, found that parents answer children's questions informatively most of the time and even provide additional relevant information beyond that which was addressed in the children's original questions to help support their children's learning.

This may indicate that some parents understand, even intuitively, that these exchanges are critical for children's learning more broadly, beyond the immediate context of children's questions or the scope of their original information search. Children are also strategic in their approach to question-asking and often repeat or rephrase their questions to get the information that they initially requested if unsatisfied with the response (e.g., Chouinard et al., 2007; Kurkul & Corriveau, 2018).

The Questioning Stance

Throughout children's development, they show both individual and age-related changes in their ability to ask good questions. However, there are other key factors of these social exchanges that inform children's ability to use them strategically for their information searches. Like the father-child dyads described in the previous chapter, differences in parenting style have been shown to relate to positive response. The tendency for mothers to orient their children towards exploration, for example, has been found to be robustly associated with children's subsequent curiosity (Endsley, Hutcherson, Garner, & Martin, 1979).

Ronfard, Bartz, Cheng, Chen, and Harris (2017) speculate that many of the individual differences in children's questioning likely arise due to differences in parental beliefs about how these question-asking exchanges ought to be characterized and whether open questioning should be encouraged. By implication, parents' conversational and questioning practices have significant implications for children's willingness to pose questions and the expectations they form about whether their questions will be answered. While conversational environments have a robust effect on many aspects of children's questioning, children must first establish whether there is something that they want to question. To do so, they must evaluate the context at hand and make determinations about what they do not know by reflecting on their existing knowledge structures.

Knowing what you do and do not know

Children are receptive to pedagogical instruction, making strong generalizations and drawing robust inferences about causal phenomena from pedagogical demonstrations, with reductions between ages 3 and 4 in their reliance on intentional demonstrations (that is, those which do not expressly indicate that the information in question is being illustrated for the benefit of the child) (Butler & Markman, 2012). Children younger than 3 also show a sensitivity to communicative cues, following others' eye gaze toward target phenomena and showing a proclivity for joint attention— "shared attention is the shared focus of two individuals on an object or event in the world" (Akhtar & Gernsbacher, 2014)— which enables instructional figures to isolate pedagogical information (e.g., Grossmann & Johnson, 2010).

Bonawitz, Shafto, Gweon, Goodman Spelke, and Schulz (2011b), for example, found that children who received pedagogical demonstrations for a novel toy function tailored their exploratory actions to suit the scope of the information they appeared to believe was available. In other words, children constrained their play only to the pedagogically relevant cues. These cues, early in development, may be particularly helpful in encouraging infants to direct their focus towards phenomena that they know nothing about (e.g., Gweon & Schulz, 2008; Schulz & Gopnik, 2004). As children age, however, they begin to phrase information requests largely for information about which they have some uncertainty (e.g., Coughlin, Hembacher, Lyons, & Ghetti (2014); pedagogical instruction, as Bonawitz and colleagues (2011b) suggest, may come to inhibit children's information seeking, instead leading to the belief that information not provided by pedagogical instruction does not exist or is not relevant. By the time children reach elementary school, they tend to search for information in response to the same cues that adults do (e.g., Graesser & McMahen, 1993; Sobel, Sommerville, Travers, Blumenthal, & Stoddard, 2009).

A preference for exploring phenomena which are surprising, or which violate expectations, can also be observed in studies with 6- and 7-year-olds who, when provided with confounding evidence and permitted to explore to resolve their confusion, prefer to explore more when the evidence is inconsistent with their existing beliefs (Bonawitz, Schijndel, Friel, & Schulz, 2011a). In other words, when the evidence violates their expectations—which they form based on pre-existing knowledge of that topic—children prefer to interact with and explore that violation more than in situations when their expectations were not violated. For those children who do not have that existing knowledge (e.g., an understanding of mass theory), the reverse finding is true, and they instead show a novelty preference. By the time they reach kindergarten and early elementary school, children can therefore integrate their prior knowledge about physical phenomena in guiding their information-seeking behaviors.

Knowledge of the physical world is not the only conceptual or functional knowledge that young children seem to have. Children as young as two, for instance, can navigate some social interactions involving others' testimony and possess some argument evaluation skills regarding the claims that others make (Castelain, Bernard, & Mercier, 2018). Tamis-LeMonda and colleagues (2008) found that young infants ignored others' testimony in favor of their own assessments about how risky a particular action would be; children weigh competing sources of information (between their prior knowledge and others' communicated information) when making decisions about what course of action to follow. Only when these young children determined that they had insufficient information to decide on their own did they defer to social testimony.

Children can also make these distinctions by integrating their prior knowledge when considering the affordances of their environments. Researchers often equate this reasoning to the construction of "probabilistic models of expected information gain," which necessarily uses existing knowledge structures in examining which courses of action are more or less likely to yield helpful additional information (Cook, Goodman, & Schulz, 2011, p. 341). In work by Cook and colleagues (2011), for example, three conditions differentiated the probabilistic models that preschool-aged children could construct to determine the orientation of a magnetic bead set that would cause a novel toy to play music.

During a brief training period, children witnessed some variability in the number and type of beads that would cause the toy to play music. During the test phase, they were given one of two combinations of beads: either a separable pair, which could be pulled apart and tested individually, or a "stuck pair," which were glued together and remained bonded, therefore necessitating that they be rotated to test them individually on the surface of the toy. Preschoolers demonstrated the ability to use their existing knowledge, constructed based on the probability distributions from the training period, to adapt their exploratory actions (either separating or rotating) to elicit the causal function (music) during a free play session (Cook et al., 2011).

Children also show an ability to use existing conceptual knowledge to tailor the kinds of questions that they ask. Preschoolers have been found to alter the questions that they ask given the expectations they hold about what kind of information they are likely to receive (Greif, Kemler Nelson, Keil, & Gutierrez, 2008). In this study, the information differed based on whether the target object was an artifact, yielding questions that had more to do with function (e.g., *design stance;* review Bloom, 1996; Dennett, 1987 for additional information), or an animal, yielding questions that had more to do with category membership. Taken together, these findings suggest that children as young as preschool tailor their information searches given what they already know about a topic (that is, that questions about artifacts are more appropriately geared towards their functional use, while questions about animals are more appropriately geared towards features of their identity, such as habitat and diet).

Children also show an ability to attend to relevance when determining what new information they will accept as true. Children as young as four, for example, selectively learn new word meanings only for those words with immediate linguistic relevance (that is, that pertained to phenomena close by, Henderson, Sabbagh, & Woodward, 2013). Preschoolers also show some adeptness in monitoring what other people do and do not know; children monitor the identity of the informant providing novel word labels, tracking whether they were present and familiar, having taught the label to them before. Relatedly, in a study with 3- and 4-year-olds, Birch, Vauthier, and Bloom (2008) found that preschoolers could effectively monitor the relative accuracy of others when making determinations about whom to trust in a novel word learning task. Children as young as preschool, then, show some ability to integrate what they know about accuracy with others' tendency to provide true information when making decisions about credibility.

This is particularly critical when considering how children should be oriented toward receiving information from other people. Previous evidence suggests that, by age 4 or 5, young children can be strategic in directing questions to a specific potential teacher, based on the expertise of that individual, though their performance is nowhere near perfect (e.g., Mills et al., 2010). These findings suggest the existence of early questioning strategies that shape not only the types of questions that children ask, but their anticipation of the knowledge states of the people at their disposal to answer them.

Other work has explored this phenomenon in classic trust-in-testimony paradigms in which young children are prompted to select between two informants who provide them with conflicting information (usually object labels) based on which individual they believe is more reliable. In these studies, the criteria that children can use to make these decisions range anywhere from social considerations (e.g., the individuals' group membership, language accent, physical appearance) to epistemic considerations (e.g., checking for evidence, having prior experience or expertise). This work has been well documented, and the next section will explore these different criteria further in the context of what Mills (2013) refers to as the "critical stance" – "an approach toward evaluating information, one that involves the ability to weight multiple pieces of information to determine the truth value of encountered claims, being prepared to doubt if necessary" (pg. 404).

The Critical Stance

It is well established that other peoples' accumulated knowledge helps children to amass their knowledge frameworks, and they show a readiness to learn from direct instruction and to internalize, generalize, and share that testimony (i.e., communicated information) with other people (e.g., Ronfard et al., 2018; Clegg & Legare, 2016; Paradise & Rogoff, 2009). Lucas, Gopnik, and Griffiths, (2010) determined that young children show a readiness to learn causal relationships very quickly in the context of social situations and can do so based on extremely limited input. Butler and Markman (2012) also found that preschoolers are sensitive to contexts in which information is being communicated for their benefit (i.e., pedagogically) and use that information to guide strong generalizations. Preschool-aged children show a documented bias to trust what they are told, favoring deceptive testimony in a search-for-occluded-object task even when they had already been misled (Jaswal, Croft, Setia, & Cole, 2010). Children's preference for social learning partners may even be biased by such things as attractiveness. For instance, 4- and 5-year-olds show a selective preference for a more attractive informant when no epistemic information is available to them, and they prefer the more attractive of two informants if they demonstrate equal levels of accuracy (Bascandziev & Harris, 2016).

However, children are not blindly accepting of other's testimony either. In a comprehensive review, Mills (2013) details extensive evidence indicating that young children use a variety of social and epistemic cues—characteristics either of the informant themselves or cues to what the informant knows—to make decisions about which informants (typically of two, in a forced-choice paradigm) are better suited to provide trustworthy information about some topic of interest. This sensitivity to informant reliability occurs early in development: even 14- month-old infants prefer to follow the gaze of an informant who has looked inside a container holding a hidden object (the "reliable looker") over one who looked into a container with nothing inside (the "unreliable looker") (Chow, Poulin-Dubois, & Lewis, 2008).

Fourteen-month-olds also show a preference to learn from individuals who have competently interacted with familiar artifacts over those who have shown incompetency or uncertainty (Zmyg, Buttelmann, Carpenter, & Daum, 2010), indicating that very young infants seem to be monitoring the relative knowledge states of others as a cue for who is more or less likely to provide them with reliable information. This kind of knowledge-state monitoring also has significant implications for young infants' learning, because the ability to discriminate between reliable and unreliable behavioral models also impacts whether and how infants learn novel actions.

Their sensitivity to cues like uncertainty continues throughout development as well: preschoolers show a preference for knowledgeable and confident informants over ignorant or uncertain ones both in learning novel actions and in learning novel words (e.g., Jaswal & Malone, 2007; Sabbagh & Baldwin, 2001). When children have a choice of informants, with a relatively constrained set of contrasting cues to reliability, they show an early-emerging and quickly developing capacity to be selective of the information that they accept as true. In many of these classic selectivity paradigms, children make decisions about reliability with a choice of two contrasting informants (e.g., Mills, 2013), and thus have a comparatively more scaffolded problem space for making decisions about reliability. In reality, young children often encounter much more amorphous problem spaces, wherein they must make decisions about the information they seek as well as the persons to whom they wish to address their questions based on very little other guidance.

Seeking Explanatory Information

Before proceeding, it is important to consider the role of constraint-seeking and hypothesis-scanning strategies outside the scope of questions: in the context of generating cohesive explanations. Explanations serve a unique role in human cognition—involving many different subsidiary cognitive processes, such as attention, executive function, and memory (Horne, Muradoglu, & Cimpian, 2019) that help inform our understanding of how the world works, structure our conceptual categories, help us make predictions and generalizations, and guide our behavior (Cimpian & Keil, 2017). Explanations provide us with a framework for establishing parameters about what is knowable, and the ability to phrase questions or hypothesize about specific explanations is a key feature of successfully building new knowledge.

The ability to strategically navigate a complex knowledge space by asking efficient questions and producing appropriate explanations cannot be understated, particularly as that space becomes more crowded. Until 1900, human knowledge doubled roughly once per century. After the end of World War II, it doubled roughly every 25 years. Today, all the information available to humans doubles every 13 months (Buckminster Fuller, 1982; Schilling, 2013). In the future, it is anticipated for this growth to increase exponentially, such that all available information doubles every twelve hours (Schilling, 2013). This rapid-fire growth of human knowledge in the new information age is critical for obvious reasons, but only amplifies the intellectual risk that young learners face when trying to master that available knowledge and build a cohesive understanding of the world. Specifically, children must navigate denser and more complex landscapes for acquiring explanatory information that helps them to build rich, cogent explanations for why their physical and social worlds operate in the way that they do.

Questions can serve as an organic medium by which means children can gain direct access to this rich explanatory information, and adult social peers can model strategies for using and responding to questions to help children learn how to be more efficient in their information search strategies and in their production of plausible explanations for phenomena that they observe or encounter. Classrooms, in which one might expect questions to feature heavily—given that children are, by design, faced with the task of building new knowledge—appear to have their own limitations in meeting this need.

Recent work, for example, has shown that a shockingly small proportion of teachers use questions in their pedagogical practice in traditional classroom settings (approximately 9-12%; Hirsh-Pasek, 2021). Children also only spend approximately 20% of their time in school, meaning that their learning exchanges with other members of their social worlds (e.g., parents, siblings, friends) are the primary settings in which children engage to learn (e.g., Bustamante et al., 2020; Meltzoff et al., 2009). This consideration only underscores the importance of children's developing abilities to be judicious in whom they seek information from, what they ask about, and how they phrase their questions to obtain the information they are looking for.

As alluded to in an earlier section, children's questioning abilities map clearly onto the foundational skills required from broader, domain-general scientific reasoning and critical thinking. In the process of developing a question, children must consider what a potential answer would look like and structure their question to elicit an appropriate answer. Likewise, when generating a plausible explanation, children must interact with their existing knowledge, pull from evidence in their environment, and hypothesize about what can be learned. Explanations are produced by asking questions, and *wh-* questions, like those investigated specifically in the father-child dyad language study mentioned earlier (Rowe, Leech, & Cabrera, 2017), have a unique ability to generate broad, explanatory information about how the world functions (e.g., *why* things are the way that they are).

Asking constraint-seeking questions enables children to conceive of explanations that have broad, conceptual or categorical merit (e.g., "I think X is the right type of response), which they can subsequently narrow down with more refined questions. Asking a hypothesis-scanning question enables children to consider only single possible explanations at one time (e.g., "I think X"). Consider the following example:

> A patient visits their doctor's office complaining of dizziness. If the doctor generated a hypothesis-scanning explanation to try to account for the patient's problem, she might say, "*I think the patient is dehydrated.*" The doctor could

be correct, but there are several other plausible explanations for the patient's symptoms. The constraint-seeking explanation might be something like, "*I think the patient's complaint is related to a cardiovascular problem.*" In posing this explanation the physician has opened the door for several possible methods for assessing the problem (e.g., echocardiogram, measuring blood pressure). In introducing categorical explanatory information, the physician also makes it possible to consider other physiological systems (e.g., neurologic, metabolic) should the cardiovascular explanation not bear out.

In a scientific reasoning or causal learning sense, posing the narrower explanation is a limited approach to learning. In fact, previous work has shown that good explanations are generally characterized by two central properties: they can accommodate new information in the context of existing beliefs, and they foster generalization to subsequent new information (e.g., Lombrozo, 2006). Asking constraint-seeking questions meets both demands, and arguably, therefore, has greater utility in the context of higher-order conceptual learning. They also, as a feature, help a learner clarify and simplify what is otherwise a complex, ill-defined problem: generating explanatory information about an unknown topic with vague, perhaps non-existent boundaries to the problem space (e.g., Horne, Muradoglu, & Cimpian, 2019).

Presuming that the learner has successfully generated an appropriate explanation, or a broad, sufficiently categorical question, their next task must be to involve members of their social world to get an answer or confirm their explanation. In examining this ability, the present dissertation will refer to Ronfard and colleagues’ (2018) model of children’s question-asking and pull from Mills’ (2013) review of children’s selective social learning.

Knowing who to question

Ronfard and colleagues (2018) note in their review that children and adults typically have a sense of what information they are looking for when they pose questions, and what appropriate responses might look like, given the nature of that information. This is the first screener in children’s selective information searches: they ask people who demonstrate a higher likelihood of giving them their desired information. While deciding which individuals are more or less likely able to provide that information is no small feat, children show a remarkable capacity to learn from others, both via linguistic and non-linguistic cues (Butler & Markman, 2012). Three- and 4-year-olds, for example, show striking developmental growth in their use of pedagogical cues for drawing causal inferences (Butler & Markman, 2010). Young children even use the verbal framing of an event strategically to draw inferences about relevant variables (Butler & Markman, 2012).

By the time children reach preschool, they also show a capacity to distinguish between more and less likely sources of information, directing their questions to adults rather than to other same-age peers (Choi, Lapidow, Austin, Shafto, & Bonawitz, 2016). In 40-minute sessions during their preschool day, researchers recorded spontaneous utterances, paying special attention to when children directed questions towards an adult, towards another child in their class, or towards themselves. Results indicated that children directed their questions towards adults far more frequently than they did either to themselves or to other children. Questions used specifically for learning, such as those requiring clarification, specific information questions, or general learning questions, made up most of children's adult-directed speech. There was also a strong main effect of age, indicating that as children advanced through preschool, they calibrated their information searches with more finesse, directing them largely towards members of their environment who were better suited to providing them with information. Children's use of primarily *wh*-questions (e.g., "what," "why") also increased over this brief course of development.

Children show a marked ability to use others—specifically parents and caregivers—to learn things about the world and are strategic in how they probe these caregivers for information. However, there are differences in the quality of responses that caregivers provide, and the equality with which they give them. For instance, in a study involving nearly 300 parent-child interactions staged around an interactive science exhibit at a museum, parents were nearly three times more likely to explain science to boys than to girls (Crowley, Callanan, Tenenbaum, & Allen, 2001). The equitable provision of information across boys and girls is essential because involving children in these exchanges has significant consequences for their factual scientific learning. These exchanges also speak to children's ability to access information about the world more generally, not only scientific information. While the learning value of these exchanges is perhaps most salient when the content involves some formal educational topic, pedagogical contexts can convey many different types of information.

Pedagogical contexts have a distinct power to convey unambiguous information (Gelman, Manczak, Ware, & Graham, 2013). This is likely because both children and adults show a proclivity for using generic language— language that refers whole kinds or categories of entities rather than individuals—when engaging in these pedagogical exchanges. Generic language allows for communicating important, generalizable information very efficiently, and so naturally features heavily in pedagogical contexts and in language generally directed to children. Children are dependent on what adults tell them to learn about the world and, despite the powerful impact of generic language on their reasoning, demonstrate an early understanding that testimony is not always reliable. For instance, in a study with preschool children, when a child actor proved to be more reliable than an adult one, children would suppress the bias to trust the adult informant in favor of the testimony provided by a more trustworthy child actor (Jaswal & Neely, 2006).

As alluded to earlier in this review, perhaps the most comprehensive assessment of children's selectivity was proposed by Mills (2013), who described children's critical stance as motivated by three types of cues: characteristics of the informants providing the information, characteristics of the claim itself, and the skills and background knowledge children bring to the exchange. Children demonstrate a skeptical stance from very early in development (e.g., Koenig & Harris, 2005). For instance, even 16-month-old infants appear to understand that other people can provide inaccurate information and that there can exist meaningful differences in the usefulness of even the accurate information that people provide (Koenig & Echols, 2003). Much of what motivates this selectivity may be infants' early expectations of which individuals are likely to provide them with more valuable (presumably accurate) information. For instance, in a neuroimaging study of 11-month-old infants, there was a documented increase in theta activation when they encountered informants who shared their native language and, importantly, this increased cortical activity was associated with their anticipation of gaining new information (Begus, Gliga, & Southgate, 2016).

Not only do young children appear to consider potential information gain, but they also demonstrate an early capacity to track which informants have been reliable in providing them with useful information in the past and use these regularities to guide what novel information they will accept from those people. Three- and 4-year-olds show a preference for learning new words and object functions from informants who demonstrated an established history of accuracy (accurately labeling familiar objects, and successfully performing the correct uses for familiar objects, Birch, Vauthier, & Bloom, 2008). More recent research has also demonstrated that children can track which aspects of an informants' history of reliability are informative for their future trustworthiness. Preschoolers can even differentially weigh the role of situation-specific cues (direct access to the relevant supporting evidence) and person-specific cues (a demonstrated history of accuracy) when making decisions about what information to accept (Brosseau-Liard & Birch, 2011). Children also appear to generalize that judgment when deciding whether to share that information with another naïve learner or when an actor who proved previously reliable suddenly neglects to perform the right kinds of epistemic actions, like gathering evidence to support what they say (Butler, Gibbs, & Tavassolie, 2020). In this way, children not only monitor the knowledge states of others as they pertain to their general trustworthiness but also map those characterizations onto local informational demands, discounting an informant's history of accuracy if it does not adequately pertain to questions of their immediate reliability. Moreover, preschoolers show an ability to consider the valence with which an informant provides them with information, discounting a confident informant's testimony if they have proven to be inaccurate, instead favoring a more accurate, if hesitant, informant (Brosseau-Liard, Cassels, & Birch, 2014). Children monitor other kids of social characteristics of their prospective informants as well, preferring informants who have visual access to the evidence about which they make claims over and above whether the informant shares their gender (Terrier, Bernard, Mercier, & Clément, 2016).

The ability to monitor epistemic characteristics, such as the magnitude of an informant's inaccuracy, when making decisions about whether to trust that individual in future learning events also appears relatively early in development. Children show an ability to integrate what they already know into their decisions about trusting what someone else tells them. For example, preschool and early-elementary-aged children can use what they know about animal types and numbers to guide their judgments about whether to accept an informant's claims as true, and younger children who, presumably, need clearly quantifiable content to estimate error magnitude, perform better in the number context as opposed to the animal-labeling context (Einav & Robinson, 2010). Older children, however, showed a clear preference for the informant whose responses, though wrong, were still closer to the correct answer than the informant whose claim was more egregiously wrong.

Children also monitor the reliability of the information, not only in terms of accuracy but in terms of general informativeness. In a study of corpus data from the

Child Language Data Exchange System (CHILDES), preschool children showed a tendency to ask follow-up questions, or to agree, when their adult conversation partners offered them causal explanations (Frazier, Gelman, & Wellman, 2009). When their adult conversation partners offered less-informative non-explanations, children more often re-stated their initial questions or invented their own explanations. In an empirical follow-up, these authors replicated these findings, providing both corpus and experimental evidence in support of the notion that young children monitor for and seek out causal information, strategically adapting their conversation styles to obtain it.

Moreover, young children can update their exploratory behaviors if they suspect insufficient, or under-informative explanations. Gweon, Pelton, Konopka, and Schulz (2014) presented kindergarten-aged children with a toy, which varied across conditions by its number of available functions (either a one-function toy or a four-function toy), which children were permitted to play with and explore to discover. Following, children were introduced to a toy teacher, whose job was to teach a naive learner about the functions of the novel toy. In both conditions, the teacher revealed only one function to the learner, and children were subsequently allowed to rate the informativeness of the teacher. Children reliably preferred and awarded higher ratings to the more informative teacher who demonstrated one function when there was only one to be found, as compared to when there were four functions. A follow-up study also demonstrated that 6-year-olds explored a novel toy more broadly when the informant who demonstrated its functions proved to be under- informative. These findings suggest that young children flexibly adapt their active learning strategies when they suspect that there is more information to be gained, both in pedagogical demonstrations and in direct response to the questions that they pose. This is also true for children's evaluations of how informants empirically gather evidence, demonstrating a robust preference for informants who accumulate full evidence in support of their claims (e.g., checking inside all four of four boxes before making claims about their contents) as opposed to insufficient (e.g., checking inside only one of four available boxes) or no evidence (e.g., checking inside none of the boxes) (Butler, Schmidt, Tavassolie, & Gibbs, 2018).

Importantly, however, there are some circumstances under which children fail to be appropriately selective. For example, including information about informants' benevolence interrupts younger children's abilities to monitor competence (Johnston, Mills, & Landrum, 2015), suggesting that there are some circumstances under which children may struggle to tease apart relevant cues to reliability when determining from whom would prefer to learn.

Posing Questions Selectively

As mentioned in Chapter 1, in most of the work on children's question-asking, children's inquiry styles are typically identified by two primary types: *constraint-seeking* versus *hypothesis-scanning* (e.g., Herwig, 1982; Ruggeri, Sim, & Xu, 2017, see *Figure 1* in Appendix I). Constraint-seeking questions, typically thought of as more effective than hypothesis-scanning questions, enable the question-asker to eliminate several plausible responses at once. Hypothesis-scanning questions, by contrast, typically isolate single plausible responses at a time. Children show remarkable improvements in their ability to pose these questions strategically as they develop. Even up to age 7, children ask predominantly *hypothesis-scanning* questions (that is, those questions which target a single plausible response in the set), and do not transition to using predominantly *constraint-seeking* questions until adulthood (e.g., Herwig, 1982; Ruggeri & Feufel, 2015; Ruggeri & Lombrozo, 2015). Ruggeri, Sim, and Xu (2017) took previous paradigms further in probing children's understanding of effective questioning by introducing a limited series of options, such that children did not have to generate their questions to complete the task. Three- to 5-year-old children have shown an ability to strategically adapt their choices of questions to elicit an accurate response and this skill seems to improve with age.

Children also show a developing capacity to refine the types of questions that they ask to control the problem space more effectively. In a study with 4-, 5-, and 6-year-olds, for example, older children tended to ask more *constraint-seeking* questions (that is, those questions designed to strategically eliminate several plausible responses at once) than the younger children, as opposed to redundant or ineffective questions (Legare, Mills, Souza, Plummer, & Yasskin, 2013). The number of constraint-seeking questions children asked in this study also served as the only predictor of the accuracy of the response they acquired in solving the problem at hand.

The process of asking intentional question types and direct them in effective ways plays a central role in children's ability to navigate novel information searches and to solve problems. Children also show an ability to navigate informational contexts in which there is no satisfactory trove of knowledge to tap, showing a systematic preference for known facts in the case that the information they seek is factual while accepting conjectures in the case that their questions do not have known answers (Chu & Schulz, 2018). As mentioned previously, children are also motivated to explore by ambiguous information, or when evidence violates their existing expectations (e.g., Buchsbaum, Bridgers, Weisberg, & Gopnik, 2012; Legare, 2012; 2014). When obvious answers are not available, however, children show an ability to independently evaluate the acceptability of speculations. Children can also strategically seek information from people they know have gained access to the information that they seek. More specifically, preschool- and kindergarten-aged children have been found use indirect cues to knowledge (e.g., marking the location of a hidden object on a picture) and selectively endorse suggestions that come from an informant who has, for instance, already gained access to the necessary information (e.g., the location of the hidden object, Robinson, Butterfill, & Nurmsoo, 2011). This is also true when the informant demonstrated relevant knowledge, as opposed to providing an unsupported guess, even if they are still correct.

Children less frequently take knowledgeable informants' testimony into account when that testimony is elicited by the question. This may be because, while children do frequently prompt others for information, they may begin to do so before they understand the implications of the responses they will receive (Robinson, Butterfill, & Nurmsoo, 2011). More to the point of the present dissertation, the literature examining when and under what conditions children accept the information that others provide them is critical for their broader learning.

The ability to start out their learning exchanges by posing questions selectively is also motivated by the extent to which children can engage in both cognitive control and metacognitive awareness, such that they have a sense of what and who would be most fruitful to ask. When they fail to take others' intentions and mental states into account, or when they fail to see the connection between the question they pose and the response they are likely to receive, young children struggle to use those responses to effectively update their beliefs or guide their inferences.

Knowing what to ask

Once young children have established that there is some gap in their knowledge, they must determine what kind of exploration or inquiry would be most effective in closing that gap. A general approach to starting an information search begins with establishing what Bergstrom, Moehlmann, and Boyer (2006) refer to as *boundary conditions*. Doing so enables the learner to identify the inferential potential of whatever information will be encountered in that information search. However, establishing the *boundary conditions* of a particular problem necessarily requires recruiting existing knowledge, which tends to contaminate our perspectives about what remains to be known (Birch, Brosseau-Liard, Haddock, & Ghrear, 2017)—a phenomenon referred to as the *knowledge bias*. This knowledge bias also has demonstrable effects on the judgments that people will make about others' less-informed perspectives and about their memories of responses that they previously gave, frequently overestimating the extent to which they were originally right (e.g., Fischoff, 1975). This bias can be especially problematic when making decisions about what to ask of other people—it requires a twofold mentalizing process: first, an evaluation of what one already knows; second, an evaluation of what others are likely to know.

Even adult participants will perseverate on specific information search methods, failing to switch to more effective methods when their original search does not yield the information they are looking for (Chin, Payne, Fu, Morrow, & Stine-Morrow, 2015). In other words, even in the face of diminishing returns on the amount of information gained in each search, adults—though less common among younger as compared to older adults— persist in less effective search strategies. It is possible that information search strategies may have differed between age groups among adults due to differences in perception about information gain. For the young child, knowing what can be gained from a particular information search—particularly through questioning—is contingent upon an understanding of the sources of that information gain: other peoples' knowledge.

Young children struggle more than older children in attributing the appropriate level of knowledge to another individual (e.g., in a false-belief task, Birch & Bloom, 2003). Younger children, more often than older children, find it difficult to suppress what they already knew about the context when attributing mental states to another person (e.g., their existing knowledge about the false-belief task). Using existing knowledge as a guiding framework for posing questions to others may therefore be a particular challenge for young children, both because they may struggle to recruit existing knowledge to establish appropriate *boundary conditions* and because they may lack the metacognitive awareness to calibrate what they already know to what someone else is likely to know to solve a problem.

Children also pose questions that pertain to specific domains, relative to the knowledge they are interested in gaining— questioning what researchers refer to as “*theorylike*” domains, such as social and physical phenomena (Callanan & Oakes, 1992). Children’s tendency to seek explanatory information about kinds or categories, and seek out information (by asking, “*why*”) to help build on the richness of these conceptual representations has been well-documented (e.g., Cimpian & Petro, 2014). Children also show early emerging abilities to respond adaptively to the kind of evidence they observe to generate additional requests for information (Busch & Legare, 2019). In this way, while children certainly show a tendency to focus on topics for learning— likely because learning about kinds or categories can produce large bodies of information more efficiently—they are not limited by this bias and can strategically leverage the questions they ask to learn about any number of topics, adapting their searches over the course of their question-asking exchange. The next challenge the young learner must face, however, is posing the question in such a way that it can be understood by their conversational partner and can produce the kind of information they are looking for.

Knowing how to ask the question

How children phrase questions is heavily predicted by what they already know, and by their attitude towards the information they seek (Molinero & Garcia-Madruga, 2011). While questioning behaviors appear early in development, and question-asking has significant implications for children’s learning, research shows that young students struggle to ask questions, and even more so to ask good ones. However, not only does the ability to use the information acquired through questioning improve over the course of the preschool years, but children also incorporate information resulting from others’ questions (Mills, Danovitch, Grant, &

Elashi, 2012). In this way, children demonstrate an early understanding that questioning is a fruitful learning strategy and attend to the products of these questions to leverage for their knowledge gain. There is also evidence that while young children, even in the early school years, struggle to *construct* their own high-quality questions, that does not mean that they cannot adaptively discern better quality questions that *others* pose.

Question construction. Young children engage in questioning behaviors from very early in development and begin by asking questions of many different forms and for many different reasons (e.g., Kemler Nelson, & O'Neil, 2005; Legare, Mills, Souza, Plummer, & Yasskin, 2013), though these questions are somewhat lacking in strategic prowess. Over the course of development, children's questions become more refined, and their construction comes to reflect the strategic goal of their information search. This improvement in their questioning strategies is critical, as Courage (1989) points out, because as children acquire new information, they necessarily increase their knowledge and expand the scope of their abilities to solve novel problems and learn about other, higher-order concepts. As mentioned earlier in this review, research in children's question asking has identified two primary types of questions: *constraint-seeking* and *hypothesis-scanning* questions (e.g., Mills, Legare, Bills, & Mejias, 2010; Ruggeri, Sim, & Xu, 2017). Young children start with unrefined questioning skills, asking largely ineffective questions, and sometimes directed toward inappropriate sources (Mills et al., 2010). Though the ability to ask strategically-targeted questions does not show much improvement until early elementary school, by the time kids are 5, they show an ability to direct their questions towards more fruitful information sources, reflecting development in their understanding of the relation between knowledge and expertise (children around this age come to understand that experts in specific knowledge domains are likely to have more knowledge about the content in that domain; mechanics know more about cars and doctors know more about anatomy, for example; see Lutz & Keil, 2002).

There is also some evidence of a strong relation between children's abilities to use questioning as a problem-solving strategy and their accuracy in solving a given problem (Chouinard et al., 2007; Mills et al., 2010). In general, studies aimed at examining children's question-asking abilities provide them with a constrained choice between pre-constructed questions and probes their understanding of relative information gain, which, in these scaffolded tasks, young children do appear to understand (e.g., Samuels & McDonald, 2002; Sodian, Zaitchik, & Carey, 1991). Less is known, however, about how children construct their own questions, or how what broader generalizations they make about other people's abilities to ask questions with high expected information gain.

In a study examining preschoolers' and kindergartners' abilities to characterize more knowledgeable informants as more reasonable sources of information (contrasted with ignorant and inaccurate informants), 5-year-olds sometimes struggled to recognize which of the choice of informants was the most knowledgeable and did not systematically direct their questions to those people (Mills, Legare, Grant, & Landrum, 2011). Older children, compared to younger preschoolers, showed better questioning skills overall, but younger preschoolers' question-asking strategies showed some improvement, particularly after having had effective questions modeled for them (Mills et al., 2011). Children also struggled to understand when they ought to persist for more information, failing to recognize that they had incomplete information after receiving an answer to a single question. This may be related to the challenge that young learners face in deciding how to construct questions that will produce the information they are looking for—as compared to those which leave room for more learning. This, in turn, may be constrained by the developing, though still nascent, cognitive skills mentioned earlier in this review: It is critical to monitor the status of our own knowledge to determine what questions are most likely to appropriately address the scope of the problem space.

There is a distinct developmental shift in children's abilities to flexibly adapt the questions that they ask; not until later elementary school can children strategically generate hypothesis-scanning and constraint-seeking questions to identify a causal antecedent (Ruggeri & Lombrozo, 2014). Earlier in development, hypothesis-scanning questions predominate children's question-asking strategies, shifting later to a greater reliance on constraint-seeking questions. However, this work also demonstrated that even children as young as second grade could flexibly adapt their question construction when faced with a problem wherein greater information gain was an obvious consideration (Ruggeri & Lombrozo, 2014). Given that this developmental shift in the capacity to understand when one question type might be more informative than the other parallels other developmental changes in children's cognitive capacities, it makes sense to control for the relative effectiveness of the questions produce for a question-asking exchange over and above other developing cognitive capacities.

However, children do not generate questions absent these cognitive demands in real life and must use many cognitive skills concurrently to make determinations about what kind of question to ask, pulling from an awareness of their own knowledge states, the knowledge states of others, and the relative information gain associated with each question type to close the gap between the two.

Question construction is as instrumental for the child learner as it can be for the teacher. Indeed, it is estimated that some 80% of the questions used in classrooms are for the purpose of teaching, and a majority are prompts for concrete knowledge or to elicit deeper thinking about course content (e.g., Gall, 1970; Siraj-Blatchford & Manni, 2008). Parents, as well as teachers, often pose rhetorical questions, typically referred to *pedagogical questions*, designed to signal to children that there is some opportunity for deeper learning by drawing their attention specifically to elicit more interactions about a topic about which the question-asker is already knowledgeable (Yu, Bonawitz, & Shafto, 2017). The proportion of pedagogical questions that parents ask of their children is related to many factors, such as the child's age and the socioeconomic status of the family.

Previous work has also shown that caregivers adjust their communicative styles more generally as a function of the age of their children (e.g., Kuchirko, Tamis-LeMonda, Luo, & Liang, 2015; Snow, 1972). The home environment, therefore, plays a critical role in children's and caregivers' question-asking exchanges, not only in the acquisition of language that enables children to pose their own questions but also in the questioning styles of the caregivers.

The questioning strategies that parents and children use are clearly influenced by many different factors, including the recognition of information gain, the age of the child, and the home environment. Not only do these factors seem to influence children's and caregivers' question construction, but they may also influence how persistent children are in extending these questioning exchanges to elicit more information beyond the content of their original search. One foremost factor which may influence children's persistence in posing questions—and the types of questions that they pose—is the quality of the responses that they receive for those questions. Children show a developing ability to monitor the quality of an explanation and show a specific resistance to *circular* explanations that do not address the content of their question.

Reasoning About Responses

There are several cues that children appear to monitor when deciding whether they should persist in their questioning, above and beyond obvious indicators that the responses they have received fall short of addressing the gap in their knowledge. One notable indicator is when the explanations offered to children simply do not offer new information, but instead reiterate the question. These circular explanations are often offered by adult conversational partners—even unwittingly—when they are limited in recognizing the pragmatic factors which influence whether an explanation can be interpreted as circular (e.g., Baum, Danovitch, & Keil, 2008; Rips, 2002). Young children show some capacity to identify circular explanations: even young children can identify circular explanations, provided that these explanations are short enough (Corriveau & Kurkul, 2014). When young children can identify circular explanations, they also demonstrate a corresponding selectivity in their choice of informants. This ability to identify circular explanations develops over the course of early elementary school, during which a preference for noncircular explanations emerges and appears regularly by the time children reach age 10 (Baum et al., 2008).

Understanding when an explanation is circular is necessary, not only to monitor logical inconsistences and for the reliability of prospective teachers, but also for children's abilities to navigate and extend questioning exchanges when necessary. Children younger than 8 who encounter these kinds of logical inconsistences (e.g., "The chip in my hand is blue and it is not blue") often treat them as empirical statements, and thus do not request additional explanatory information (e.g., Osherson & Markman, 1975). This has the potential to be damaging to children's learning simply because they fail to understand when it is necessary to continue a questioning exchange or to resort to a new person for information when that person demonstrates an inability to answer their question satisfactorily.

However, this work was largely conducted with logically inconsistent claims offered in isolation. When children are given a contrast of logically consistent and logically inconsistent claims, children as young as 4 can evaluate epistemic reliability—a step-up from the distinctions that 3-year-olds can make, given very short explanations (e.g., Corriveau & Kurkul, 2014)—and also demonstrate a preference for informants who provide logically consistent information (Doebel, Rowell, & Koenig, 2016). These findings are consistent with evidence mentioned earlier in this review: (1) though not tested in the studies described above, the context in which information is provided has significant implications both for children's perseverance in extending a questioning exchange and for their selectivity; (2) the capacity to be selective about the information children accept develops in conjunction with several other underlying cognitive abilities, including working memory, metacognition, and cognitive control (e.g., Doebel et al., 2016). Mills, Danovitch, Rowles, and Campbell (2017) extended this work by demonstrating that elementary-aged children not only show a preference for noncircular explanations about unfamiliar animals, but they also show greater interest in obtaining additional information in the face of weak explanations.

In addition to the ability to distinguish between circular and noncircular explanations, children as young as 4 also show a developing capacity to discern between relevant and irrelevant explanations (even when both are true), finding relevant explanations more informative and helpful (Johnston, Sheskin, & Keil, 2019). The ability to recognize when explanations have relayed relevant information is particularly critical for children's questioning, because it presents children with a clear indicator of whether an informant's response has satisfactorily closed the gap in their knowledge. Children also sometimes generate explanations for surprising or unexpected phenomena to frame their own learning. This ability also appears to be related not only to children's perseverance in questioning others who might be able to provide relevant explanatory information, but also to their own active exploration. When causal evidence is inconsistent with what children expect, the kinds of explanations that they will generate are related to the kind of exploratory behavior that they engaged in when trying to resolve the inconsistency and to the extent to which they modify or generate new working hypotheses (Legare, 2012). Children's abilities to explain causal phenomena have also been found to generate greater learning and generalization of those causal properties (Legare & Lombrozo, 2014).

Taken together, these findings demonstrate several important considerations for this dissertation: First, the quality of the responses that children receive for their questions have significant implications for their selectivity and further engagement in information-seeking exchanges. Second, the context in which children receive responses for their questions influences children's determinations of circularity and relevance in conjunction with other developing cognitive abilities, such as working memory, metacognition, and cognitive control. When a child receives a satisfactory response to their question, they must then decide the extent to which that response has closed the gap in their knowledge that they sought to address and whether they should pursue additional questions. In other words, even when an explanation is noncircular and relevant to the informational context, it may still fall short of constraining the problem space, prompting children to extend the questioning interaction in the search for more information. In these cases, children must again draw on these same underlying cognitive capacities, in addition to incorporating the new information they have just received in answer to their original question, to constrain the problem space further and consider next steps for navigating that exchange.

Children must reason about how to constrain the problem space before they have even received new information from others. They must consider the role of existing evidence in the world when constructing the question that they want to pose. However, as detailed extensively in this chapter, preschoolers' question-asking skills have been found to be exceptionally poor. The way in which children embark on their information search is in many ways predictive of both how constrained the scope and how informative of the responses that they receive will be.

In this sense, the people children ask for information also have implications for how constrained (not just non-circular or informative) of responses they will receive. One consideration that may be relevant for children, when they are trying to decide who is most able to constrain the evidence of interest to them, has to do with the goals of the informant. Danovitch and Keil (2004) explored this question in two studies with elementary-aged children. They note that by predicting what specific kinds of information an informant might know and share, children have the power to divide the intellectual burden, freeing them of the requirement of acquiring all that information on their own. Children also show a tendency to group their representations of related bodies of knowledge—referred to as *goal-clustered knowledge* (e.g., Teske & Pea, 1981)—which enables them to group questions together based on the assumption that a person with knowledge in one area can be reasonably assured to demonstrate knowledge in another, related area.

Relatedly, children also show a capacity to constrain the evidence by considering whether the claim made by that informant matches observable reality and that the informant had direct perceptual access to that information. The ability to match perceptual access to reliable epistemic claims—claims about *knowing* some situation or truth about the world—is particularly important not only for evaluating the immediate reliability of some bit of information, but for ascribing trustworthiness, as a character trait, to the individual providing that information (Fedra & Schmidt, 2019). This gives children a relatively reliable heuristic for future information searches, counting on specific informants over others to provide them with reliable testimony, which is most likely to constrain the problem space in the case of novel information.

In a study with 4- and 5-year-olds, Fedra and Schmidt (2019) examined whether young children could successfully disregard the testimony of an informant who gave them information that contrasted with observable reality, providing a direct test of children's understanding of the connection between *seeing* and *knowing*. While both the younger and older preschoolers correctly accepted knowledge claims made by the informant who had direct perceptual access, only the older preschoolers (5-year-olds) reliably rejected *incorrect* knowledge claims which did not match reality. This work speaks both to children's developing understanding that people who have direct perceptual access to the information they share can be trusted to provide reliable knowledge, and an early-emerging understanding of the norms surrounding the justifiability of knowledge claims.

As this understanding develops and becomes more refined, it may contribute to children's abilities to constrain the evidence by directing their inquiries toward informants who knowledge states they have already considered or anticipated. The people who have direct perceptual access to the problem space, for instance, are more likely to provide trustworthy testimony, and are therefore better candidates for inquiry-based exchanges.

An extensive body of research has investigated how children make decisions about the kinds of questions to ask of others, who to ask, and how to reason about the information that others give in answer to those questions (e.g., Cook, Goodman, &

Schulz, 2011; Greif, Kemler, Keil, & Gutierrez, 2008; Ruggeri, Sim, & Xu, 2017). Much of this work has been synthesized into a framework of children's question-asking which characterizes children's inquiry as involving four primary stages that develop over the course of a child's early years (Ronfard, Zambrana, Hermansen, & Kelemen, 2018).

This framework is foundational in many important ways but falls short regarding two primary points: First, as mentioned in Chapter 1, this framework does not fully capture the underlying cognitive capacities which motivate children's abilities both to generate effective questions and to evaluate the responses they receive for their questions. Secondly, this framework does not illustrate the ways in which children's inquiry is inherently cyclical: they first must identify a gap in their existing knowledge that they, alone, cannot satisfy. They accomplish this by engaging in a kind of temperature-taking process—assessing what they do and do not know about a topic. Then, children must make decisions about how to construct a question which would most successfully satisfy this gap in their knowledge. Children then must ask their question first, to an individual in their social world who is perhaps best equipped to address that question, and second, in such a way that this individual will understand the nature of the information the child is asking about. Once this person has answered the child's question, the child must (1) evaluate the quality of the response they received; and (2) use their judgments about this response to evaluate the person who provided it. These assessments are critical for children to make reliable predictions about whether this person is apt to provide reliable information again in the future.

This process involves a considerable amount of cognitive effort on the part of the child. The ability to pose *good quality* questions, as noted above, requires additional cognitive skills and experience that children gain and improve over the course of early development. The capacity to evaluate the kinds of responses that they receive for their questions also mirrors this development. These skills put together: (1) the ability to pose effective questions (i.e., those that sufficiently yield the information that they seek) and (2) being appropriately skeptical of the answer s they receive lay the foundation for children's learning on the broadest level, independent of specific content area, and give them an extraordinary amount of autonomy in guiding their own learning. Advancing these skills and shaping them to the demands of 21st century learning have wide-ranging implications, including for children's question-asking, their developing selectivity, and their broader critical thinking and science literacy.

Chapter 3: The Present Study

Chapters 1 and 2 detail two main elements of children's inquiry-based exchanges: (1) how they construct and pose questions (see The Questioning Stance); and (2) how they reason about the answers that they receive for their questions future (see The Critical Stance and Posing Questions Selectively) and make determinations about (a) whether the information itself is accurate and should be incorporated into their developing knowledge structures and (b) whether the person who provided that information should continue to be a source of information in the future. Both components require similar underlying skills, which emerge early in childhood and develop over the course of preschool and early elementary school (e.g., cognitive control, metacognition, vocabulary), though previous research suggests that children do not exhibit adult-like questioning skills until later elementary school or even middle school.

While each of these literatures, alone, provides critical insight into how children develop and engage in each of these skillsets, they do not fully capture the cyclical nature of children's question-asking exchanges, and the ways in which these skillsets necessarily implicate one another. In a domain-specific sense, children must regularly make decisions about whether the information they got in answer to their question is accurate and successfully addresses some gap in their knowledge or a problem they want to solve. Children must also be able to choose between reliable informants or sources, to ensure that they have cultivated a collection of sources who can provide them with reliable information again in the future. In a domain-general sense, children must implement this critical lens to every kind of learning episode they have. When children are directing their learning exchanges, the success with which they obtain reliable information is shaped by the degree to which their information-seeking skills are effective and well-honed. Perhaps the most salient instance in which this can be observed is in the development of children's scientific and information literacy.

In a world with vastly increasing stores of information (e.g., Schilling, 2013), much of which is accessible through online sources which endure far fewer institutional checks for reliability, learners must develop the skills early to successfully navigate that informational landscape and extract the most pedagogically useful and trustworthy information. For children, the risk of encountering unreliable information and not having the tools to correct their misconceptions (either because they lack the requisite cognitive abilities or the relevant background knowledge), is far greater and can have more lasting consequences that are harder to correct.

Consider the example of climate literacy (e.g., Kuthe et al., 2020; Milér & Sládek, 2011): recent research suggests that the public's acceptance of the dangers of climate change are less significantly predicted by increased science literacy and numeracy, but significantly predicted by cultural polarization and the social groups with which they affiliate (Kahan et al., 2012). By this view, children, who are largely at the mercy of the people in their immediate social spheres to receive messaging about what knowledge to accept and from whom they should accept it, must cultivate an objective ability to evaluate the information they receive and the people who communicate it. Furthermore, to protect themselves against the onslaught of misinformation, perpetuated across digital platforms that children access for many different aspects of their learning (e.g., to satisfy their personal curiosity and as a resource for formal classroom-based learning), children must be able to initiate effectives searches for information and be able to reflect on the degree to which the sources that provide them with information can be trusted.

Though the work described here cannot account for this much broader goal of improving children's global critical stance towards information, it can provide some insight into the foundational skills they must employ to do so successfully. In the current study, I aimed to integrate the two literatures described above to contribute to this insight. The dissertation described in the next section sought to provide critical evidence that these two skills are related to one another by establishing that those children who can identify a better-quality question can also determine which of two informants is likely the more reliable and may demonstrate other related attributes, such as knowledgeability or broader competence.

Study Rationale

In synthesizing existing research paradigms from previous work on children's questioning asking and their selective trust, the present study sought to provide foundational evidence that children's skillsets characterized by these respective literatures can be thought of as inherently related to one another. Though this could not be explored in the current study, it is thought that performance in (1) identifying better-quality questions (those with greater relative information gain) and (2) identifying more trustworthy sources of information based on that identification will correlate significantly in large part due to the same underlying cognitive capacities, such as cognitive control and metacognition which support the development of these capacities.

This work also aimed to take a novel step forward in examining the extent to which young children view better question-askers as more adept at solving problems, more generally. That is, it targeted key remaining questions about whether young children see better information-gatherers as being more knowledgeable or competent in tasks unrelated to the nature or content of their questions. Understanding how and when these skills arise in development has significant implications for supporting children's abilities to use them in later, higher-order cognitive processes. Particularly in an age when access to various kinds of information is undergoing constant, significant change, early skill development in the ability to search for information effectively and to determine its veracity is of critical importance (see Butler, 2020). For young children in school, the ability to identify when the individuals providing them with information can be trusted regarding the reliability of that information and with their identification as figures who can be relied upon in future, is central to their learning, broadly.

The present dissertation sought to: (1) replicate previous work that has established that, by age 5, young children can identify a more effective or informative question (Ruggeri et al., 2017), even if they, themselves, cannot yet produce them (Legare et al., 2013); (2) investigate the extent to which this capacity is related to children's abilities to identify a more reliable informant; (3) investigate whether children make broader assumptions about the qualities better question askers possess, such as general knowledgeability or competence; and (4) establish whether children make similar adjudications about these individuals' abilities to troubleshoot and solve novel problems. The present study was also the first to prompt children to provide explicit rationales for their responses, a first step in understanding some of the underlying calculations children may be making while actively engaged in an information exchange.

Methods

Participants included 160 children between 4 and 7 years of age (M_{age} = 5.92 years, SD_{age} = 13.89 months, 50% female) recruited from a database of interested families through the University of Maryland Infant and Child Studies Consortium and family sign-ups via a Google Form posted to the Cognition and Development Lab's Facebook page, which were compiled into a working in-house database. Families therefore came from a range of locations, though predominantly from the mid-Atlantic region of the United States. Sample size was determined using *a priori* power analyses using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009), which revealed that to detect small-to-medium effects, a minimum of approximately 114 participants would be necessary to test our hypotheses. To keep recruitment across ages and genders equal for the four planned experimentally counterbalanced orders, a final sample of 160 was collected.

The sample represented a range of racial and ethnic backgrounds (62% white/Caucasian, 6% Black/African American, 10% Asian/Pacific Islander, 4% Hispanic/Latinx, 1% Native American/Alaska Native, 16% Biracial/Multiracial). The sample also represented a range of socioeconomic backgrounds (49% from households reporting $151,000 or more in annual earnings, 33% reporting $101,000-

$150,000 in annual earnings, 31% reporting $76,000-$100,000 in annual earnings, 13% reporting $60-$75,000 in annual earnings, 7% reporting $46,000-$59,000 in annual earnings, 5% reporting $31,000-$45,000 in annual earnings, 6% reporting $15,000-$30,000 in annual earnings, and 3% reporting less than $15,000 in annual earnings).

Procedure

This project was approved by the Institutional Review Board at the University of Maryland College Park. Initially, a waiver of consent was approved, such that parents were only asked to provide their consent out loud during a recorded unmoderated session using the platform Discoveries in Action. However, as the project was later moved to a moderated format, such that parents and their children met with a researcher at a scheduled time via Zoom, they were instead sent a link to a Qualtrics form containing all consent materials prior to their scheduled appointment. Once they read through the consent documents, parents were prompted to check a box indicating consent and to provide a virtual signature. All children gave explicit verbal assent prior to the start of the study in the scheduled virtual session. Participants completed individual interviews from their homes with trained experimenters from the Cognition and Development Lab.

The interview was accompanied by a PowerPoint presentation depicting puppet characters playing a scripted Question Game; after each trial, children were asked to indicate which character asked the 'better' question. Following, children were asked an overall assessment question, to serve as a self-generated memory check and to orient children to the generalization questions in the final phase with the characters' questioning abilities in mind. Finally, children were asked a series of three questions to determine whether they could extend questioning ability to other target cognitive abilities, such as reliability in a novel learning task, knowledgeability, and competency in helping to trouble shoot a problem. The interview lasted approximately 20 minutes, including time at the beginning of the session to obtain child assent, and a debrief at the end of the session to ensure that the child left the exchange in good spirits and could ask their own questions about the activity, if they had any, as we had previously done when testing in person. I was confident that this mode of data collection would be both fruitful and reliable; recent work has found that large-scale online studies can have the same effectiveness as in person testing, and even combat the problems of small sample size and lack of diversity which have historically plagued psychological research (e.g., Sheskin et al., 2020).

Design

Participants were first introduced to two target puppet characters, Bunny and Monkey, who were both described as friends of a third character named Duck. Children were told that Duck completed a series of errands that day and that Bunny and Monkey, in the interest of determining what Duck did, would ask Duck a series of yes-or-no questions. Children were told at the outset that they would be asked to determine which character, Bunny or Monkey, asked the "better" question.

***The Question Game*.** After the initial study set-up, children were shown a series of four scripted Question Game trials in which Duck (1) went to an ice cream store, (2) went someplace new in town, (3) visited the zoo, and (4) stopped by the library (see *Figure 4* in Appendix I for full study schematic). In each trial, Bunny and

Monkey aimed to discover, out of an array of six options which comprised each vignette's problem space, what Duck did in each vignette (e.g., in the case of the ice cream store, whether Duck selected one of two milkshake options or one of four ice cream cone options). In each trial, Bunny and Monkey each posed one question, one that was always a constraint-seeking question (broader and more efficient, e.g., "*did you choose some kind of ice cream?"*) and one that was a hypothesis-scanning question (narrower and less efficient, e.g., "*did you choose a chocolate milkshake?"*). After each trial, children were asked to determine which character asked the "better" question and to provide an explicit justification for their choice (e.g., "*what makes you think [child's choice] asked the better question?*"). Across all four orders, the character that asked the constraint-seeking question was marked as the "correct" answer, as it was always the broader, more efficient question. Children could therefore select the correct questioner a maximum of four times, across all trials of the Question Game.

Counterbalancing. Each of the four trials was counterbalanced relative to the scripted Question Game, accounting for the following four factors: (1) which character was introduced first (Bunny vs. Monkey); (2) placement of the "correct" character (right vs. left on the screen); (3) which character posed the constraint-seeking question (Bunny vs. Monkey); and (4) which question type was asked first (constraint-seeking vs. hypothesis-scanning). The following four trials (overall questioner assessment and the three generalization trials (reliability, knowledgeability, and competency) were presented to participants in a fixed order).

Overall Questioner Assessment. Following the end of the Question Game, children were asked to provide an overall questioner assessment (e.g., "*If you were thinking about all of the questions that Bunny and Monkey asked Duck, who would you say asks better questions overall?*"). This question was included to serve as a self-generated memory check for children's choices regarding the quality of the characters' questions in the scripted game and to orient children to the last three trials, which targeted their generalizations of the characters' questions to other, related cognitive abilities.

Reliability Task. To test whether children viewed more effective questioners as more likely to provide reliable information, children were shown a picture of a novel toy and were told that Bunny and Monkey had already asked the toymaker a question about how the toy operates, but that they came away with conflicting conclusions (e.g., Bunny reported that the toy played music by pressing a purple button on the back; Monkey reported that the toy played music by pressing a yellow button on the back). Without any additional information or context, children were asked to determine which character they believed really learned how the toy played music, and to provide an explicit justification for their choice.

This prompt was modeled after a classic trust-in-testimony task (see Mills, 2013) in which children are shown two characters who provide conflicting information (often inconsistent object labels) and, either without additional information beyond the social characteristics ostensibly available to them or based on epistemic behaviors those characters had previously demonstrated, to determine which they trusted to provide them with information about an unrelated domain or task. In this case, children's assessments regarding the characters' questioning abilities were thought to factor into their selections between the two in a novel reliability task.

Knowledgeability Task. To test whether children viewed more effective questioners as more knowledgeable, children were shown a picture of a classroom and heard the following script:

> *Now let's talk about teachers! There are lots of things that make a teacher a* good *teacher. Good teachers are good at explaining how things work and answering questions about why things happen… If* you *were thinking about what you think makes a good teacher, who would you say would be a better teacher?*

Participants were then shown images of Bunny and Monkey and prompted to select which one they believed would serve as a better teacher and to provide an explicit justification for their choice. The role of a teacher, for children of the ages included in the present sample, was thought to serve as the best proxy for a knowledgeable individual. This task was included as a straightforward measure of children's assessments of which character, presumably based on their performance in the scripted Question Game, they believed to be more knowledgeable.

Competency Trial. To test whether children viewed more effective questioners as more broadly competent, I asked children to identify which character they thought of as more able to successfully troubleshoot and solve and novel problem. Children were shown an image of a broken car toy that would be difficult to repair, paired with the following script:

Look at this toy. Oh no! It looks like this toy is broken… And there are so many parts and confusing instructions for how to fix it… I know! We should ask one of our friends to help us fix it. Who would you want to ask for help fixing this toy?

Participants were then shown images of Bunny and Monkey and prompted to select which character they would prefer to help them troubleshoot and solve the problem of fixing the broken toy. As with all previous trials, they were asked to provide an explicit justification for their choice. This task was included as a measure of children's generalization of questioning strategy to the ability to navigate and solve novel problems, a proxy for broader competency in in the face of a challenging task.

Justifications. While previous work has used some similar measures, previous research on children's question-asking has not included prompts for children's explicit justifications regarding their reasoning about the quality of others' questions. One previous study (Pratt, 1990) found that children aged 5 to 7, when asked to provide explanations for why a bizarre question did not make sense, were able to do so with adult-like accuracy. In a more recent study using cases from the CHILDES database, Goetz (2010) found evidence that by age 4, children regularly use justifications as expansions of their discourse in social exchanges, with questions as the discourse motivators increasing between ages 3 and 4. I therefore had reason to believe that even the youngest participants in the present sample (i.e., 4-year-olds) would be reasonably able to respond to the prompts to provide explicit justifications for their reasoning in the present dissertation, and that this measure would give fruitful insight into the real-time processes underlying children's decisions.

For the purposes of exploring children's reasoning about questioning strategy and efficiency in the present study, I developed a novel justification coding scheme (see *Table 2* in Appendix II). According to this scheme, children's justifications were sorted into two categories: (A) responses that did not consider relative information gain or questioning strategy or were more conceptually related to preferences and mental states, hereafter referred to as "Mental State/Preference Attributions"; and (B) responses that alluded to relative information gain or were more conceptually related to questioning strategy, hereafter referred to as "Information Gain Attributions".

Within the Mental State/Preference Attributions group, children could receive one of four categorical assignments: (1) *Reference to the item in the vignette/puppets' preferences* (e.g., "Because I think Duck wanted a milkshake"; "Because it's purple"); (2) *Reference to the characteristics of the puppet* (e.g., "Because humans evolved from monkeys, so he might be smarter"); (3) *Reference to the child's own preferences* (e.g., "Because I like lemons and strawberries"); or (4) *Other/I don't know*. Within the Information Gain Attributions group, children could receive one of four strategically escalating assignments (such that the higher the score, the more adult-like and nuanced the participant's justification is thought to be): (1) *Reference to the puppets' guesses about a correct answer* (e.g., "Because I think he picked all of the things right"); (2) *Reference to the puppets' production of 'better' questions* (e.g., "Every single question got the exact same answer and it was always Bunny"); (3) *Reference to the overall number of items in the problem space* (e.g., "Because Bunny has different kinds of flavors"); or (4) *Reference to the puppets' strategies/narrowing down the problem space systematically* (e.g., "Because Bunny did many kinds of flavors and Monkey only picked one flavor that he thought might be it"). Four research assistants who were blind to the order-assignment of each participant conducted the coding in two teams (two assistants coded 100% of the sample, two assistants coded 50% of the sample). All disagreements were resolved by discussion.

While children's Mental State/Preference Attributions were not directly related to the empirical questions of interest in this dissertation, they will be revisited in the results section, to provide additional detail regarding how children may have reasoned about their choices outside the scope of relative information gain. To address the quality of children's justifications relative to the empirical questions of interest, those children who provided Information Gain Attributions will be analyzed in greater detail. The results section will describe both the frequency with which children provided these types of justifications and, within that group, the relative quality of children's justifications.

Measures

There were six primary measures for this study: (1) participants' scores in the scripted Question Game (out of 4); (2) children's selections between the two characters in the overall questioner assessment (0 – hypothesis-scanning questioner; 1 – constraint-seeking questioner); (3) children's selections between the two characters in the reliability task (0 – hypothesis-scanning questioner; 1 – constraint-seeking questioner); (4) children's selections between the two characters in the knowledgeability task (0 – hypothesis-scanning questioner; 1 – constraint-seeking questioner); (5) children's selections between the two characters in the competency task (0 – hypothesis-scanning questioner; 1 – constraint-seeking questioner); and (6) children's justifications, which were coded according to the pre-determined coding scheme detailed above.

Hypotheses

There were several predictions for children's performance across all measures in the present dissertation. First, regarding the Question Game, I predicted children would select the constraint-seeking question-asker more often than can be expected by chance. Moreover, I anticipated that older children (6- and 7-year-olds) would outperform younger children (4- and 5-year-olds), consistent with previous research on children's abilities to identify better questions (e.g., Ruggeri, Sim, & Xu, 2017), such that they selected the "better" questioner (i.e., the constraint-seeking questioner) more often. I also predicted that the within-clustered age differences (4- and 5-year-olds and 6- and 7-year-olds) would be nonsignificant, but that the measure of difference between 5-year-olds' performance and 7-year-olds' performance would be statistically significant.

Second, regarding the generalization trials, I predicted children's scores on the Question Game (out of 4) would be directly related to their generalizations, such that the children who scored higher in the game would select the constraint-seeking questioner across the four generalization trials (i.e., overall questioner, reliability, knowledgeability, and competency). I also expected that older children would again outperform younger children in selecting the constraint-seeking questioner above what could be expected by chance.

Third, regarding participants' justifications, I predicted that children's ability to provide explicit justifications which allude to relative information gain would improve with age (such that older children are coded according to Information Gain Attributions more often than that of younger children). I also anticipated that children's scores on the Question Game would predict their justification scores, such that those who preferred the constraint-seeking questioner as the "better" question-asker could better justify their selections according to relative information gain.

Finally, I hypothesized that this finding would also hold true for the generalization trials, such that children who provided Information Gain Attributions would be more likely to prefer the constraint-seeking questioner as an overall better questioner, and as more reliable, more knowledgeable, and broadly more competent.

Analytic Plan

In order to address these hypotheses, several planned analyses were conducted, broken down by the analyses conducted for the following sections: Phase 1 (Question Game); Phase 2 (Generalizations); and Justifications.

Question Game. First, one-sample t-tests were conducted to determine whether children's choice of Constraint-Seeking questioner in the Question Game differed significantly from chance (chance = 2). One-way ANOVAs were used to determine whether there were any differences in children's performance by age group (4-year-olds, 5-year-olds, 6-year-olds, 7-year-olds). An additional exploratory t-test was run to determine whether children selected the Constraint-Seeking questioner more often than the Hypothesis-Scanning questioner in the Question Game.

Generalization Trials. Second, binomial tests were used to assess children's performance in the generalization trials to determine whether children selected the Constraint-Seeking questioner more often than chance (chance = 0.5) across each of these trials. Logistic regressions were fit for each trial, with choice of questioner as the outcome and children's scores in the Question Game as the predictor, to determine whether their ability to identify a better questioner predicted their generalizations to overall questioning ability, reliability, knowledgeability, and competency.

Justifications. Children's justifications were coded according to the justification coding scheme detailed earlier in this section. A one-way ANOVA was conducted to determine whether there were differences by age in children's justification scores, both relative to their category grouping (Mental State/Preference Attributions vs. Information Gain Attributions) and, within the Information Gain Attribution group whether the quality of their justifications increased with age. Exploratory descriptive statistics were collected about those justifications classified as Mental State/Preference attributions and the frequency with which children generated each type of justification subsumed under that category have been reported in the next chapter.

For those children who provided Information Gain Attribution justifications (n = 93), their justification scores were fit as the outcome variable, with children's Question Game scores as the predictor, to determine the degree to which their ability to identify a more competent questioner was related to their ability to provide a sound rationale for their choice related to relative information gain. To determine whether children's justifications were predictive of their generalizations of questioning ability to overall questioning ability, reliability, knowledgeability, and competency, individual logistic regressions were fit, with justification scores as the predictor and children’s scores in these generalization trials (1 = Constraint-Seeking Questioner; 0 = Hypothesis-Scanning questioner) as the outcome variable.

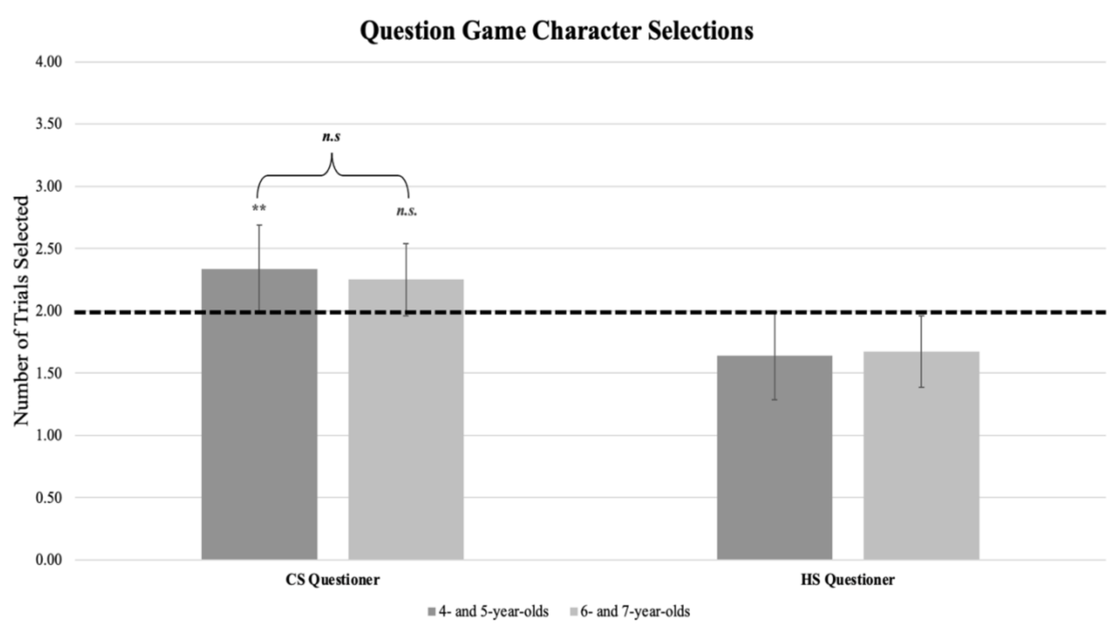
Chapter 4: Analysis and Results

Results were conducted using IMB SPSS Version 27. I first sought to confirm that there were no statistically significant differences in children's selections of the constraint-seeking questioner in the scripted Question Game (the experimental basis for their judgments in the following three generalization trials) based on child sex. Finding no main effects of sex, the variable was thereafter removed from subsequent analyses (*p*s > 0.05).

Question Game

Overall, children selected the constraint-seeking questioner (the more efficient questioner across all trials) more often than expected by chance (t (159) = 3.42, $p <$ 0.001). In addition, a paired-samples *t*-test revealed that children selected the Constraint-Seeking questioner significantly more often than the Hypothesis-Scanning questioner (t (159) = 3.79, $p <$ 0.001).

Figure 1 Age Comparison: Question Game (Scores Compared to Chance Performance)



Following, I sought to determine whether there was a main effect of age in children’s performance. A one-way ANOVA revealed that there were no age-related differences (F (3) = 0.3, p = 0.83, η^2 = .006). However, this overall performance was driven by the 4- and 5-year-olds (t (79) = 3.24, p <0.001), as 6- and 7- year-olds did not reliably select the more-efficient questioner more often than chance (t (79) = 1.83, p = 0.07) (*Figure 1,* Appendix II).

Seventy-eight percent of children selected the constraint-seeking questioner on at least two out of the four trials. Forty-four percent selected the constraint-seeking questioner for at least three of the four trials. Only 6% of children in the entire sample selected the hypothesis-scanning (meaning that they selected the less efficient questioner as the ‘better’ question-asker for all four trials. Five children struggled to select between the two question-askers for at least one of the four trials and provided justifications for their inability to choose such as, “*well, Duck could say yes or no to probably both of them*,” and *“it* [the correct answer] *depends on Duck’s personality and what he would like.”*

It was originally hypothesized that there would be no difference in Question Game performance between 4- and 5-year-olds and 6- and 7-year-olds, but that there would be significant differences in performance from 5 to 7 years of age. Participants were thus collapsed into two age cells (younger: 4- and 5-year-olds; older: 6- and 7-year-olds) to compare across age groupings. An independent samples t-test revealed no significant differences between these two collapsed age groupings (t (158) = 0.51, p = 0.6).

Independent samples *t*-tests were conducted within each of these collapsed age groups (4-year-olds and 5-year-olds; 6-year-olds and 7-year-olds) to establish that there were no mean differences within groups in their choices of the more efficient questioner. Results revealed that this was the case: there were no significant differences in performance between 4- and 5-year-olds (t (78) = 0.59, p = 0.56) and between 6- and 7-year-olds (t (78) = 0.55, p = 0.56).

It was originally hypothesized that from age 5 to 7, there would be significant differences in performance (such that collapsing across age could reveal this age progression). An independent samples *t*-test was therefore conducted between the age groups at the upper end of each collapsed cell (5-year-olds and 7-year-olds) to establish whether any inferences related to main effects of age can be isolated at the age-group level, rather than at the condensed age-cell level. Between 5-year-olds and 7-year-olds, there were no significant differences (t (78) = 0.427, p = 0.67).

Given the finding that the performance of children in the younger collapsed age cell was slightly better than that of children in the older cell, an additional exploratory analysis, not previously planned, was conducted to compare means in the Question Game between the youngest (4-year-olds) and oldest (7-year-olds) age groups included in the sample, which also revealed no statistically significant differences in performance (t (78) = 0.891, p = 0.375). This suggests that from between the ages of 4 and 7, there is no statistically meaningful change in children’s abilities to identify a more efficient questioner and, moreover, that this ability appears to emerge earlier in development than previously thought. However, these findings are marginal, and should therefore be regarded with caution. Additional work is necessary to clarify the degree to which children as young as 4 can implement this ability. Additional findings from children's justifications, detailed later in this section, also provide some basis for caution when interpreting the explicit awareness younger children have for questioning strategies in learning exchanges.

Overall Assessment

An overall questioner assessment was included following the four-trial Question Game to serve as an internal check regarding children's assessments of the two characters in the Question Game and to orient the child to the generalization tasks with the notion of the characters' questioning strategies in mind. The proportion of children who selected the constraint-seeking question-asker was greater than what can be expected by chance (60%; 0.50, binomial test, $p = 0.014$), suggesting that children were consistent in their view of the more efficient questioner as an overall better questioner.

Question Game Score Prediction. A binary logistic regression was conducted to assess whether children's scores in the Question Game (CS (constraint-seeking); max = 4) significantly predicted their choice of constraint-seeking question-asker as the overall better questioner. As expected, the higher children scored in the Question Game, the more likely it was that they selected the constraint-seeking questioner as the overall better questioner (χ^2 (1) = 37.15, $p < 0.001$).

Reliability Assessment

In the first generalization trial, children were asked to identify which of the two characters from the previous Question Game they would believe regarding a non-obvious function of a new toy. The only additional information provided was that the two characters had already asked the toy maker about the function of the toy. Thus, if children are inclined to generalize question-asking ability to broader reliability, we would expect children's selection to be informed by their assessment of that character's questioning strategies observed in the Question Game.

The proportion of participants that selected the constraint-seeking question-asker, however, was no different than what would be expected by chance (54%; 0.50, binomial test, $p = 0.304$), indicating that children do not generalize evaluations of questioning ability to broader reliability as it is operationalized in this study.

Question Game Score Prediction. A logistic regression was conducted to determine whether children's scores on the Question Game (CS) were predictive of their choice of constraint-seeking questioner in the reliability trial. The Question Game score did not significantly predict the choice of the constraint-seeking questioner (χ^2 (1) = 1.19, $p = 0.276$). This finding further confirms that children, in this context, are not generalizing their characterizations of the questioning strategies used by the individuals in the Question Game to conditions under which those individuals would provide them with novel information.

Knowledgeability Assessment

In the second generalization trial, children were prompted to select which of the two characters from the Question Game they believed would serve as a better teacher. Children selected the constraint-seeking questioner roughly at chance levels (49%; 0.50, binomial test, $p = 0.94$).

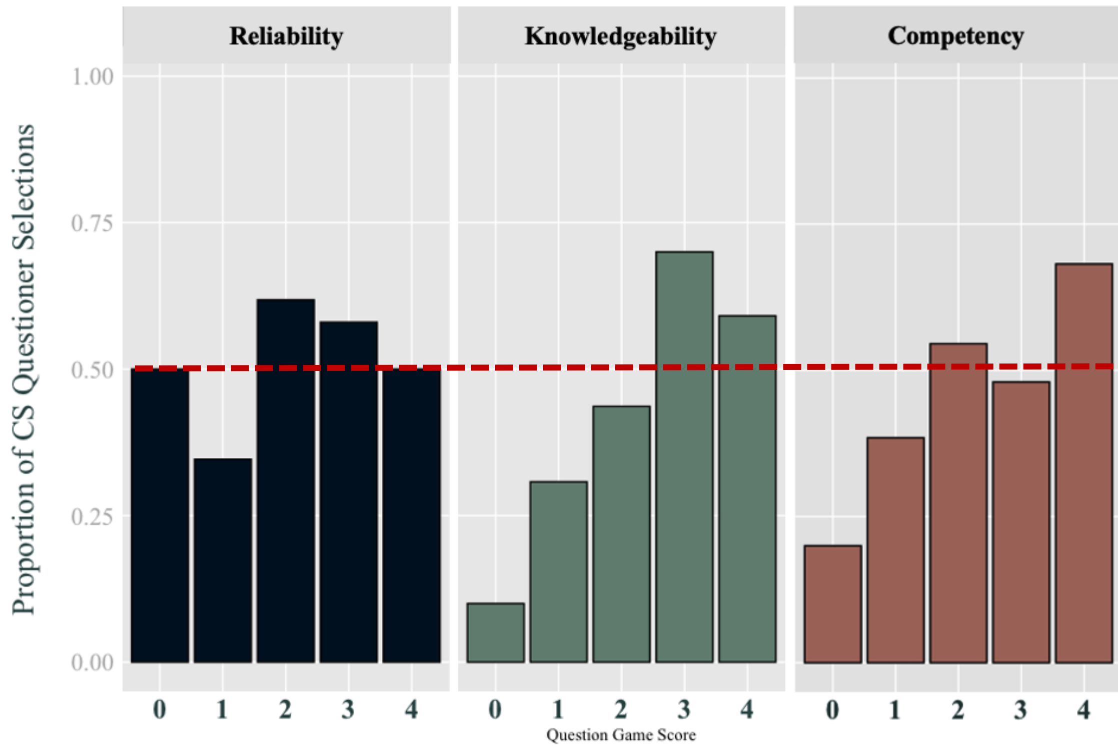
Question Game Score Prediction. A binary logistic regression revealed that children's scores in the Question Game (CS) were significantly predictive of their choice of constraint-seeking questioner as the better teacher (χ^2 (1) = 15.06, $p <$ 0.001). Thus, only when accounting for children's selections of the more efficient questioner, an understanding of what constitutes a more efficient question is predictive of identifying that individual as a better prospective teacher. In other words, young children view individuals who ask more informative or efficient questions as better candidates as teachers, in this experimental context, a proxy for their view of that individual as broadly more knowledgeable. This suggests that young children may view the ability to generate better questions as related to some underlying knowledgeability state, although further research is necessary to determine whether it is children's view that the ability to ask better questions makes someone more knowledgeable, or that being more knowledgeable enables someone to ask better questions.

Competency Assessment

In the final generalization trial, children were shown an image of a broken toy, and were prompted to select which of the two characters from the Question Game they would prefer to help them trouble-shoot the problem and fix the broken toy. The ability to navigate a novel problem space and generate solutions in this way was used as an experimental proxy for general competence. However, children were exactly divided between selecting the constraint-seeking question-asker and selecting the hypothesis-scanning question-asker, at rates equal to those which can be expected by chance (0.50, binomial test, p = 1).

Question Game Score Prediction. A binary logistic regression was conducted to determine whether children's scores in the Question Game were predictive of their choice of constraint-seeking questioner as more able to help them troubleshoot and solve a novel problem, in this case, to fix a broken toy. The Question Game score significantly predicted the choice of the constraint-seeking questioner troubleshooter

Figure 2 Children's Performance on the Generalization Trials, Relative to their Question Game Scores



Justifications

Separate analyses were conducted to clarify the role of children's justifications in their overall performance in the Question Game and in each of the subsequent generalization trials. Differences in the production of justifications referencing relative information gain are also detailed below.

Inter-coder reliability for all justifications for the Question Game were calculated using an SPSS macro called KALPHA, which uses Krippendorff's alpha (Hayes & Krippendorff, 2007) to establish an estimate of reliability for subjective judgments about any level of measurement, with any number of coders, and with or without missing data, for which an estimate greater than 0.7 is considered substantially reliable (Lombard, Snyder-Duch, & Bracken, 2002). In the present study, this estimate was generated at two levels: (1) to determine reliability in coding children's justifications among Mental State/Preference Attributions or Information Gain Attributions; and then, (2) Information Gain Attribution justifications only, to determine reliability among the four levels of assessment referring to the degree of nuance in children's justifications, such that 4 was the most strategic response, and 1 the least strategic.

Mental State/Preference Attributions

Approximately 41% of the sample provided Mental State/Preference Attributions (*n* = 67); the other 59% provided at least one Information Gain Attribution across the 8 total study trials (*n* = 93). Of those children who provided Mental State/Preference Attributions, approximately 11% provided justifications referencing (1) the puppets' preferences or an item in a Question Game vignette (e.g., *Because I think Duck wanted a milkshake*); (2) the child's own preferences (e.g., *Because I like lemons and strawberries)*; and (3) something other or unrelated (e.g., *I don't know/I forgot*) respectively. The remaining 8% provided justifications referring the puppets' characteristics (e.g., *Because humans evolved from Monkeys so he might be smarter*). Though these types of justifications were not strictly relevant for the present dissertation, the topic of mental state attributions will be returned to later in Chapter 5.

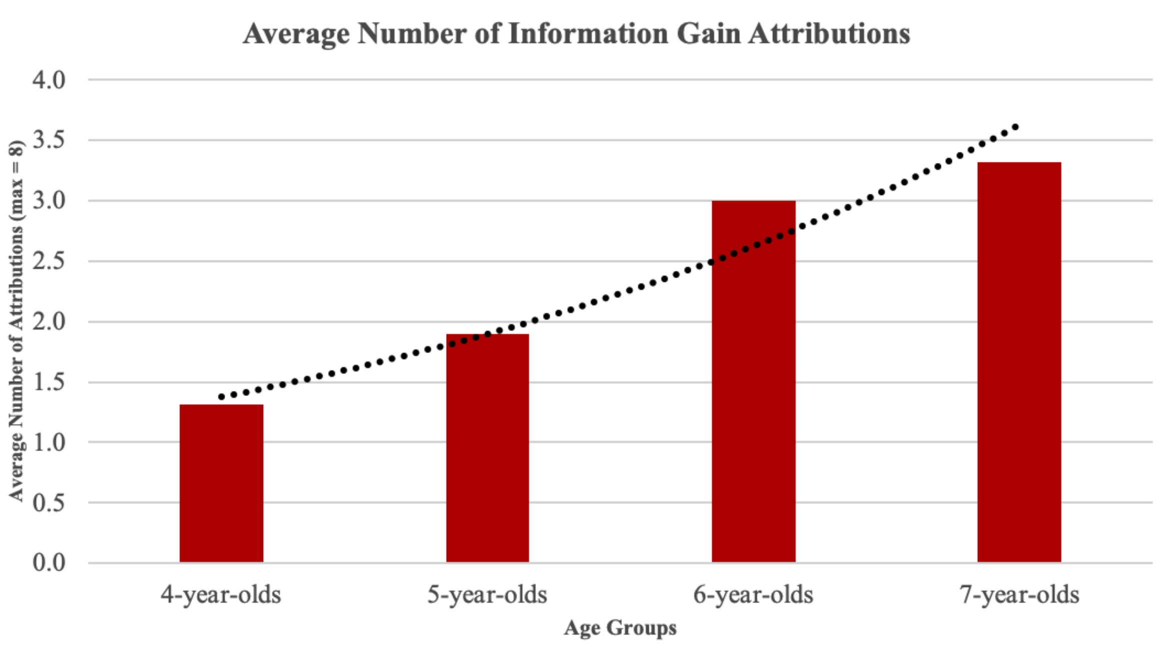
Question Game

Among the Information Gain Attribution group, sufficient inter-rater reliability was established (α = 0.74). Among the 74% of cases for which there was agreement between both coders at this first level, the reliability of the coding scheme for only Information Gain Attributions was assessed; Krippendorff's alpha reliability estimate obtained also indicated good reliability in the present study (α = 0.78).

An initial bivariate correlation revealed that children's age group (4-year-olds, 5-year-olds, 6-year-olds, and 7-year-olds) was significantly correlated with their rate of Information Gain Attributions (r (158) = 0.405, $p < 0.001$). That is, with age, children more frequently generated justifications classified as relating to relative information gain. For only those children who provided Information Gain Attributions; Mental State/Preference Attributions removed), an additional bivariate correlation between age group and overall score was conducted. Findings yielded a significant relation between these two variables (r (91) = 0.252, $p < 0.05$). That is, with age, among those children who provided justifications related to relative information gain, their justifications also became more nuanced and more often referenced the strategy underlying the characters' questions (e.g., narrowing down the problem space, asking targeted questions related to the number of items yielded by each question).

A one-way ANOVA by individual age group (4-year-olds, 5-year-olds, 6-year-olds, and 7-year-olds) was also conducted to determine whether there were significant differences by age in the production Information Gain Attributions. Findings suggest that, with age, children generate more of these relative information gain type justifications for their choices (F (3) = 7.86, $p < 0.001$, $\eta^2 = 0.21$). *Table 1* in Appendix II depicts descriptive information regarding the average rate of Information Gain Attributions by age.

Figure 3 Average Number of Information Gain Attribution justifications by Age Group



An ordinal logistic regression model was fit, with children's justification scores (i.e., the number of trials for which children provided an Information Gain Attribution; max =8) as the outcome and children's Question Game scores (max = 4) and children's ages (in months; continuous) as predictors, to determine the degree to which children's abilities to explicitly detail an understanding of relative information gain was predicted by their sense of what constitutes a better question. An interaction term between justification scores and age was also entered into the model to establish the degree to which the interplay between children's ages and their selection of a better questioner independently predicts their ability to provide a cogent rationale for that choice.

Findings revealed a not-quite-significant main effect of children's Question Game scores on their ability to provide a justification that referenced relative information gain or questioning strategy (χ^2 (4) = 8.76, $p < 0.06$). There was, however, a significant main effect of children's age and their ability to provide relevant explanations (χ^2 (1) = 17.8, $p < 0.001$). This finding is consistent with other analyses previously reported; with age, children show an improved ability to explicitly justify their choices in terms of questioning strategy, rather than by referencing features of the vignette, preferences of the characters, or personal preferences. There was also a significant interaction between children's ages and their Question Game scores (χ^2 (4) = 10.53, $p < 0.05$), further underscoring the finding that with age, children improve both in their ability to identify a more informative or efficient questioning strategy, and to provide explicit justifications that highlight the features of that questioning strategy that make it a more fruitful choice.

An exploratory ordinal logistic regression was also fit to establish the degree to which children's Question Game scores and age in months (and an interaction between the two) predicted children's Information Gain Attribution scores (e.g., the nuance with which children were able to represent questioning strategy; max = 4; see *Table II* in Appendix II for a detailed justification coding scheme). All three terms significantly predicted the nuance with which children could explain their selections, of those children who provided a justification that referenced relative information gain or questioning strategy (Question Game score (CS): χ^2 (4) = 21.47, $p < 0.001$; Age: χ^2 (1) = 14.18, $p < 0.001$; CS*Months: χ^2 (4) = 23.24, $p < 0.001$). This further supports the notion that, with age, children become more adept both at identifying a better question, and at providing evidence of an explicit understanding of what makes that question better.

It should be noted that only one-third of the participants who provided Information Gain Attributions did so once out of the eight total trials; one-quarter of the participants provided a relevant justification on at least two of the trials. Only fifteen participants provided relevant justifications for more than half of the trials, and only one participant did so for all eight trials. This suggests that while children's selections of a more efficient questioner, at least in the Question Game, were significantly above what can be expected by chance, in general they struggled to provide cogent rationales for their choices (although this ability did significantly improve with age). While additional research is necessary to clarify the underlying factors contributing to children's reasoning here, it is plausible that young children are demonstrating an awareness of strategy before they can explicitly verbalize their understanding of how strategy contributes to greater information gain and subsequent learning.

Generalization Trials

Logistic regressions were fit for each of the three generalization trials to determine whether children's justification scores (of those who provided at least one Information Gain Attribution) were predictive of their choice of constraint-seeking question asker regarding each of those attributes.

Reliability. The results of a binary logistic regression with choice of constraint-seeking questioner as the binary outcome and the number of trials (max = 8) for which children generated an Information Gain Attribution (referencing relative information gain) was not significant (χ^2 (1) = 0.065, p = 0.78). This suggests that the number of trials for which children provided a justification pertaining to relative information gain was not at all predictive of their choice of constraint-seeking questioner in the reliability trial.

Knowledgeability. The results of a binary logistic regression with choice of constraint-seeking questioner as the better teacher as a binary outcome and the number of trials for which children provided a justification relating to relative information gain was likewise nonsignificant (χ^2 (1) = 0.017, p = 0.89).

Competency. The results of a binary logistic regression with choice of constraint-seeking questioner as the better choice to troubleshoot and solve a novel problem as the binary outcome and the number of trials for which children provided a justification relating to relative information gain was likewise nonsignificant (χ^2 (1) = 0.074, p = 0.78).

Chapter 5: Discussion and Future Directions

There are several key findings to note in the present dissertation: (1) The results supported the hypothesis, and extended previous research, that children as young as 4 can identify a more efficient question-asker; (2) Children generalized questioning strategies to other relevant skills in the case of identifying a better prospective teacher and as a competent trouble-shooter in the context of solving a new problem but, contrary to the original hypothesis, not when characterizing an individual as broadly more reliable; (3) Children's justifications were significantly predicted by their abilities to identify a better questioner, when accounting for their age, corresponding to improvements in their justifications between the ages of 4 and 7. That is, as hypothesized, with age, children who more often referenced relative information gain were likewise more skilled in identifying a strategic question-asker.

First, the present study extends findings from previous research (e.g., Ruggeri et al., 2017) that children even younger than 5 (in this dissertation, as young as 4) can identify a more efficient questioning strategy, even when both question options were equally relevant to the items in the problem space. In including equally relevant questions, the design of the present study provided a stricter test than that of previous work regarding children's abilities to identify a more efficient or informative question. Ruggeri and colleagues (2017), for example, found that children as young as 5 could flexibly adapt their preference for constraint-seeking versus hypothesis-scanning question-asker when the proportion of different items in the problem set varied (such that one type of response was more likely the correct one). In more recent work (De Simone & Ruggeri, 2020), researchers have found that when an experimenter identifies the more efficient questioner *for* a child, they can generalize that character's questioning abilities to other relevant capacities, such as being good at school, being clever, and being good at puzzles, but not irrelevant abilities or preferences, such as liking ice cream, kicking a ball the farthest, or seeing the farthest. In the present study, children could not only identify a more efficient questioning strategy, but they could also generalize the use of that strategy to the individual who produced it, such that children independently identified the more efficient questioner, without the aid of the experimenter (as demonstrated in the overall questioner assessment).

Second, although children could identify more informative questions and confirm their characterization of a 'better' question-asker, they did not systematically generalize that ability to all other targeted capacities, such as reliability. However, children's scores in the Question Game did significantly predict their choice of constraint-seeking question-asker in the knowledgeability task, suggesting that children may view a more competent questioner as more apt to serve as a better teacher, as well as in the competency task, suggesting that children may view better questioners as broadly more competent, thereby seeking them out to help troubleshoot and solve an unrelated problem.

There are several possible explanations for these findings. Children may genuinely see question-asking and the purveyance of knowledge or developing a strategy for solving a complex problem as inherently related skillsets. In other words, children may think that better teacher is someone who both can gather and share information equally effectively, and a more competent person may ask better questions by virtue of their ability to consider multiple angles of a complex problem. In addition, of the three generalization trials, the knowledgeability prompt was the most straightforward and may have required the least mental computational effort on the part of the child, as was required to monitor what an individual would learn from questions that they asked someone else (as in the reliability trial). It is possible that the contextual demands of the reliability trial was simply too great for children of these ages (e.g., Papafragou et al., 2018; Verbuk & Shultz, 2010). In the case of the competency trial, even though children were asked to think more about the relation between question-asking and solving an unrelated problem, they showed a systematic tendency to view the more efficient questioner as also more competent. It is possible that, for children, generating a strategic question and developing a strategy more generally are not so distinct.

Finally, children's abilities to justify their choices improved significantly between the ages of 4 and 7, both in terms of the frequency with which they refer to relative information gain, and the nuance with which they can capture considerations of questioning strategy. Moreover, when accounting for age, children's justifications significantly predicted their scores in the Question Game. This finding suggests that, with age, children's understanding of strategy in inquiry-based learning shapes their characterizations of what constitutes a good question. Children also appear to use the strategies the puppets used in the Question Game to make broader character judgments about those puppets, such that they may be making dual assessments about the quality of the individual strategy and more global characterizations of the question-asker. In interpreting this finding, it is helpful to reflect on the proposed model of children's question-asking.

Returning to the Revised Model

A primary motivating factor for the present dissertation was to provide initial evidence supporting a revised model of children's learning through inquiry which incorporates elements from the Ronfard et al. (2018) framework with the literature on children's selective trust (e.g., Mills, 2013). There is significant organic overlap between how children search for information and the decisions they must make about what information to trust. In receiving information from others, children must evaluate both the specific instance of that communicated information and make more global generalizations about the person who provided it, to determine whether that person would be a good candidate as a future source of information.

In the revised model, this process is best captured in the fourth phase: the interplay between response evaluation (e.g., children's active evaluation of the quality of the response they received, and whether the information satisfies their original question) and testimony evaluation (e.g., children's reflection on the relation between the quality of the response and the candidacy of the informant as trustworthy, or their potential as a future source of information). In the present dissertation, while children did not seem to extend their assessments of the quality of the questions to their views of the characters as reliable or unreliable, they did generalize individual questioning strategies to other related capacities, such as knowledgeability and competence. This suggests that, early in development, children are forming connections between other people's questions and the sorts of domains children might go to those people to master (e.g., learning new information and solving new problems).

Extension of Previous Work and Novel Contributions

The present dissertation contributes to existing literature in several notable ways: First, it extends similar work conducted by Ruggeri and colleagues (2017) which found that young children can identify a better question when presented with contrasted options. In the present work, the contrast was made less distinct, such that both questions were equally relevant (e.g., both pertained to items in the same problem, or hypothesis, space). Children were also given no information regarding the likelihood of one solution over the other, meaning that they could evaluate only the questioning strategy, and not the odds of the prospective response being correct.

Second, this is the first study of children's understanding of questioning strategies that calls for them to provide explicit justifications for their reasoning. While there is evidence that children's justifications improved significantly with age and, when accounting for that development, were predictive of their abilities to identify better questions, few children overall produced justifications that referenced relative information gain, and only one child did so for all eight trials in the study.

This could be for a couple of reasons: First, despite previous work demonstrating that children as young as four can generate some explanations for their reasoning, children of this age may still simply be too young to clearly verbalize their reasoning about inquiry-based strategies in coherent, relevant ways given the obscure nature of the tasks and the fact that children never discovered which question produced a correct answer. Similar previous research (Butler, Schmidt, Tavassolie, &

Gibbs, 2018) has shown that young children, when asked to justify their judgments of characters who provided full, partial, or no evidence to support a claim, struggled to generate explanations that referenced verification, but their ability to do so improved with age and corresponded to the strength of their differentiation between verified and unverified claims.

The way in which the prompt to generate an explanation was worded (e.g., "*what makes you think [child's choice] asked the better question?"*) may have also been confusing to children, or they may have interpreted the prompt in terms of elements unrelated to the questioning strategy the character used (e.g., other attributes assumed about those characters, the likelihood of a correct response given other elements in the vignette, or features assumed about the target character). However, while very few children provided justifications referring to relative information gain, this work establishes a foundation for additional research to explore the conditions under which children can reason according to this crucial aspect questioning and help children develop more efficient and strategic approaches to generating their own questions earlier in development. There is also some recent research relating questioning strategies to the broader construct of children's curiosity. If adult conversational partners can help scaffold children's reasoning about the elements of a question that are more informative or what kinds of responses they will likely produce, children can become better equipped with the knowledge and skills to ask better questions. This opens the door for them to approach their learning in more dynamic and self-directed ways.

One additional point of consideration is that children's Mental State/Preference Attributions, though not strictly relevant for the present empirical questions, may represent other informative types of reasoning children are using to support their choices. It is certainly probable that children's abilities to consider others' mental states relates to their sense of those individual's abilities to generate better questions, or to provide them with information as expected in the context of reliability, knowledgeability, and competency. In the process of producing their own questions, children must consider the things that they already know in order to ask a question that will adequately constrain the problem space and lead them and their conversational partner to the information that they seek. Children could likewise apply this reasoning as a preemptive measure when deciding who to ask for information, considering that that person is likely to know. In fact, Ronfard and colleagues (2018) point out that domain specific knowledge is necessary both for the construction of an effective question and in carrying out an effective questioning exchange by posing that question to a person who is most likely able to provide a sufficient response. The extent to which mental state attributions, as a domain general process, also informs this ability is a question for future research.

Finally, the present dissertation also extends previous work by De Simone and Ruggeri (2020) which found that by age seven, children show adult-like generalizations from characters' questioning strategies to other related abilities, such as being good at school, being clever, being good at puzzles, but not unrelated abilities or preferences, such as liking ice cream, or being able to kick a ball very far. In that study, researchers administered a familiarization task in which children were shown two alien characters posing questions about a visually depicted problem space. One character asked an informative question and the other asked an uninformative question (e.g., one that unhelpfully targeted *all* items in the problem space, or targeted something entirely unrelated, not in the problem space). Following, researchers told children which character was good at asking questions and which one was bad at asking questions (e.g., "*Bobo/Kila always asks good/bad questions, because they are very informative/not informative at all. She is a good/bad question asker!*") (De Simone & Ruggeri, 2020, pg. 9). In the present study, researchers never identified who the better question-asker was, instead prompting children to generate their own assessments, and even to generalize that assessment to determine which individual was an *overall* better question-asker. Findings revealed that children across the full sample could do both successfully, even when both questions were equally relevant—arguably a more challenging distinction to make, particularly for younger children included in this dissertation.

Limitations and Future Directions

The present dissertation is not without its limitations: first and perhaps most considerably is the issue of cognitive demand for a relatively young sample. Children in the present study were unable to generalize questioning strategy to considerations of broader reliability even when by seven in previous research (e.g., De Simone & Ruggeri, 2020) they showed an ability to generalize questioning strategies to a whole host of other abilities, and to gauge the degree to which those abilities were related to questioning (such that those of a cognitive domain were more strongly related than those pertaining to preference or physical attributes). This suggests that there may have been some challenges for children inherent to the questions themselves—perhaps the mental calculus required by children, for example, in the reliability generalization trial, in which they were required to connect the characters' previous questioning strategies (in the Question Game) to the question they likely posed to the toy maker, and to infer what information that likely yielded, based on hypothetical questions to which they had no access, was too great to manage. Moreover, though no children referred to the toy maker in their justifications, it is also possible that they may also have assumed that the toy maker simply gave one of the characters inaccurate information, lending to a less reliable answer.

Future research may aim to replicate the previous paradigm with an older sample of children (e.g., 9- and 10-year-olds), who may perform better yet in identifying a more efficient questioning strategy and have by that age adequately developed the cognitive capacities (e.g., cognitive control, theory of mind) which would support their ability to make these inferences. Mills and Sands (2020) likewise view executive function skills as foundational for the ability to initiate or to cease a question-asking exchange: they inform the capacity to decide what to ask, how to articulate that question, and the nature of the problem the question seeks to clarify or solve. Previous research has also demonstrated a connection between this ability and children's selectivity: in a study with preschoolers, those children with greater inhibitory skills were also more adept at navigating the conditions which would maximize the likelihood of their obtaining accurate information (e.g., waiting for a more knowledgeable person rather than accepting information from a less knowledgeable, but more available person) (Jaswal et al., 2014).

Second, an additional limitation may have had to do with the number of questions children were asked in each of the generalization trials. While children had four trials in the Question Game by which to establish which character is more apt to pose efficient questions (a trial number supported by previous research, e.g., Ruggeri & Feufel, 2015), there was only one question per domain in the latter generalization trials. In this way, children only had one opportunity per domain to infer that there was a connection to be made, and in what way that connection could bear out in their choices. This decision was made strategically, given the young ages included in the present study, to combat issues with children's abilities to attend to study stimuli for a lengthy period, a consideration made even more salient with the transition to virtual data collection. However, it is possible that with additional generalization trials, children may have a greater opportunity to recall their assessments from the first phase of the study and use them as a basis for their reasoning when generalizing to these other related domains.

Future research may aim to include additional, similar vignettes, that mimic the current paradigm to establish whether, with additional exposures, children may more successfully generalize questioning ability to new contexts. The present study also sought to expand upon the work by De Simone and Ruggeri (2020) by presenting children with opportunities to generalize questioning ability to other domains with more real-world contexts, such as those children might encounter when deciding who to trust in the case of obtaining new information about something of interest to them (e.g., a toy function). Given that this cognitive burden may have been too great, future research may also benefit from simplifying this kind of task such that they are a more incremental extension of this previous work, and children's reasoning about reliability is more scaffolded than in the present paradigm.

Third, particularly given the finding that children's justifications became more nuanced and referenced relative information gain more frequently with age, future research may benefit from exploring conditions under which children's attention to relative information can be enhanced through interventions that specifically highlight relative information gain (e.g., *"If we asked X question, what could we learn?" "Given that Bunny asked X question and Monkey asked Y question, who do you think could help us with Z?"*). Previous research has used 20-Question Game and decision tree paradigms (e.g., Meder et al., 2019) to generate conditions that guide children through inquiry-based learning. Similar methods could be used here to explore both the factors that might improve children's overall Question Game scores and their ability to generalize their assessments of the characters from the first phase to the domains targeted in the second phase.

Finally, there is also reason to believe that children may be more discerning in these generalization trials when there is more epistemic cost to selecting an unreliable or incompetent character. Rowles and Mills (2017), for example, found that when children were prompted to seek information from either a more socially engaged individual or a more competent one, they tended to seek out the socially engaged person, such that their primary focus was social in nature (e.g., interacting with someone who is more likely to socially reciprocate or is more pleasant to interact with). Where the process by which children seek support from a potential informant is motivated more by an epistemic drive (e.g., learning the right thing, getting the right information for some instrumental purpose), they may show greater sensitivity to the role that the characters' previous questioning strategies play in their candidacy in these subsequent exchanges.

Broader Implications

The following section will detail implications of the present dissertation in three primary domains: (1) the literature on children's question-asking, and the development of tools to support the development of more efficient strategies of inquiry; (2) children's trust in testimony, such that an additional cue to which children might attend—others' questioning abilities—might be included in future considerations of the conditions under which children can adopt a critical stance; and (3) children's science and information literacy, with a focus on the foundational skills children need to be successful in the 21st century, as developments in science and access to the wealth of human knowledge continue to grow at an exponential rate.

Children's Question-Asking

This work has both immediate and longer-term implications for children's learning. Eschach, Dor-Ziderman, and Yefroimsky (2014) offer an analysis of the role of children's active exploration strategies, such as question-asking, in their early classroom experiences. This work underscores a broader conversation about the connection between research and practice regarding researchers' and teachers' conflicting attitudes about the function that questions play in a science classroom. Most notably, while teacher attitudes generally reflect a positive appraisal of children's questioning, because it reflects a higher-order engagement with the course material and serves as a metric for what students understand and value, they still disrupt the flow of pedagogy in the classroom (e.g., Rop, 2002). In this regard, the negative appraisals of students' questioning outweighed the positive ones, for teachers. Previous research also reports that of the questions that students did ask, they were few in quantity and not particularly high-level (e.g., Brill & Yarden, 2003; Dillon, 1988). Eshach and colleagues (2014) found some incongruence between teachers' beliefs about the value of question asking and their practice of encouraging student inquiry during their courses, pointing out that "some of their classroom practices appear to be misguided and perhaps even detrimental to the fostering of question-asking practices among their students" (Eshach et al., 2014, p.79).

Other people's attitudes, particularly those people who serve an authoritative role in children's learning, have significant implications for children's engagement and subsequent learning in their inquiry-based interactions. When children feel as though their questions are not welcome, the individuals with whom they are engaging are not apt to provide them with the desired information, or they have reason to reject the information those people do provide, children's capacity to learn about that specific idea or phenomenon under investigation is impeded. Direct instruction may encourage young children to rely more heavily on what others tell them, taking for granted the problem of unreliable or incomplete information (e.g., Haber, Sobel, & Weisberg, 2019). Inquiry-based instruction, which capitalizes on questions children might already be wondering about, works to foster their engagement with course material and speculate about what might constitute a reliable answer for their questions. Moreover, inquiry-based instruction appears to support some of the cognitive prerequisites for higher-order metacognitive strategies by allowing them to engage in a “collaborative student discourse,” and participate in their own learning in more reflective and self-directed ways. Metacognitive awareness is associated with learning and achievement in school (Kuhn & Pearsall, 1998), reading and math performance (Schneider, 2008), and the ability to transfer knowledge acquired in one context to another (e.g., Pintrich, 2002).

This work also has the potential to contribute to the literature on children’s curiosity, which draws heavily on Loewenstein’s (1994) Information-Gap Theory (e.g., Jirout & Klahr, 2012). Under this view, people are motivated to engage in information search because of a drive to gain information or to make sense of their environment in some way; the drive to close an information gap produces an unpleasant arousal state in the brain which the acquisition of the sought-after information can satisfy. In this way, the Information-Gap Theory is a model of deprivation, that only the acquisition of resources (e.g., new knowledge or the resolution of some ambiguous data) can alleviate. This theory maps relatively clearly onto the existing framework of children’s question-asking: they are motivated to seek information about which they have limited knowledge, and they selectively explore to disambiguate causal phenomena—findings that speak to the role of children’s inherent curiosity in initiating an inquiry-based exchange.

Jirout and Klahr (2012) note that Endsley and colleagues (1979), by examining parent-child interactions, provided direct evidence that children’s active exploration of novel objects was significantly related to their question-asking. There is ongoing debate in this literature about what constitutes a sufficient operational definition of *curiosity*, including an orientation towards spontaneous exploration, exploratory preference, novelty preference, preference for complexity or the unknown, and preference for uncertainty or ambiguity. Research on children's question-asking has the potential to address some of this conflict by focusing on the elements that motivate children's information searches, specifically by prompting children to give explicit accounts of their own curiosity or to justify their reasoning about a particular problem that they want to learn about.

Children's Trust in Testimony

Despite the epistemological challenge that learners face in relaying on information from other people, young children show early abilities to be skeptical of the information that they accept as true—and the cues that they attend to when exercising that skepticism undergo development early in childhood. There are, however, some conditions under which children succumb to false or unreliable information. The framework of children's trust in testimony generated by Landrum, Eaves, and Shafto (2015) predicts that the information other people offer to a learner shape whether the learner will ask that individual for information in the future or endorse the claims that those people make. In this way, the level of skepticism that people can use to protect themselves against unreliable information—potentially even mis- or disinformation—corresponds directly with the course of their subsequent inquiry. This critical lens of information has more significant implications for learning today than in past generations.

Whereas up until the 1980's and 1990's, the answer to a question could be found in an encyclopedia, a textbook, or a manual—all resources that undergo significant conceptual and editorial pruning before being made public—learners in the 21st century digital age have access to all human knowledge through the internet—a venue that does not always guarantee reliable information. The consequences of this grab-bag model of learning from digital sources can be in the collapse of the public trust in mainstream media sources in 2016; Lazer and colleagues (2018), for example, note a drop to 14% of polled Republicans expressing explicit trust in mass media as a news source. Moreover, it is estimated that the average American encountered between one and three "*fake news*" stories online during the month leading up to the 2016 Presidential election. Consistent with previous work on confirmation bias, "individuals tend not to question the credibility of information unless it violates their preconceptions or they are incentivized to do so" (Lazer et al., 2018, p. 1095). This speaks to some of the literature described earlier in Chapter 2 regarding young children's tendency to explore more comprehensively and strategically when what they witness is in direct conflict with their expectations or prior knowledge. As with children's active exploration, the ability to identify belief structures that should be challenged requires some previous knowledge about the object or information under examination. When a person is searching for information about which they have no basic understanding, or that they might have some bias about, they run the risk of skewing the scope of the information they make available to themselves. For children who are developing foundational cognitive capacities necessary for information search, honing their abilities to be appropriately skeptical, and are still acquiring the skills to use digital resources, this risk is even more pronounced.

Science and Information Literacy

Children's abilities to engage in inquiry-based learning develop early and show significant improvement over the course of preschool and elementary school. It is also in this developmental window that children typically encounter formal scientific principles for the first time. Formulating a question about some unknown problem, establishing reasonable hypotheses about what can be known, cultivating a methodological approach to address those hypotheses, making sense of the data obtained during subsequent exploration, and determining whether this data has sufficiently addressed the initial question describes precisely what scientists across a broad range of disciplines do in their areas of expertise. In a domain-general sense, this is the set of practices that every individual must use to learn new things about the world, whether they be of a physical, social, or even political nature.

To consider the broader implications of this work for information literacy, we turn to an example from real events: in the months leading up to the 2016 US election, an online conspiracy theory, subsequently dubbed Pizzagate, circulated the internet. It suggested that there was a child sex ring housed in the basement of a DC pizzeria called Comet Ping Pong. The claims were debunked—the pizzeria does not even have a basement—but the conspiracy theory nevertheless circulated widely and resulted in a local man arming himself with weapons and attempting to storm the restaurant. Without the critical skills necessary to scrutinize the plausibility of that story, pausing to consider who generated it, who benefits from it, and what parameters should be set in evaluating how likely it is (like whether the restaurant has a basement at all), people are hindered in their ability to decide the truth of that story.

Critical learning strategies, such as lateral reading, have been developed to help young students gain these skills in the context of their classroom learning, and have applicability to situations such as the one described above. Wineburg and McGrew (2017) define lateral reading as a strategy that helps readers to build both digital and information literacy. It involves drawing broadly from multiple sources to determine the truthfulness of a claim, as opposed to relying on a single or only a couple of resources. In a study that included Stanford undergraduates, professional historians, and professional fact-checkers, the fact-checkers were found to use lateral reading far more often compared to the other subjects and were subsequently less likely to fall victim to flagrantly-used red flags, like official-looking logos and domain names (Wineburg & McGrew, 2017).

For researchers, understanding how these skills manifest and the factors that work to foster or suppress their development demands a more comprehensive model that can point to specific opportunities for propitious intervention. In the 21st century, children's inquiry-based learning may deviate from what is typically considered in the social learning literature and may also look like a particularly well-phrased Google search or prompt for Siri or Alexa. In the era of mass-access to information, not only must children adequately integrate answers to their questions into their knowledge structures and decide whether they want to seek more information, but they must also decide whether this is information that can be repeated as fact to other learners. When even adults struggle to assess the reliability of online or digital resources (false information is shared online far more frequently and quickly than true information, e.g., Vosoughi, Roy, Aral, 2018) the connection between children's inquiry-based learning and their ability to judge a reliable source has paramount importance in the digital learning landscape (e.g., Butler, 2020).

On a broader level, understanding how to phrase a question has implications for *where* the young learner is likely to find information. The ability to consider who is sharing information, to check across multiple sources as necessary, and to reflect on what can be learned from a given source has consequences for what children will learn and where they choose to seek information again in the future. The ability for the public to sense whether information is reliable and valid, and whether it is worth sharing with someone else in the community, has the potential to determine the degree of proliferation of mis- and disinformation in the public sphere.

The findings from the present dissertation also have implications for more general considerations about epistemology: for it to be said that a person has knowledge of something, we should expect that they have a foundational understanding of the conditions which make that thing true and that they provide evidence of that understanding (e.g., Williamson, 2000). The concept of evidence is a critical component of epistemology and to the philosophy of science (e.g., Roush, 2006). In this context, we would say that identification of a more efficient questioner and a justification that references questioning strategy have an evidential relationship, which describes the connection between two constructs or entities by virtue of which one counts as evidence for the other (e.g., Achinstein, 2001). By seeking out opportunities to strengthen the relation between children's abilities to identify, and eventually to generate, better questions and their knowledge of what makes that question more fruitful for their learning, we can help children develop the broader skills necessary for being successful 21st century learners. At the core of this consideration is a more robust understanding of the twin elements to which children must be attuned to gain new knowledge through their social exchanges: the nature of the information, and the reliability of the informer.

Conclusion

The present dissertation examined two main questions: (1) can young children when two questions are equally relevant distinguish between more and less efficient or informative strategies? And (2) can children generalize their assessments of an individual's questioning abilities to other, related domains, such as reliability, knowledgeability, and competence?

This study found evidence that children as young as four can identify a better questioning strategy, even when both questions were equally relevant to the problem space, and they can spontaneously generalize individual questions to a global assessment of that individual as an overall better question-asker. While children did not generalize questioning ability to the domain of reliability, they did view the character who posed better questions as a better potential teacher and a better choice to help them trouble-shoot and solve a new, unrelated problem.

This study was also the first, to my knowledge, to prompt children for explicit justifications for their assessments of the characters' questioning strategies. Although their justifications were not predictive of their choice of more efficient questioner as more reliable, knowledgeable, or competent, they did significantly improve both in type and in degree of nuance between the ages of four and seven. Additionally, children who were more successful in identifying a better questioner were consequently better able to articulate their reasoning in accordance with considerations of relative information gain. Future research is necessary to clarify some of the null findings in the present dissertation, and to further examine the conditions that best support children's effective questioning strategies for their own use in subsequent learning exchanges.

Appendices and Supplemental Materials

Appendix I: Figures

Figure 1 Question Types (Constraint-Seeking, left vs. Hypothesis-Scanning, right)

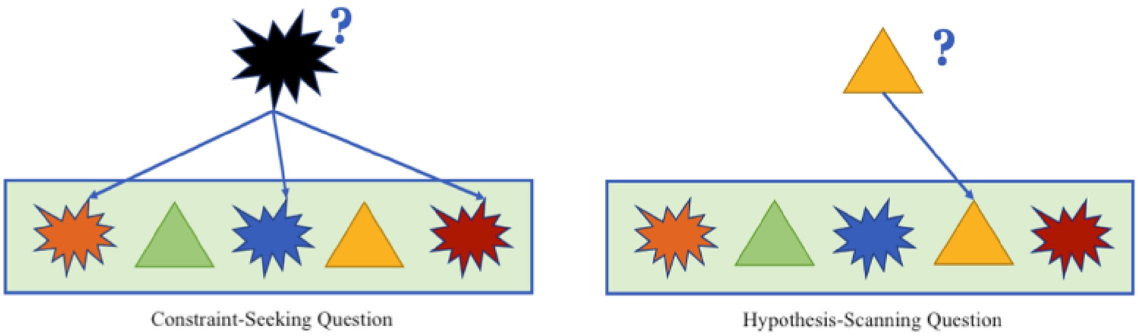


Figure 2 Ronfard and colleagues (2018) model of children's question-asking

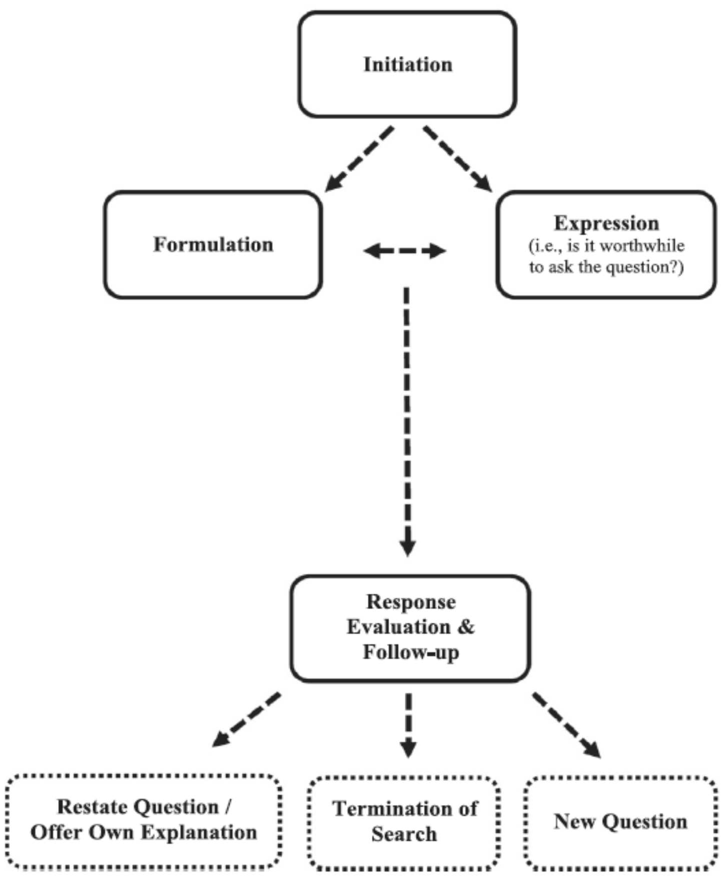


Figure 3 Revised model of children's question-asking

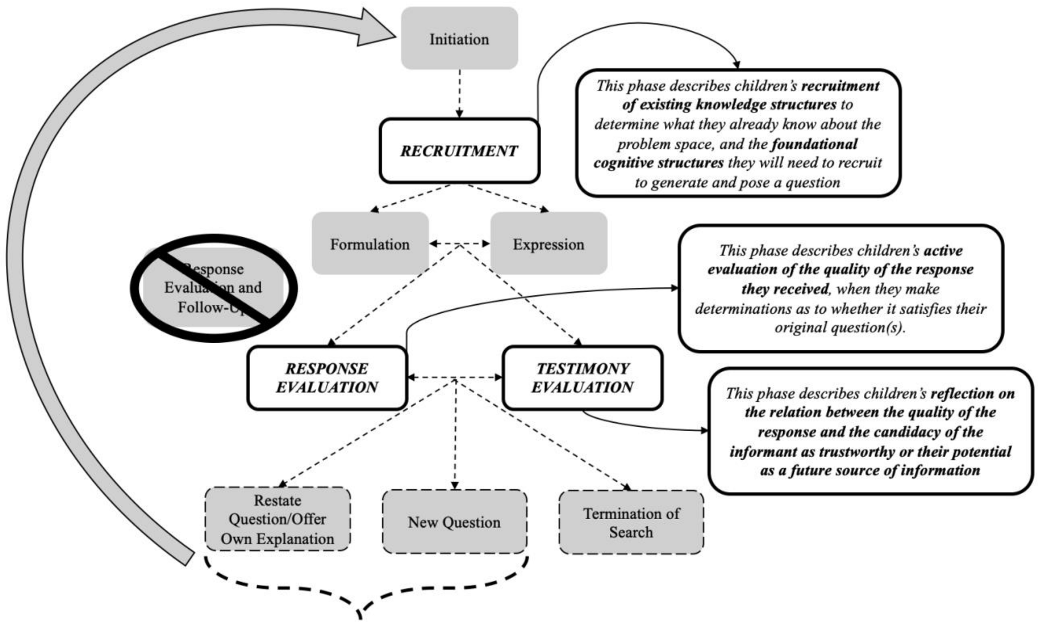
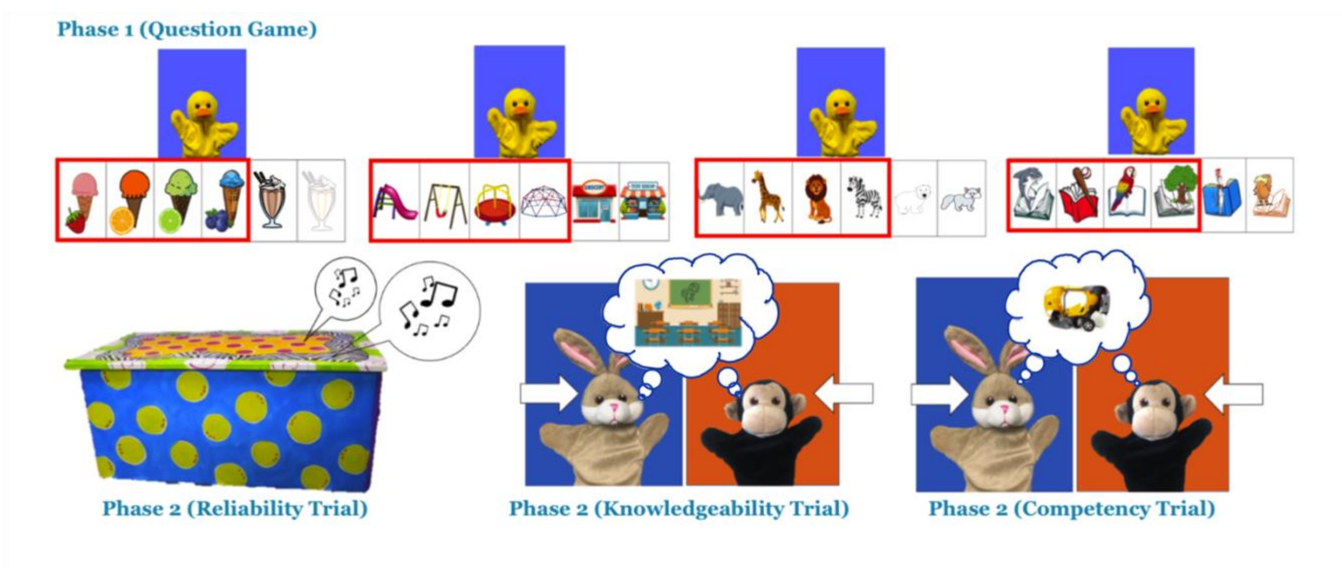


Figure 4 Full study schematic (Top: Question Game; Bottom: Generalization Trials, Excluding Overall Questioner Assessment)



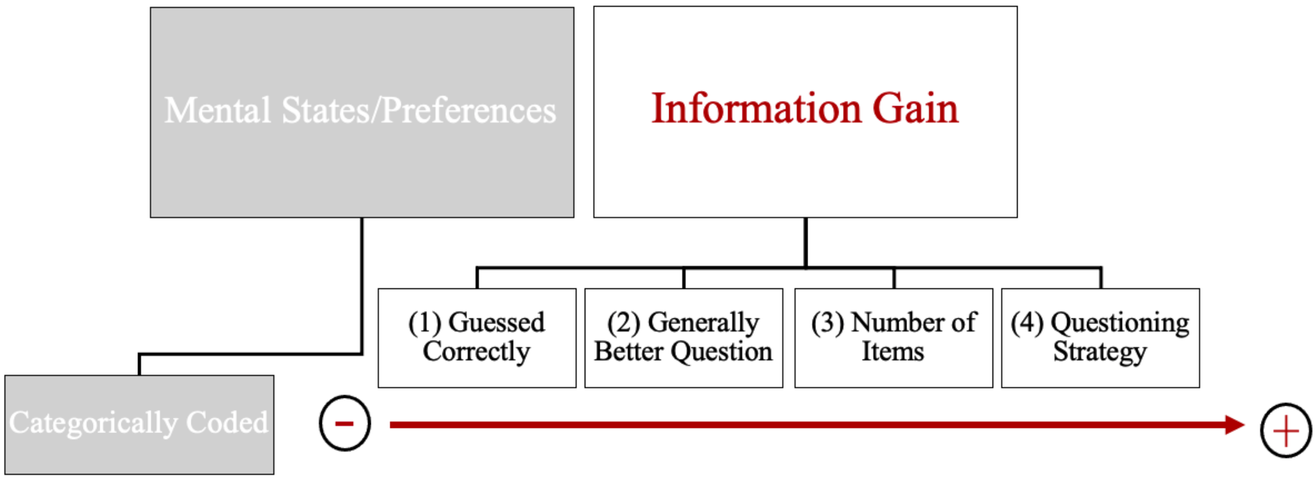
Appendix II: Tables and Graphs

Table 1 Descriptives: Group by Justifications by Age

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	16	1.31	.602	.151	.99	1.63	1	3
2	20	1.90	1.165	.261	1.35	2.45	1	5
3	29	3.00	1.753	.325	2.33	3.67	1	7
4	28	3.32	1.847	.349	2.61	4.04	1	8
Total	93	2.57	1.697	.176	2.22	2.92	1	8

1 = 4-year-olds
2 = 5-year-olds
3 = 6-year-olds
4 = 7-year-olds

Table 2 Justification Coding Scheme



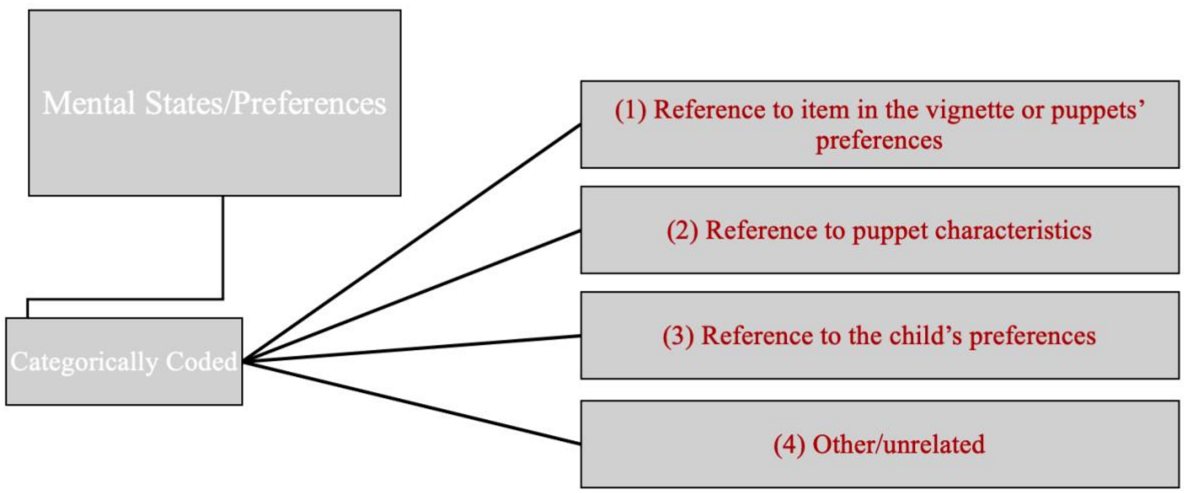


Figure 1 Age Comparison: Question Game (Scores Compared to Chance Performance)

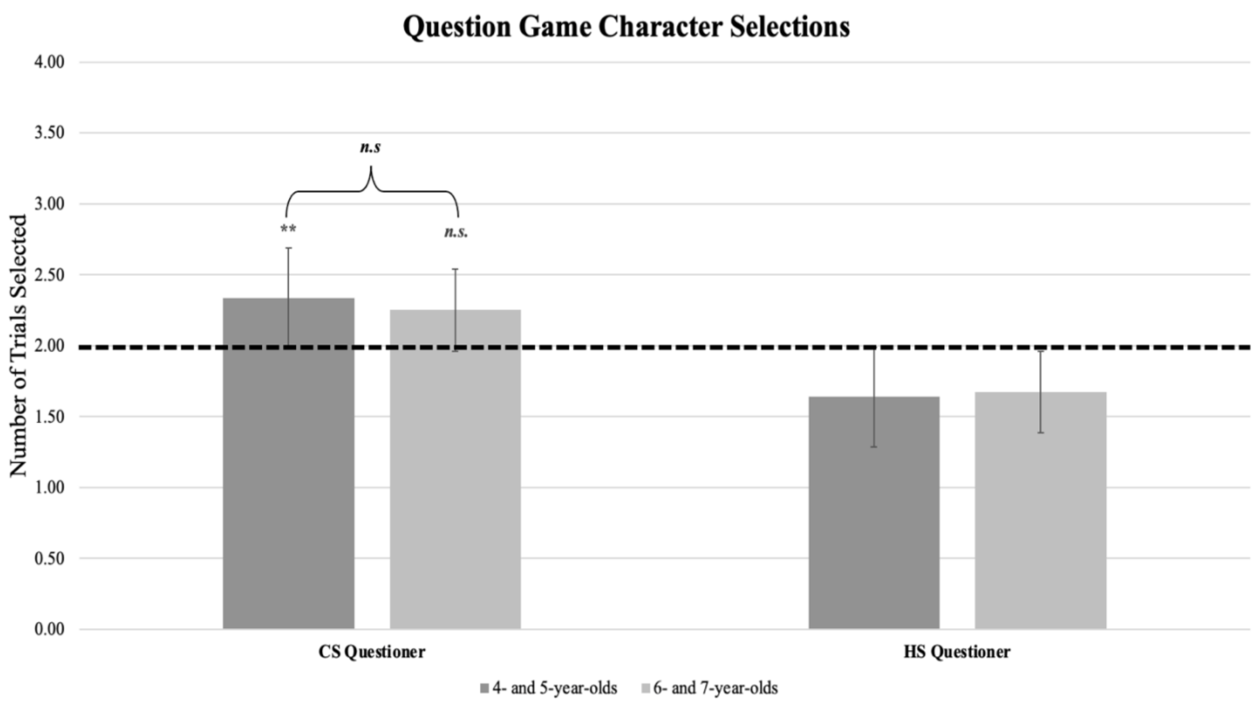


Figure 2 Generalization Trial Performance as Related to Question Game Scores

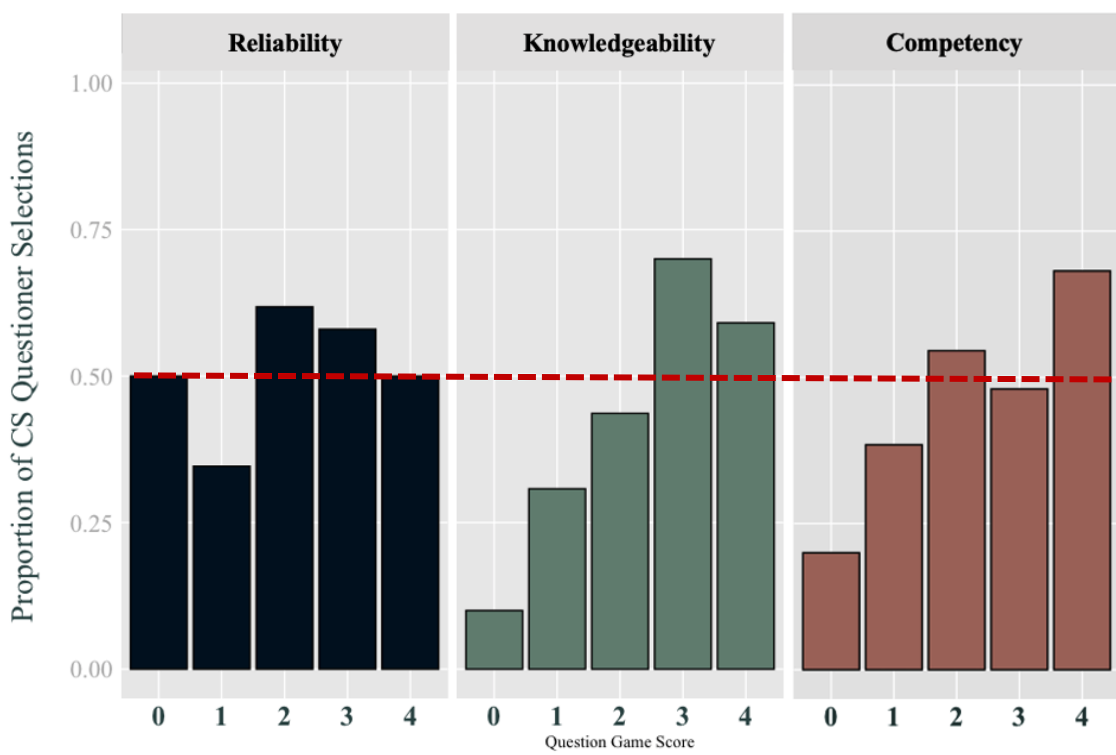
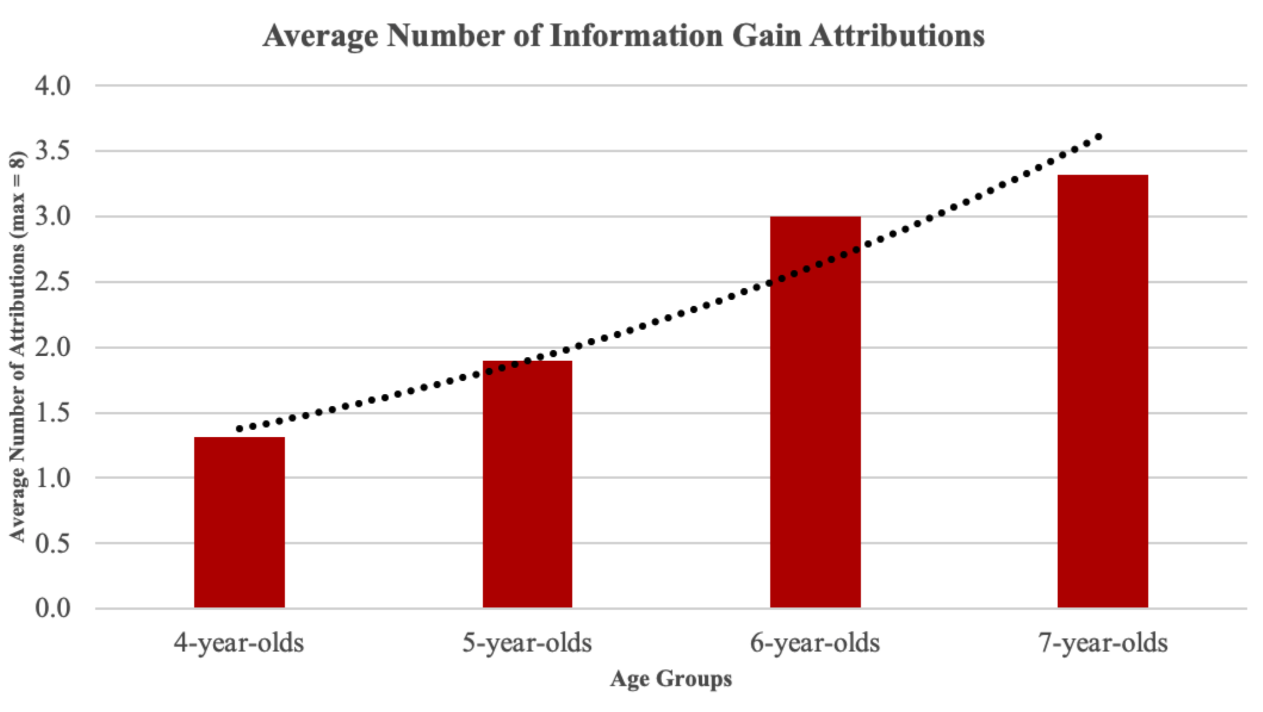


Figure 3 Average Number of Information Gain Attribution Justifications by Age



Supplemental Materials

IRB Approval Letter, Consent Form, Recruitment Email, Demographic Form

This appendix includes the University of Maryland Institutional Review Board approval letter, consent form, recruitment email, and parent demographic form used for the present dissertation.

UNIVERSITY OF MARYLAND

INSTITUTIONAL REVIEW BOARD

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College Park, MD 20742-5125
TEL 301.405.4212
FAX 301.314.1475
irb@umd.edu
www.umresearch.umd.edu/IRB

DATE:	May 15, 2020
TO:	Lucas Butler, PhD
FROM:	University of Maryland College Park (UMCP) IRB
PROJECT TITLE:	[1556238-3] Children's Understanding of Question Quality and Related Problem Solving Skills
REFERENCE #:	
SUBMISSION TYPE:	Amendment/Modification
ACTION:	APPROVED
APPROVAL DATE:	May 15, 2020
EXPIRATION DATE:	February 19, 2021
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # 7. Subpart D applies, 45CFR46.404. Waiver of Written Consent: 45CFR46.117(c)(1).

Thank you for your submission of Amendment/Modification materials for this project. The University of Maryland College Park (UMCP) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

Prior to submission to the IRB Office, this project received scientific review from the departmental IRB Liaison.

This submission has received Expedited Review based on the applicable federal regulations.

This project has been determined to be a MINIMAL RISK project. Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of February 19, 2021.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Unless a consent waiver or alteration has been approved, Federal regulations require that each participant receives a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others (UPIRSOs) and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

Please note that all research records must be retained for a minimum of seven years after the completion of the project.

If you have any questions, please contact the IRB Office at 301-405-4212 or irb@umd.edu. Please include your project title and reference number in all correspondence with this committee.

Cognition & Development Lab
at the University of Maryland, College Park

CONSENT

About the Study

- This research is conducted by University of Maryland researcher Dr. Lucas Payne Butler. This study seeks to find out:

  What kids think about other people's questions

- This study **does not** evaluate abilities of individual children. We are looking to understand how kids learn <u>in general</u>.

Participation

- Your child will complete an **online activity,** including **watching some short videos** or **looking at pictures,** and then **answering some questions.**
- Sessions generally last no longer than **20 minutes**. However, your child can proceed at their own pace. ***Parents must remain present for the duration of the study***
- You and your child's participation are **<u>entirely voluntary</u>**. You may choose to stop the study session at any point without penalty.

CONSENT

Video Recording & Use of Data

- Your child's responses will be video-recorded via your computer's **webcam** and **microphone**.
- **No identifying information** will be linked to your child's recording and all video data will be sent securely to our lab to be stored on a **password-protected** server.
- At the end of the session, you will **select a privacy level.**
  Unless otherwise specified:
    - Only lab members will access your data
    - Video clips will not be shared
    - Personal information will not be published

Risks & Benefits

- There are **no known risks** to this kind of study.
- Children usually very much enjoy these studies, but there are no direct benefits.
- These studies will (hopefully!) advance our understanding of **how children think and learn about science**.

WHO ASKS BETTER QUESTIONS?

Children ages 5, 6, and 7

What would my child do?

Your child would meet with a researcher over Zoom.

Your child would be introduced to two puppet characters who play a Question Game and would be asked to pick which character asks better questions!

The whole study takes about 20 minutes

Participants will be entered to win one of FIVE $50 Amazon gift cards

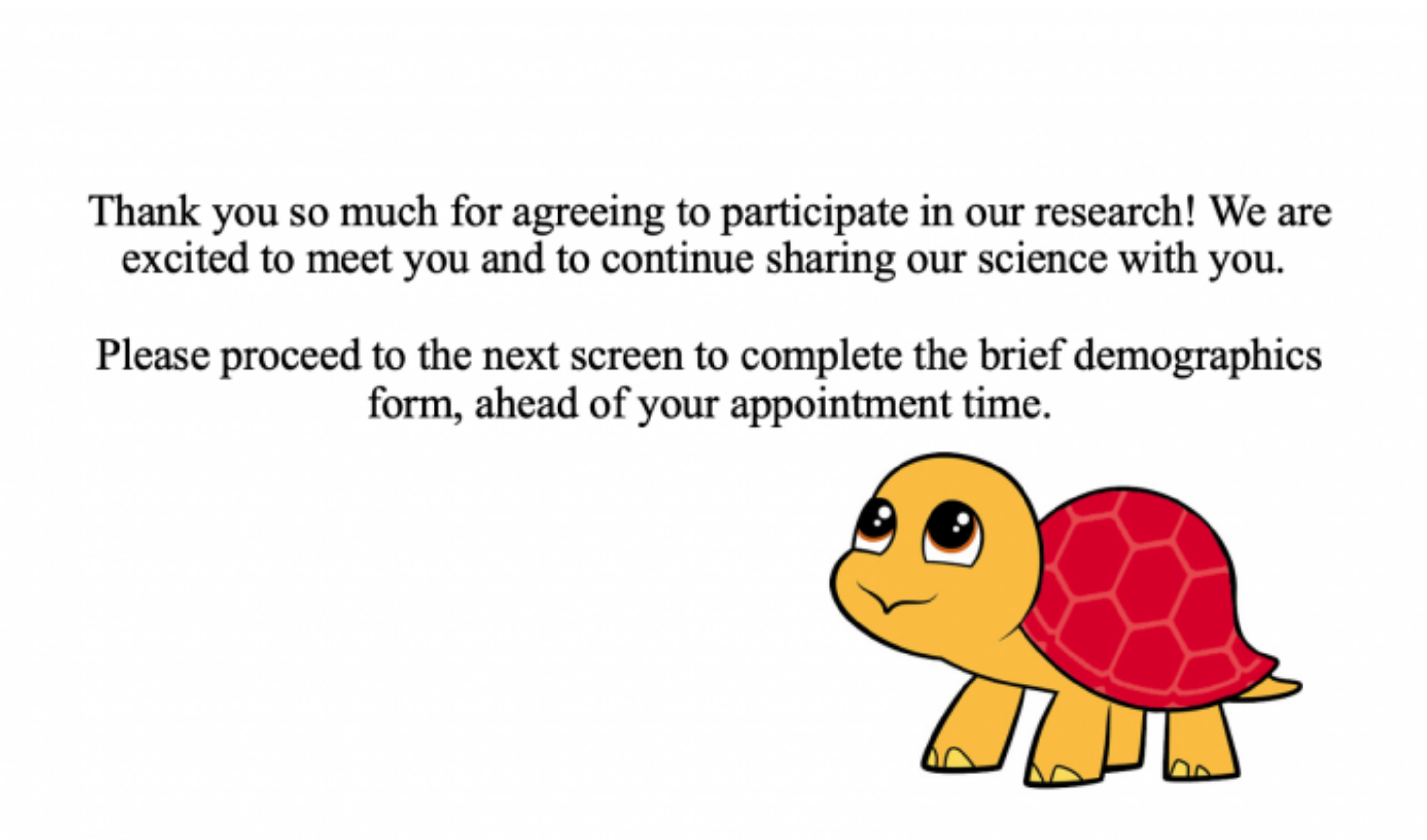
What is required?

Just a **computer** with a **webcam**!

The researcher will send you more details and the **link to the Zoom room** before your appointment!

Cognition & Development Lab
at University of Maryland, College Park

INTRO SCREEN



CONSENT PROCEDURE

Cognition & Development Lab

CONSENT

About the Study

- This research is conducted by University of Maryland researcher Dr. Lucas Payne Butler. This study seeks to find out:

What kids think about other people's questions

- This study **does not** evaluate abilities of individual children. We are looking to understand how kids learn in general.

Participation

- Your child will complete an **online activity,** including **watching some short videos** or **looking at pictures,** and then **answering some questions.**
- Sessions generally last no longer than **20 minutes**. However, your child can proceed at their own pace. ***Parents must remain present for the duration of the study***
- You and your child's participation are **entirely voluntary**. You may choose to stop the study session at any point without penalty.

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CONSENT

Video Recording & Use of Data

- Your child's responses will be video-recorded via your computer's **webcam** and **microphone**.
- No identifying information will be linked to your child's recording and all video data will be sent securely to our lab to be stored on a **password-protected** server.
- At the end of the session, you will **select a privacy level.**
  Unless otherwise specified:
  - Only lab members will access your data
  - Video clips will not be shared
  - Personal information will not be published

Risks & Benefits

- There are **no known risks** to this kind of study.
- Children usually very much enjoy these studies, but there are no direct benefits.
- These studies will (hopefully!) advance our understanding of **how children think and learn about science**.

I consent to allow my child to participate in this online study.

Yes, I consent	No, I do not consent.
○	○

DID NOT CONSENT

Got it! We're sorry to miss you, and hope that we'll be able to reach out to you about future studies.
If you have any questions or concerns in the meantime, please do not hesitate to reach out to us at umdcogdevlab@gmail.com.

Have a great day!

Demographics Form

Demographics Questionnaire

The questions below ask about yourself and your family. Any information provided will be kept confidential.

We greatly appreciate your time in providing this background information.

Child's FIRST Name:

Child's DATE OF BIRTH:

Month

Day

Year

Child's GENDER:

- Male
- Female
- Please specify:

Your child's ethnicity:

- ◯ African American or Black
- ◯ Caucasian or White (Not of Hispanic Origin)
- ◯ Hispanic, Latinx, or Spanish origin
- ◯ South or East Asian
- ◯ Native Hawaiian or Other Pacific Islander
- ◯ Middle Eastern or North African
- ◯ American Indian or Alaska Native
- ◯ [ ] Biracial/Mixed Race (please list all groups that apply)
- ◯ [ ] Not listed above (please indicate group that applies below)

Language(s) spoken by your child:

(Check all that apply)

- ☐ English
- ☐ Spanish
- ☐ Chinese
- ☐ [ ] Other

Percentage (%) of the time spoken:

[ ]

Percentage (%) of the time spoken:

[ ]

Percentage (%) of the time spoken:

Percentage (%) of the time spoken:

The **zip code** in which your child *lives:*

The **zip code** in which your child *attends school:*

Has your child been diagnosed with any disability or impairment?

- Yes
- No
- I prefer not to answer

If yes, which of the following have been diagnosed:

(Check all that apply)

- ◯ A sensory impairment (vision or hearing)
- ◯ A mobility impairment
- ◯ A learning disability (e.g., ADHD, dyslexia)
- ◯ A disability or impairment not listed above

Please indicate the highest level of education completed by each of the child's parents:

	Parent 1	Parent 2
Some high school	☐	☐
High School Diploma/GED	☐	☐
Some College Coursework/Vocational Training	☐	☐
2-year College Degree (Associates)	☐	☐
4-year College Degree (BA/BS)	☐	☐
Postgraduate or Professional degree (MA, PhD, MD, JD)	☐	☐

Please indicate your annual household income:

Feedback Form

We would appreciate your feedback regarding our contact methods. Thank you!

Please let us know how you found us:

- ○ **University of Maryland Infant & Child Studies Consortium** *(i.e., you previous agreed to be added to a database of families to be contacted by a group of developmental research labs at UMD including the Cognition and Development Lab)*
- ○ **Cognition and Development Lab Family List** *(i.e., you previously signed up through our lab website to be added to a list of families that we contact for study opportunities)*
- ○ **Children Helping Science- Online Platform**
- ○ **Facebook Ad**
- ○ **Personal Contact/Word-of-Mouth**
- ○ [ ] **Other** *(please indicate below)*

Privacy Settings

Please note that your video footage will be avaialble ONLY to authorized researchers affiliated with the Cognition and Development Lab and will be kapt on a secure, password-protected server.

If you would be willing to grant persmission for your video footage to be used for educational/academic purposes (for example, shared at an academic conference), please click the option AND sign in the box below.

Note that, even if you do grant permission for your footage to be used in this context, no identifying information about you or your child will be made available to anyone who is not an authorized researcher affiliated with the Cognition and Development Lab.

○ Yes, by clicking this option and signing the box below, I am granting permission for my video footage to be used for educational/academic purposes. I understand that, even so, no identifying information about my family will be made available to the public.

Please enter your signature:

SIGN HERE

×

clear

FEARLESS IDEAS

References

Achinstein, P. (2001). *The Book of Evidence*. Oxford: Oxford University Press.

Amineh, R.J., & Asl, H.D. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature, and Languages, 1,* 9-16. Retrieved from http://www.blue-ap.org/j/List/4/iss/volume%201%20(2015)/issue%2001/2.pdf.

Akhtar, N., & Gernsbacher, M.A. (2014). Joint attention and vocabulary development: A critical look. Lang Linguist Compass, 1, 195-207. https://doi.org/10.1111/j.1749-818X.2007.00014.x.

Bascandziev, I., & Harris, P.L. (2016). The beautiful and the accurate: Are children's selective trust decisions biased? *Journal of Experimental Child Psychology, 152*, 92-105. https://doi.org/10.1016/j.jecp.2016.06.017

Baum, L.A., Danovitch, J.H., & Keil, F.C. (2008). Children's sensitivity to circular explanations. *Journal of Experimental Child Psychology, 100,* 146-155. https://doi.org/10.1016/j.jecp.2007.10.007.

Begus, K., Gliga, T., & Southgate, V. (2016). Infants' preferences for native speakers are associated with an expectation of information. *Proceedings of the National Academy of Science, 113,* 12397-12402. https://doi.org/10.1073/pnas.1603261113

Bergstrom, B., Moehlmann, B., & Boyer, P. (2006). Extending the testimony problem: Evaluating the truth scope, and source of cultural information. *Child Development, 77,* 531-538. https://doi.org/10.1111/j.1467-8624.2006.00888.x

Birch, S.A.J., & Bloom, P. (2003). Children are cursed: An asymmetric bias in mental-state attribution. *Psychological Science, 14,* 283-286. https://doi.org/10.1111/1467-9280.03436

Birch, S.A.J., Brosseau-Liard, P.E., Haddock, T., & Ghrear, S.E. (2017). A ‘curse of knowledge’ in the absence of knowledge? People misattribute fluency when judging how common knowledge is among their peers. *Cognition, 166,* 447-458. https://doi.org/10.1016/j.cognition.2017.04.015

Birch, S.A.J., Vauthier, S.A., & Bloom, P. (2007). Three- and four-year-olds spontaneously use others’ past performance to guide their learning. *Cognition, 107,* 1018-1034. https://doi.org/10.1016/j.cognition.2007.12.008

Bloom, P. (1996). Intention, history, and artifact concepts. *Cognition, 60,* 1-29. https://doi.org/10.1016/0010-0277(95)00699-0

Bonawitz, E.B., van Schijndel, T.J.P., Friel, D., & Schulz, L. (2011a). Children balance theories and evidence in exploration, explanation, and learning. *Cognitive Psychology, 64,* 215-234. https://doi.org/10.1016/j.cogpsych.2011.12.002

Bonawitz, E., Shafto, P., Gweon, H., Goodman, N.D., Spelke, E., & Schulz, L. (2011b). The double-edged sword of pedagogy: Instruction limits spontaneous exploration and discovery. *Cognition, 120,* 322-330. https://doi.org/10.1016/j.cognition.2010.10.001

Bridgers, S., Gweon, H., Bretzke, M., & Ruggeri, A. (2018). How you learned matters: The process by which others learn informs young children’s decisions about whom to ask for help. In Kalish, C., Rau, M., Zhu, J., & Rogers, T.

(Eds.), *Proceedings of the 40th Annual Conference of the Cognitive Science Society* (pp. 1402-1407). Austin, TX: Cognitive Science Society.

Brill, G., & Yarden, A. (2003). Learning biology through research paper: A stimulus for question-asking by high school students. *Cell Biology Education, 2,* 274-276. https://doi.org/10.1187/cbe.02-12-0062

Brosseau-Liard, P.E., & Birch, S.A.J. (2011). Epistemic states and traits: Preschoolers appreciate the differential informativeness of situation-specific and person-specific cues to knowledge. *Child Development, 82,* 1788-1796. https://doi.org/10.1111/j.1467-8624.2011.01662.x

Brosseau-Liard, P., Cassels, T., & Birch, S. (2014). You seem certain but you were wrong before: Developmental change in preschoolers' relative trust in accurate versus confident speakers. PLoS One, 9, 1-6. https://doi.org/10.1371/journal.pone.0108308

Buchsbaum, D., Bridgers, S., Weisberg, D.S., & Gopnik, A. (2012). The power of possibility: Causal learning, counterfactual reasoning, and pretend play. *Philos Trans R Soc London B: Biol Sci, 367,* 2202-2212. https://doi.org/10.1098/rstb.2012.0122

Busch, J.T.A., & Legare, C.H. (2019). Using data to solve problems: Children reason flexibly in response to different kinds of evidence. *Journal of Experimental Child Psychology*, *183*, 172-188. https://doi.org/10.1016/j.jecp.2019.01.007

Bustamante, A.S., Schlesinger, M., Begolli, K.N., Golinkoff, R.M., Shahidi, N., Zonji, S., Riesen, C., Evans, N., & Hirsh-Pasek, K. (2020). More than just a game: Transforming social interaction and STEM play with Parkopolis, Developmental Psychology (56). 1041-1056. http://dx.doi.org/10.1037/dev0000923

Butler, L.P. (2020). The Empirical Child? A Framework for Investigating the Development of Scientific Habits of Mind. *Child Development Perspectives, 14,* 1-7. https://doi.org/10.1111/cdep.12354

Butler, L.P., Gibbs, H.M., & Tavassolie, N.S. (2020). Children's developing understanding that even reliable sources need to verify their claims. *Cognitive Development, 54,* 1-12. https://doi.org/10.1016/j.cogdev.2020.100871

Butler, L.P., & Markman, E.M. (2012). Preschoolers use intentional and pedagogical cues to guide inductive inferences and exploration. *Child Development, 83,* 1416-1428. https://doi.org/10.1111/j.1467-8624.2012.01775.x

Butler, L.P., Schmidt. M.F.H., Tavassolie, N.S., & Gibbs, H.M. (2018). Children's evaluation of verified and unverified claims. *Journal of Experimental Child Psychology, 176,* 73-83. https://doi.org/10.1016/j.jecp.2018.07.007

Caffarella, R.S., & Merriam, S.B. (1999). Perspectives on adult learning: Framing our research. In *40th Annual Adult Education Research Conference Proceedings.* Northern Illinois University.

Callanan, M.A., & Oakes, L.M. (1992). Preschoolers' questions and parents' explanations: Causal thinking in everyday activity. *Cognitive Development, 7,* 213-333. https://psycnet.apa.org/doi/10.1016/0885-2014(92)90012-G

Carey, S. (1985). *Conceptual Change in Childhood.* Cambridge, MA: MIT Press.

Castelain, T., Bernard, S., & Mercier, H. (2018). Evidence that two-year-old children are sensitive to information presented in arguments. *Infancy, 23,* 124-135. https://doi.org/10.1111/infa.12202

Chin, J., Payne, B.R., Fu, W-T., Morrow, D.G., Stine-Morrow, E.A.L. (2015). Information foraging across the life span: Search and switch in unknown patches. *Topics in Cognitive Science*, *7,* 428-450. https://doi.org/10.1111/tops.12147

Choi, K., Lapidow, E., Austin, J., Shafto, P., & Bonawitz, E. (2016). Preschoolers are more likely to direct questions to adults than to other children (or selves) during spontaneous conversational acts. Retrieved July 29, 2019. https://osf.io/tj42h.

Chouinard, M.M., Harris, P.L., & Maratsos, M.P. (2007). *Children's Questions: A Mechanism for Cognitive Development.* Monographs of the Society for Research in Child Development, Vol. 72, No. 1.

Chow, V., Poulin-Dubois, D., & Lewis, J. (2008). To see or not to see: Infants prefer to follow the gaze of a reliable looker. *Developmental Science, 11,* 761-770. https://doi.org/10.1111/j.1467-7687.2008.00726.x

Chu, J., & Schulz, L. (2018). Cognitive pragmatism: Children flexibly choose between facts and conjectures. Retrieved from http://junyichu.mit.edu/sites/default/files/documents/2018-05-14%20CogSci%20Final.pdf.

Cimpian, A., Keil, F. Preface for the special issue on The Process of Explanation. *Psychonomic Bulletin & Review 24,* 1361–1363 (2017). https://doi.org/10.3758/s13423-017-1378-5

Cimpian, A., & Petro, G. (2014). Building theory-based concepts: Four-year-olds preferentially seek explanations for features of kinds. *Cognition, 131,* 300-310. https://doi.org/10.1016/j.cognition.2014.01.008

Clegg, J.M., & Legare, C.H. (2016). Instrumental and conventional interpretations of behavior are associated with distinct outcomes in early childhood. *Child Development 87,* 527-542. https://doi.org/10.1111/cdev.12472

Cook, C., Goodman, N.D., & Schulz, L.E. (2011). Where science starts: Spontaneous experiments in preschoolers' exploratory play. *Cognition, 120,* 341-349. https://doi.org/10.1016/j.cognition.2011.03.003

Corriveau, K.H., & Kurkul, K.E. (2014). "Why does rain fall?" Children prefer to learn from an informant who uses noncircular explanations. *Child Development, 85,* 1827-1835. https://doi.org/10.1111/cdev.12240

Coughlin, C., Hembacher, E., Lyons, K.E., Ghetti, S. (2014). Introspection on uncertainty and judicious help-seeking during the preschool years. *Developmental Science,18,* 957-971. https://doi.org/10.1111/desc.12271

Courage, M.L. (1989). Children's inquiry strategies in referential communication and in the game of Twenty Questions. Child Development, 60, 877-886. https://www.jstor.org/stable/1131029

Crowley, K., Callanan, M.A., Tenenbaum, H. R., Allen, E. (2001). Parents explain more often to boys than to girls during shared scientific thinking.

Psychological Science, 12, 258-261. https://doi.org/10.1111%2F1467-9280.00347

Danovitch, J.H., & Keil, F.C. (2004). Should you as a fisherman or a biologist? Developmental shifts in ways of clustering knowledge. *Child Development, 75,* 918-931. https://doi.org/10.1111/j.1467-8624.2004.00714.x

De Simone, C., & Ruggeri, A. (2020, April 8). What is a good question asker better at? From unsystematic generalization to adult-like selectivity across childhood. https://doi.org/10.31219/osf.io/6jupw

Dennett, D. C. (1989). *The Intentional Stance*. MIT press.

Doebel, S., Rowell, S.F., & Koenig, M.A. (2016). Young children detect and avoid logically inconsistent sources: The important of communicative context and executive function. *Child Development, 87,* 1956-1970. https://doi.org/10.1111/cdev.12563

Einav, S., & Robinson, E.J. (2010). Children's sensitivity to error magnitude when evaluating informants. *Cognitive Development, 25,* 218-232. https://doi.org/10.1016/j.cogdev.2010.04.002

Endsley, R.C., Hutcherson, A., Garner, A.P., & Martin, M.J. (1979). Interrelationships among selected maternal behaviors, authoritarianism, and preschool children's verbal and nonverbal curiosity. *Child Development, 50,* 331-339. https://www.jstor.org/stable/1129407.

Eshbach, H., Dor-Ziderman, Y., & Yefroimsky, Y. (2014). Question asking in the science classroom: Teacher attitudes and practices. *Journal of Science Education Technology, 23,* 67-81. https://doi.org/10.1007/s10956-013-9451-y

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*, 1149-1160. https://doi.org/10.3758/BRM.41.4.1149

Fedra, E., & Schmidt, M. F. H. (2019). Older (but not younger) preschoolers reject incorrect knowledge claims. *British Journal of Developmental Psychology, 37,* 130-145. https://doi.org/10.1111/bjdp.12264

Fedyk, M. Kushnir, T., & Xu, F. (2019). Intuitive epistemology: Children's theory of evidence. In D. Wilkenfeld & R. Samuels (Eds.), *Advances in experimental philosophy of science.* New York, NY: Bloomsbury Academic Publishing.

Fischoff, B. (1975). Hindsight is not equal to foresight: The effects of outcome knowledge on judgment under uncertainty. *Journal of Experimental Psychology: Human Perception and Performance, 1,* 288. https://psycnet.apa.org/doi/10.1037/0096-1523.1.3.288

Fodor, J.A. (1983). *The modularity of mind.* Cambridge, MA: MIT Press.

Frazier, B.N., Gelman, S.A., & Wellman H.M. (2009). Preschoolers' search for explanatory information within adult-child conversation. *Child Development, 80,* 1592-1611. https://doi.org/10.1111/j.1467-8624.2009.01356.x

Gall, M.D. (1970). The use of questions in teaching. *Review of Educational Research, 40,* 707-721. https://doi.org/10.3102%2F00346543040005707

Gelman, R., Brenneman, K., Macdonald, G., & Román, M. (2010). *Preschool pathways to science (PrePS): Facilitation scientific ways of thinking, talking, doing, and understanding.* Baltimore, MD: Brookes.

Gelman, S.A., Ware, E.A., Manczak, E.M., Graham, S.A. (2013). Children's sensitivity to the knowledge expressed in pedagogical and nonpedagogical contexts. *Developmental Psychology, 49,* 491-504. https://doi.org/10.1037/a0027901

Gendler, T. (2000). *Thought experiments: On the powers and limits of imaginary cases.* New York, NY: Garland Publishing.

Ginsborg, J. (2006). The effects of socio-economic status on children's language acquisition and use. In J. Clegg & J. Ginsborg (Eds.), *Language and social disadvantage: Theory into practice* (pp. 9-27). New York, NY: Wiley.

Goetz, P. J. (2010). The development of verbal justifications in the conversations of preschool children and adults. *First Language*, *30(3–4)*, 403–420. https://doi-org.proxy-um.researchport.umd.edu/10.1177/0142723710370522

Gopnik, A., & Wellman, H.M. (1994). 10. The Theory Theory. (Eds.) Hirschfeld, L.A., & Gelman, S.A. *Mapping the mind: Domain specificity in cognition and culture.* Cambridge University Press.

Graesser, A.C., & McMahen, C.L. (1993). Anomalous information triggers questions when adults solve problems and comprehend stories. *Journal of Educational Psychology, 85,* 136-151. https://psycnet.apa.org/doi/10.1037/0022-0663.85.1.136

Greif, M.L., Kemler Nelson, D.G., Keil, F.C., & Gutierrez, F. (2008). What do children want to know about animals and artifacts? Domain-specific requests for information. *Psychological Science, 17,* 455-459. https://doi.org/10.1111%2Fj.1467-9280.2006.01727.x

Grossmann, T., & Johnson, M.H. (2010). The development of the social brain in human infancy. *European Journal of Neuroscience, 25,* 909-919. https://doi.org/10.1111/j.1460-9568.2007.05379.x

Gweon, H., & Schulz, L.E. (2008). Stretching to learn: Ambiguous evidence and variability in preschoolers' exploratory play. *Paper presented at the proceedings of the 30th annual conference of the Cognitive Science Society*, Washington, DC.

Gweon, H., Pelton, H., Konopka, J.A., & Schulz, L.E. (2014). Sins of omission: Children selectively explore when teachers are under-informative. *Cognition, 132,* 335-341. https://doi.org/10.1016/j.cognition.2014.04.013

Haber, A.S., Sobel, D.M., & Weisberg, D.S. (2019). Fostering children's reasoning about disagreements through an inquiry-based curriculum. *Journal of Cognition and Development, 20,* 592-610. https://doi.org/10.1080/15248372.2019.1639713

Harris, P.L. (2012). *Trusting What You're Told: How Children Learn from Others*. Cambridge, Massachusetts; London, England: Harvard University Press.

Hart, B., & Risley, T. R. (1995*). Meaningful differences in the everyday experience of young American children*. Baltimore, MD, US: Paul H Brookes Publishing.

Hayes, A.F., Krippendorff, K. (2007). Answering the call for a standard reliability measure for coding data. *Communication Methods and Measures (1)*, 77-89. https://doi.org/10.1080/19312450709336664

Henderson, A.M.E., Sabbagh, M.A., & Woodward, A.L. (2013). Preschoolers' selective learning is guided by the principle of relevance. *Cognition, 126*, 246-257. https://doi.org/10.1016/j.cognition.2012.10.006

Herwig, J.E. (1982). Effects of age, stimuli, and category recognition factors in children's inquiry behavior. *Journal of Experimental Child Psychology, 33,* 196-206. https://doi.org/10.1016/0022-0965(82)90015-7

Hirsh-Pasek, K., Adamson, L.B., Bakeman, R., Tresch Owen, M., Michnick Golinkoff, R., Pace, A., Yust, P.K.S., Suma, K. (2015a). The contribution of early communication quality to low-income children's language success. *Psychological Science, 26,* 1071-1083. http://dx.doi.org/10.1177/0956797615581493

Hirsh-Pasek, K., Zosh, J.M., Golinkoff, R.M., Grey, J.H., Robb, M.B., & Kaufman, J. (2015b). Putting education in "educational" apps: Lessons from the science of learning. *Psychological Science in the Public Interest, 16,* 3-34. https://doi.org/10.1177%2F1529100615569721

Hoff, E. (2006). How social contexts support and shape language development. *Developmental Review, 26,* 55-88. https://doi.org/10.1016/j.dr.2005.11.002

Jaswal, V.K., Croft, A.C., Setia, A.R., & Cole, C.A. (2010). Young children have a specific, highly robust bias to trust testimony. *Psychological Science, 21*, 1541-1547. https://doi.org/10.1177%2F0956797610383438

Jaswal, V.K., & Malone, L.S. (2007). Turning believers into skeptics: 3-year-olds' sensitivity to cues to speaker credibility. *Journal of Cognition and Development, 8,* 263-283. https://doi.org/10.1080/15248370701446392

Jaswal, V.K., & Neely, L.A. (2006). Adults don’t always know best: Preschoolers use past reliability over age when learning new words. *Psychological Science, 17,* 757-758. doi: 10.1111/j.1467-9280.2006.01778.x

Jaswal, V.K., Pérez-Edgar, K., Kondrad, R.L., et al. (2014). Can’t stop believing: Inhibitory control and resistance to misleading testimony. *Developmental Science, 17,* 965-976. https://doi.10.1111/desc.12187.

Jirout, J., & Klahr, D. (2012). Children’s scientific curiosity: In search of an operational definition of an elusive concept. *Developmental Review, 32,* 125-160. https://doi.org/10.1111%2Fj.1467-9280.2006.01778.x

Johnston, A.M., Mills, C.M., & Landrum, A.R., (2015). How do children weigh competence and benevolence when deciding whom to trust? *Cognition, 144,* 76-90. https://doi.org/10.1016/j.cognition.2015.07.015

Johnston, A.M., Sheskin, M., & Keil, F.C. (2019). Learning the relevance of relevance and the trouble with truth: Evaluating explanatory relevance across childhood. *Journal of Cognition and Development, 20,* 555-572. https://doi.org/10.1080/15248372.2019.1631167

Kahan, D.M., Peters, E., Wittlin, M., Slovic, P., Ouellette, L.L., Braman, D., & Mandel, G. (2012). The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nature Climate Change (2),* 732-735. https://www.ledevoir.com/documents/pdf/yale1.pdf

Kemler Nelson, D., & O’Neil, K. (2005). How do parents respond to children's questions about the identity of artifacts? *Developmental Science, 8,* 519-524. https://doi.org/10.1111/j.1467-7687.2005.00443.x

Kidd, C., & Hayden, B.Y. (2015). The psychology and neuroscience of curiosity. *Neuron, 88,* 449-460. https://doi.org/10.1016/j.neuron.2015.09.010

Koenig, M.A., & Echols, C.H. (2003). Infants' understanding of false labeling events: The referential roles of words and the speakers who use them. *Cognition, 87,* 179-208. https://doi.org/10.1016/S0010-0277(03)00002-7

Koenig, M.A., & Harris, P.L. (2005). Preschoolers mistrust ignorant and inaccurate speakers. *Child Development, 76,* 1261-1277. https://doi.org/10.1111/j.1467-8624.2005.00849.x

Kuchirko, Y., Tamis-LeMonda, C.S., Luo, R., Liang, E. (2015). 'What happened next?': Developmental changes in mothers' questions to children. *Journal of Early Childhood Literacy, 16*, 498-521. https://doi.org/10.1177%2F1468798415598822

Kuhn, D., & Pearsall, S. (1998). Relations between metastrategic knowledge and strategic performance. *Cognitive Development, 13,* 227-247. https://doi.org/10.1016/S0885-2014(98)90040-5

Kurkul, K.E., & Corriveau, K.H. (2018). Question, explanation, follow-up: A mechanism for learning from others? *Child Development, 89,* 280-294. https://doi.org/10.1111/cdev.12726

Kuthe, A., Körfgen, A., Stötter, J., & Keller, L. (2020). Strengthening their climate change literacy: A case study addressing the weaknesses in young people's climate change awareness. *Applied Environmental Education & Communication, 19,* 375-388. https://doi.org/10.1080/1533015X.2019.1597661

Landrum, A.R., Eaves, Jr., B.S., & Shafto, P. (2015). Learning to trust and trusting to learn: A theoretical framework. *Trends in Cognitive Sciences, 19*, 109-111. https://doi.org/10.1016/j.tics.2014.12.007

Lazer, D.M.J., Baum, M.A., Benkler, Y., Berinsky, A.J., Greenhill, K.M., Menczer, F., Metzger, M.J., et al. (2018). The science of fake news: Addressing fake news requires a multidisciplinary effort. *Science, 359,* 1094-1096. https://doi.org/10.1126/science.aao2998

Legare, C.H. (2012). Exploring explanation: Explaining inconsistent evidence informs exploratory, hypothesis-testing behavior in young children. *Child Development, 83,* 173-185. https://doi.org/10.1111/j.1467-8624.2011.01691.x

Legare, C.H. (2014). The contributions of explanation and exploration to children's scientific reasoning. *Child Development Perspectives, 8,* 101-106. https://doi.org/10.1111/cdep.12070

Legare, C.H., & Lombrozo, T. (2014). Selective effects of explanation on learning during early childhood. *Journal of Experimental Child Psychology, 126,* 198-212. https://doi.org/10.1016/j.jecp.2014.03.001

Legare, C.H., Mills, C.M., Souza, A.L., Plummer, L.E., & Yasskin, R. (2013). The use of questions as problem-solving strategies during early childhood. *Journal of Experimental Child Psychology, 114,* 63-76. https://doi.org/10.1016/j.jecp.2012.07.002

Livio, M. (2018). *Why? What Makes Us Curious*. New York: Simon & Schuster Paperbacks.

Loewenstein, G. (1994). The psychology of curiosity: A review and reinterpretation. *Psychological Bulletin, 116,* 75-98. https://psycnet.apa.org/doi/10.1037/0033-2909.116.1.75

Lombard, M., Snyder-Duch, J., Campanella Bracken, C. (2006). Content analysis in mass communication: Assessment and reporting of intercoder reliability. *Human Communication Research (28)*, 587-604. https://doi.org/10.1111/j.1468-2958.2002.tb00826.x

Lombrozo, T. (2012). Explanation and abductive inference. In K. Holyoak & R. Morrison (Eds.), *Oxford handbook of thinking and reasoning* (pp.260-276). New York, NY: Oxford University Press.

Lombrozo, T. (2018). Learning by thinking in science and in everyday life. In P. Godfrey-Smith & A. Levy (Eds.), *The scientific imagination.* New York, NY: Oxford University Press.

Lombrozo, T. (2006). The structure and function of explanations. Trends in Cognitive Sciences (10). 464-470. https://doi.org/10.1016/j.tics.2006.08.004

Lucas, C., Gopnik, A., & Griffiths, T.L. (2010). Developmental differences in learning the forms of causal relationships. *Proceedings of the Annual Meeting of the Cognitive Science Society, 32,* 2852-2857. https://escholarship.org/uc/item/4cr2d0fx.

Lutz, D., & Keil, F. (2002). Early understanding of the division of cognitive labor. *Child Development 73,* 1073-1084. https://doi.org/10.1111/1467-8624.00458

Meder, B., Nelson, J.D., Jones, M., & Ruggeri, A. (2019). Stepwise versus globally optimal search in children and adults. *Cognition*, *191,* 1-18. https://doi.org/10.1016/j.cognition.2019.05.002.

Meltzoff, A.N., Kuhl, P.K., Movellan, J., & Sejnowski, T.J. (2009). Foundations for a new science of learning. Science (325). 284-288. http://dx.doi.org/10.1126/science.1175626

Milér, T. & Sládek, P. (2011). The climate literacy challenge. Procedia: Social and Behavioral Sciences, 12, 150-156. https://doi.org/10.1016/j.sbspro.2011.02.021

Mills, C. M. (2013). Knowing when to doubt: Developing a critical stance when learning from others. *Developmental Psychology, 49,* 404-418. https://psycnet.apa.org/doi/10.1037/a0029500

Mills, C.M., Danovitch, J.H., Grant, M.G., & Elashi, F.B. (2012). Little pitchers use their big ears: Preschoolers solve problems by listening to others ask questions. *Child Development, 83,* 568-580. https://doi.org/10.1111/j.1467-8624.2011.01725.x

Mills, C.M., Danovitch, J.H., Rowles, S.P., & Campbell, I.L. (2017). Children's success at detecting circular explanations and their interest in future learning. *Psychological Bulletin Review, 24,* 1465-1477. https://doi.org/10.3758/s13423-016-1195-2

Mills, C.M., Legare, C.H., Bills, M., & Mejias, C. (2010). Preschoolers use questions as a tool to acquire knowledge from different sources. *Journal of Cognition* *and Development, 11*, 533-560. https://doi.org/10.1080/15248372.2010.516419

Mills, C.M., Legare, C.H., Grant, M.G., & Landrum, A.R. (2011). Determining who to question, what to ask, and how much information to ask for: The development of inquiry in young children. *Journal of Experimental Child Psychology*, *110*, 539-560. https://doi.org/10.1016/j.jecp.2011.06.003

Mills, C., & Sands, K. (2020). Understanding Developmental and Individual Differences in the Process of Inquiry during the Preschool Years. In L. Butler, S. Ronfard, & K. Corriveau (Eds.), The Questioning Child: Insights from Psychology and Education (pp. 144-163). Cambridge: Cambridge University Press. doi:10.1017/9781108553803.008

Molinero, R.I., & Garcia-Madruga, J. (2011). Knowledge and question asking. *Psicothema*, *23*(1), 26-30. https://www.ncbi.nlm.nih.gov/pubmed/21266138.

Newcombe, N.S. (2010). What is neoconstructivism? *Child Development Perspectives*, *5,* 157-160. https://doi.org/10.1111/j.1750-8606.2011.00180.x

Osherson, D.N., & Markman, E. (1975). Language and the ability to evaluate contradictions and tautologies. *Cognition, 3*, 213-226. https://doi.org/10.1016/0010-0277(74)90009-2

Papafragou, A., Friedberg, C., & Cohen, M.L. (2018). The role of speaker knowledge in children's pragmatic inferences. Child Development (89), 1642-1656. 10.1111/cdev.12841

Paradise, R., & Rogoff, B. (2009). Side by side: Learning by observing and pitching in. *Ethos,* 37*, 102-138*. https://doi.org/10.1111/j.1548-1352.2009.01033.x

Piaget, J. (1964). Cognitive Development in Children: Development and Learning. *Journal of Research in Science Teaching (2),* 176-186. https://doi.org/10.1002/tea.3660020306

Pintrich, P.R. (2002). The role of metacognitive knowledge in learning, teaching, and assessing. *Theory into Practice, 41,* 219-225. http://dx.doi.org/10.1207/s15430421tip4104_3

Pirolli, P.L.T. (2007). Information Foraging Theory: Adaptive Interaction with Information. Oxford Scholarship Online.

Pratt, C. (1990). On asking children - and adults - bizarre questions. *First Language, 10(29),* 167–175. https://doi.org/10.1177/014272379001002905

Rips, L.J. (2002). Circular reasoning. *Cognitive Science, 26,* 767-795. https://doi.org/10.1207/s15516709cog2606_3

Robinson, E.J., Butterfill, S.A., Nurmsoo, E. (2011). Gaining knowledge via other minds: Children's flexible trust in others as sources of information. *British Journal of Developmental Psychology, 29*(4), 961–980. https://doi.org/10.1111/j.2044-835x.2011.02036.x

Rogoff, B. (1998). In W. Damon (Series Ed.) and D. Kuhn & R.S. Siegler. (Vol. Eds.), *Handbook of Child Psychology, Volume 2: Cognition, perception, and language.* New York: Wiley.

Ronfard, S., Bartz, D., Cheng, L., Chen, X., & Harris, P. L. (2017). Children's developing ideas about knowledge and its acquisition. *Advances in Child Development and Behavior.* https://doi.org/10.1016/bs.acdb.2017.10.005

Ronfard, S., Zambrana, I.M., Hermansen, T.K., & Kelemen, D. (2018). Question-asking in childhood: A review of the literature and a framework for understanding its development. *Developmental Review, 49,* 101-120. https://doi.org/10.1016/j.dr.2018.05.002

Rop, C.J. (2002). The meaning of student inquiry questions: A teacher's beliefs and responses. *International Journal of Science Education, 24,* 717-736. https://doi.org/10.1080/09500690110095294

Rothe, A., Lake, B.M., Gureckis, T.M. (2018). Do people ask good questions? *Computational Brain and Behavior, 1,* 69-89. https://doi.org/10.1007/s42113-018-0005-5

Roush, S. (2006). *Tracking Truth: Knowledge Evidence and Science.* Oxford: Oxford University Press.

Rowe, M.L., Leech, K.A., & Cabrera, N. (2017). Going beyond input quantity: *Wh*-questions matter for toddlers' language and cognitive development. *Cognitive Science, 41,* 162-179. https://doi.org/10.1111/cogs.12349

Rowles, S.P., & Mills, C.M. (2017). *How timed delay and effortful timed delay affect how children seek information from others.* Poster presented at the meeting of the Cognitive Development Society, Portland, OR.

Ruggeri, A., & Feufel, M.A. (2015). How basic-level objects facilitate asking efficient questions in a categorization task. *Frontiers in Psychology, 6,* 918. https://doi.org/10.3389/fpsyg.2015.00918

Ruggeri, A., & Lombrozo, T. (2014). Learning by asking: How children ask questions to achieve efficient search. *In 36th annual meeting of the cognitive science society* (pp. 1335–1340). Austin, TX: Cognitive Science Society

Ruggeri, A., & Lombrozo, T. (2015). Children adapt their questions to achieve efficient search. *Cognition, 143,* 203-216. https://doi.org/10.1016/j.cognition.2015.07.004

Ruggeri, A., Sim, Z.L., & Xu, F. (2017). "Why is Toma late to school again?" Preschoolers identify the most informative questions. *Developmental Psychology, 53,* 1620-1632. https://doi.org/10.1037/dev0000340

Ruggeri, A., Walker, C., Lombrozo, T., & Gopnik, A. (Under Review). *Strategic use of questions to solve a causal inference task in early childhood.* Manuscript submitted for publication.

Sabbagh, M. & Baldwin, D. (2001). Learning words from knowledgeable versus ignorant speakers: Links between preschoolers' theory of mind and semantic development. *Child Development, 72,* 1054-1070. https://doi.org/10.1111/1467-8624.00334

Samuels, M.C., & McDonald, J. (2002). Elementary school-age children's capacity to choose positive and negative diagnostic tests. *Child Development, 73,* 857-866. https://doi.org/10.1111/1467-8624.00443

Schilling, D.R. (2013, April 26). *Knowledge Doubling Every 12 Months, soon to be Every 12 Hours.* Industry Tap. https://www.industrytap.com/knowledge-doubling-every-12-months-soon-to-be-every-12-hours/3950

Schneider, W. (2008). The development of metacognitive knowledge in children and adolescents: Major trends and implications for education. *Mind, Brain, and Education, 2,* 114-121. https://doi.org/10.1111/j.1751-228X.2008.00041.x

Schulz, L.E., & Bonawitz, E.B. (2007). Serious fun: Preschoolers play more when evidence is confounded. *Developmental Psychology, 43,* 1045-1050. https://psycnet.apa.org/doi/10.1037/0012-1649.43.4.1045

Schulz, L.E., & Gopnik, A. (2004). Causal learning across domains. *Developmental Psychology, 40,* 162-176. https://doi.org/10.1037/0012-1649.40.2.162

Sheskin, M., Scott, K., Mills, C.M., Bergelson, E., Bonawitz, E., Spelke, E.S., Li Fei-Fei, L., Keil, F.C., Gweon, H., Tenenbaum, J.B., Jara-Ettinger, F., Adolph, K.E., Rhodes, M., Frank, M.C., Mehr, S.A., Schulz, L. (2020). Online Developmental Science to Foster Innovation, Access, and Impact. *Trends in Cognitive Sciences*, *24,* 675-678. https://doi.org/10.1016/j.tics.2020.06.004.

Siraj-Blatchford, I., & Manni, L. (2008). "Would you like to tidy up now?" An analysis of adult questioning in the English Foundation Stage. *Early Years, 28,* 5-22. https://doi.org/10.1080/09575140701842213

Snow, C.E. (1972). Mothers' speech to children learning language. *Child Development*, *43,* 549-565. https://doi.org/10.2307/1127555

Sobel, D.M., Sommerville, J.A., Travers, L.V., Blumenthal, E.J., & Stoddard, E. (2009). The role of probability and intentionality in preschoolers' causal generalizations. *Journal of Cognition and Development, 10,* 262-284. https://doi.org/10.1080/15248370903389416

Sodian, B., Zaitchik, D., & Carey, S. (1991). Young children's differentiation of hypothetical beliefs from evidence. *Child Development, 65,* 1581-1604. https://doi.org/10.2307/1131175

Swaboda, N., Ruggeri, Z., Sim, Z. L., Gopnik, A. (2019). Shake it baby, but only when needed: Preschoolers adapt their exploratory strategies to the information structure of the task. *Cognition (193),* 104013. https://doi.org/10.1016/j.cognition.2019.104013

Tamis-LeMonda, C.S., Adolph, K.E., Lobo, S.A., Karasik, L.B., Ishak, S., & Dimitropoulou, K.A. (2008). When infants take mothers' advice: 18-month-olds integrate perceptual and social information to guide motor action. *Developmental Psychology, 44,* 734-746. https://doi.org/10.1037/0012-1649.44.3.734

Terrier, N., Bernard, S., Mercier, H., & Clément, F. (2016). Visual access trumps gender in 3- and 4-year-old children's endorsement of testimony. *Journal of Experimental Child Psychology, 146,* 223-230. https://doi.org/10.1016/j.jecp.2016.02.002

Teske, J.A., & Pea, R.D. (1981). Metatheoretical issues in cognitive science. *Journal of Mind and Behavior, 2,* 123-178. https://web.stanford.edu/~roypea/RoyPDF%20folder/A6_Teske-Pea_81.pdf

Vale, R.D. (2013). The value of asking questions. *Molecular Biology of the Cell Perspectives, 24,* 680-682. https://doi.org/10.1091/mbc.e12-09-0660

Verbuk, A., & Shultz, T. (2010). Acquisition of relevance implicatures: A case against a rationality-based account of conversational implicatures. *Journal of Pragmatics,* 2297-2313. 10.1016/j.pragma.2010.01.005.

von Stumm, S., Hell, B., & Chamorro-Premuzic, T. (2011). The Hungry Mind: Intellectual Curiosity Is the Third Pillar of Academic Performance. *Perspectives on Psychological Science*, *6*(6), 574–588. https://doi.org/10.1177/1745691611421204

Vygotsky, L.S. (1978). *Mind in Society.* Cambridge: Harvard University Press.

Vygotsky, L.S. (1986). *Thought and Language.* Transl. and ed. A. Kozulin. Cambridge, MA: The MIT Press. (Originally published in Russian in 1934).

Walker, D., Greenwood, C., Hart, B., & Carta, J. (1994). Prediction of school outcomes based on early language production and socioeconomic factors. *Child Development, 65,* 606-621. https://doi.org/10.1111/j.1467-8624.1994.tb00771.x

Weisberg, D.S., Hirsh-Pasek, K., Golinkoff, R.M., Kittredge, A.K., & Klahr, D. (2016). Guided play: Principles and practices. *Current Directions in Psychological Science, 25,* 177-182. https://doi.org/10.1177%2F0963721416645512

Williamson, T. (2000). *Knowledge and Its Limits.* Oxford: Oxford University Press.

Xu, F. (2019). Towards a rational constructivist theory of cognitive development. *Psychological Review, 126,* 841-864. http://dx.doi.org/10.1037/rev0000153.

Yu, Y., Bonawitz, E., & Shafto, P. (2017). Pedagogical questions in parent-child conversations. *Child Development*, *90*, 147-161. https://doi.org/10.1111/cdev.12850

Zippert, E.L., Daubert, E.N., Scalise, N.R., Noreen, G.D., & Ramani, G.B. (2019). "Tap space number three": Promoting math talk during parent-child tablet play. *Developmental Psychology*, *55*, 1605-1614. https://psycnet.apa.org/doi/10.1037/dev0000769

Zmyj, N., Buttelmann, D., Carpenter, M., & Daum, M.M. (2010). The reliability of a model influences 14-month-olds' imitation. *Journal of Experimental Child Psychology*, *106*, 208-220. https://doi.org/10.1016/j.jecp.2010.03.002